CITY OF LINCOLN NEBRASKA
LINCOLN PARKS & RECREATION DEPARTMENT
2740 "A" Street Lincoln, NE 68502
402-441-7847 fax: 402-441-8706 lincoln.ne.gov

MEMORANDUM

DATE: April 28, 2017

TO: City of Lincoln Parks and Recreation Department, Lower Platte South Natural Resources District Board of Directors, Nebraska Game and Parks Commission, and Nebraska Chapter Pheasants Forever, Inc.

FROM: Tom Malmstrom
Natural Resources Coordinator - Parks and Recreation Department
Saline Wetlands Conservation Partnership

RE: Saline Wetlands Conservation Partnership – 2016 Progress Report

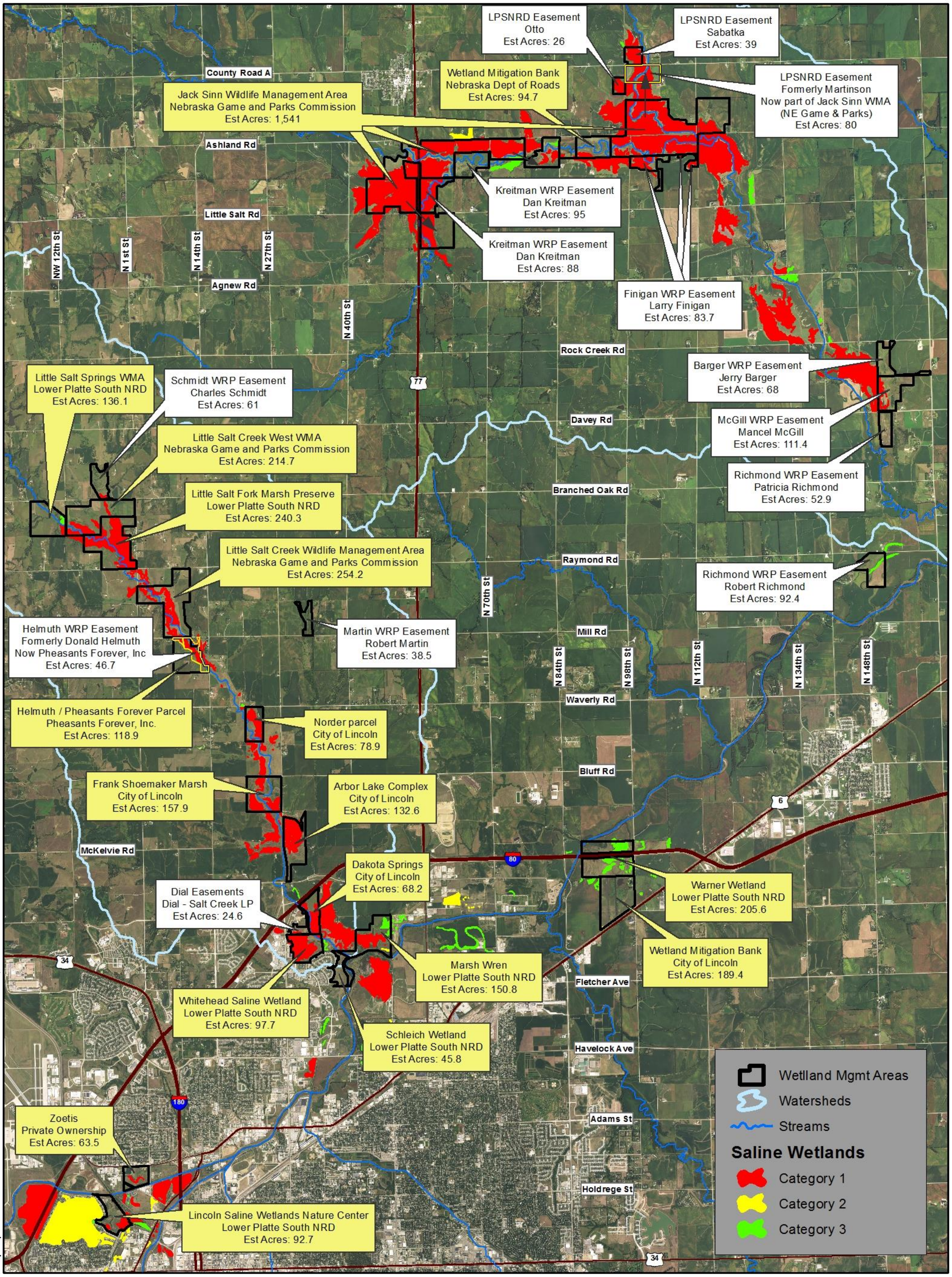
On behalf of the Saline Wetlands Conservation Partnership (SWCP) I want to make you aware of the activities, which occurred in 2016. The SWCP was initiated in 2003 and continues to progress. The City of Lincoln has been awarded five Nebraska Environmental Trust Fund (NET) grants since 2002 for the eastern saline wetlands. In 2016, the City of Lincoln received a $795,000 grant over a three year period from 2016 to 2019. The 2012 NET grant was recently expended and a Final Report will be submitted to the NET in July 2017. These grants have been used for land acquisition, wetland restoration, education, and land management purposes and provide matching funds for other grant opportunities.

Efforts of the SWCP are to protect, restore, and manage the rare and unique saline wetland habitat. The Partnership continues to utilize the "Implementation Plan for the Conservation of Nebraska's Eastern Saline Wetlands (2003)," for guidance in efforts to conserve the saline wetlands. An update of this Plan reflecting upon the past 15 years has recently begun and should be completed in 2017.

Since its inception, approximately 1,530 acres of habitat containing saline wetlands, freshwater wetlands, native prairie, and other associated upland habitat have been conserved through fee-title acquisition from willing sellers. Activities continue with education, saline wetland restoration and conservation projects, and the operation and maintenance of conservation areas.

Illustration 1 identifies saline wetland properties, which have been acquired through fee-title acquisitions or conservation easements since the 1980's. Illustration 2 identifies other saline wetland locations including Pioneers Park and saline wetland conservation easements.

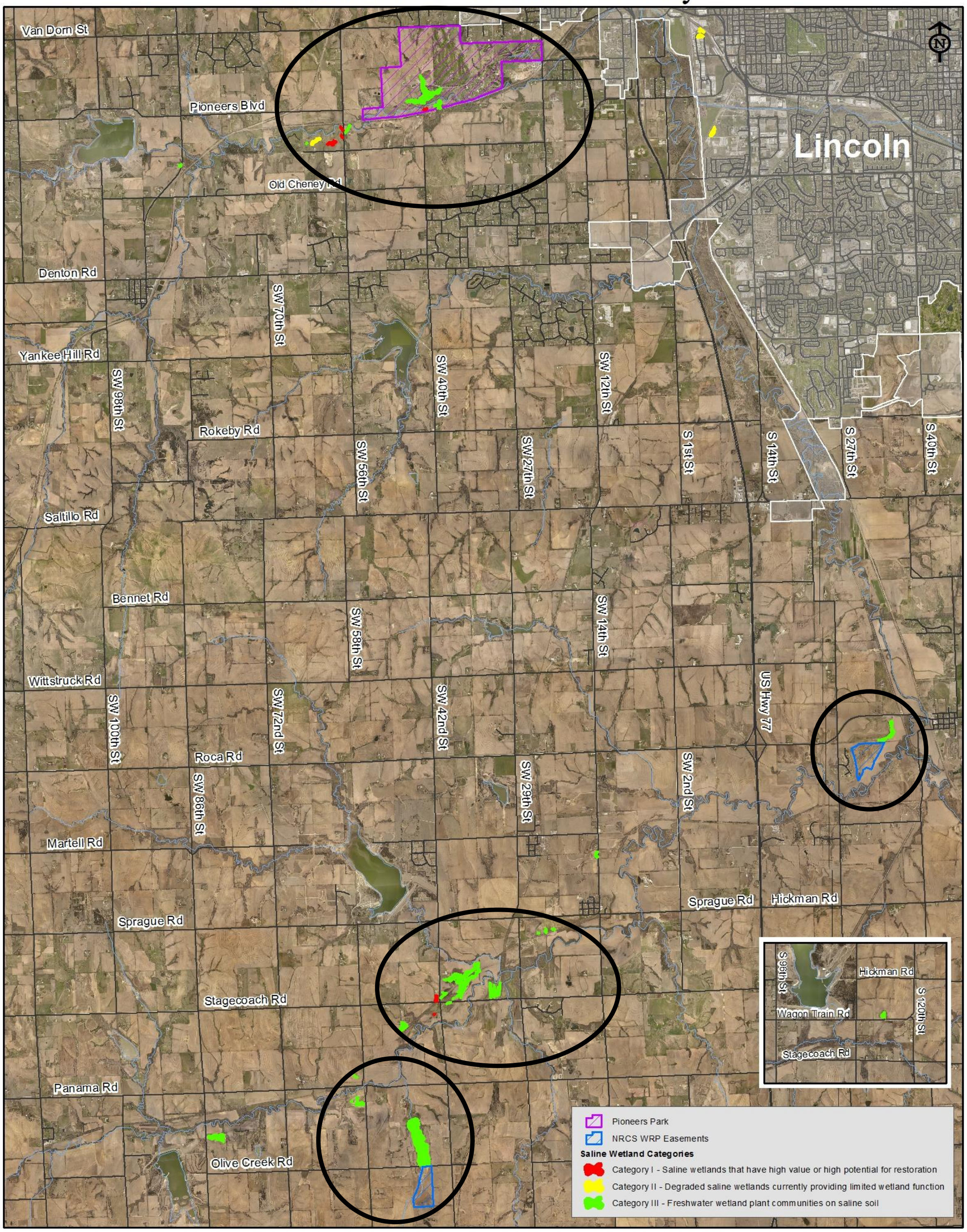
Illustration 1



Map Updated: December 2015 - Lower Platte South NRD, sdr

Illustration 2

Southwestern Lancaster County



Q:\ArcGIS_projects\Wetlands\ManagementAreas_Grouped\SW_Lancaster\SW_LancasterCo_8x11.mxd - Map Created: April 2014, LPSNRD

WETLAND RESTORATION

Marsh Wren Community Wetland Area

The property is owned by the Lower Platte South Natural Resources District (LPSNRD). This is a saline wetland restoration project of Marsh Wren which is located on the north side of Salt Creek between approximately N. 40^{th} St. and N. 48^{th} St. on the north edge of the City of Lincoln. The property includes approximately 150-acres containing saline wetlands and other habitat. A feature story by Nebraska Educational Television is included in Appendix A.


Marsh Wren restoration – viewing southeasterly toward the City of Lincoln

The Marsh Wren saline wetland restoration project was initiated with the cooperation of the Saline Wetlands Conservation Partnership. Funding for this project was provided by the LPSNRD and a 2012 Nebraska Environmental Trust grant for saline wetlands through the City of Lincoln. Construction commenced in June 2016 and will be completed in 2017.

The Marsh Wren project design generally included the following measures:

- Wetland enhancement
- Excavation/sediment removal
- Sediment control structure construction
- Water level control structure(s)
- Saline water distribution system
- Vegetation management
- Supplemental water supply
- Grade control structure(s)
- Stream bank re-shaping
- Migratory bird habitat improvement
- Pedestrian access

Marsh Wren Saline Wetland Restoration Project –Before & After Photos

Pre-Construction - Looking north toward pond

Pre-Construction
Looking northwest up Little Salt Creek at confluence

Post-Construction
Looking north toward pond and Salt Creek Access construction

Post-Construction
Looking northwest up Little Salt Creek at confluence

Little Salt Fork Marsh Preserve Wildlife Management Area

The property is owned by the Lower Platte South Natural Resources District. This is a habitat improvement project of the upland area along north 1st Street consisting of approximately 16 acres, which is adjacent the saline marsh. Little Salt Fork Marsh Preserve is located on the northeast corner of Raymond Road and north 1st street. The property includes approximately 240 acres containing saline wetlands and other habitat.

The habitat improvement area was previously cropped and left to pasture for several years. Land terraces were present and smooth brome was dominate throughout. In 2016, the area was cropped with soybeans in order to minimize brome presence and prepare a base for native seeding. The drainage areas were chemically treated to reduce invasive plant species and the land terraces were removed. The area was seeded in early 2017, with a high diversity upland seed mix containing over 150 native plant species.

WETLAND MANAGEMENT

Three seasonal employees hired by the Lower Platte South NRD performed management on the saline wetland areas. Members of the Partnership established management activities to be addressed within the saline wetlands complex. These employees primarily worked on noxious weed and woody vegetation removal, structure maintenance, and access. Funding for these positions is provided with stewardship funds through an agreement between the LPSNRD and The Nature Conservancy to support saline wetland management areas. Approximately 800 hours were worked by the seasonal employees in 2016 on saline wetland management activities from May through November. The Coordinator and LPSNRD provided supervision of the employees.

In addition, the LPSNRD has one fulltime Maintenance Technician who assists the seasonal employees with work performed on the saline wetlands. This work is also compensated through the stewardship fund.

SALINE WETLAND RESEARCH

The SWCP has worked with partners on a variety of projects within the saline wetlands. Funding for some of these projects has come from the Nebraska Environmental Trust, U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, and the Nebraska Game and Parks Commission. The following recommendations are based on the conclusions contained in the Final Report. The Final Report is included as Appendix B.

Biogeochemical controls on saline wetland plant establishment in Nebraska's Eastern Saline Wetlands

Dr. Amy Burgin, Assistant Professor
School of Natural Resources
University of Nebraska – Lincoln

Keunyea Song PhD., Postdoctoral Researcher
School of Natural Resources
University of Nebraska – Lincoln

In December 2013, the City of Lincoln executed and approved a Memorandum of Understanding with the Nebraska Game and Parks Commission to cooperate on the research project. A final report was completed in 2016. Funding for the research was provided by a Nebraska Natural Legacy Project grant received from the Nebraska Environmental Trust and funds contributed by the Saline Wetlands Conservation Partnership.

The goal of the study was to determine whether continuous saline groundwater addition to the soil surface would create a more favorable saline condition for saline plant species and other wetland ecosystem services. The project research was implemented at the Arbor Lake Complex in Lancaster County, Nebraska.

Conclusions and Restoration Recommendations

The interactions between saline groundwater and soil are an important feature of Nebraska's Eastern Saline Wetlands. **The project results imply that slow and continuous saline groundwater application has high potential to effect saline wetland restoration strategy.**

The continuous saline groundwater addition increased pore water salinity in the experimental site. The addition of a medium (18-20 ppt) and high range (26-30 ppt) of salinity groundwater and in this study induced the distinctive pore water salinity differences from those in freshwater and low salinity (2-3ppt) plots.

Slow groundwater application prolonged the connections between saline groundwater and soil, therefore, maximized the effects of saline groundwater addition on the soil surface. Slow application of medium and high salinity groundwater generated salt crusts in the soil surface.

Medium and high salinity groundwater addition (18-30ppt in the study) increased CO_2 fluxes. This suggests that the alteration of soil salinity level by saline wetland restoration activities affects carbon cycling and storage.

Salinity regulated the germination rates of saline species. Increased salinity inhibited the germination rates of the six targeted species. Seablite and Spearscale appeared to be tolerant to medium (18-20ppt) level salinity. Warmer temperature stimulated germination of most saline species under the same salinity conditions. It is suggested that the April thermos-period (5°C night and 20°C day) would be the optimal condition for better germination rates of targeted saline species and to avoid competition with terrestrial/freshwater wetland species.

Spearscale and Seablite were the most abundant species within the saline groundwater treated plots, which is consistent with the germination results. **Saltwort emerged only in the medium salinity level plots.** Decreased plant species richness with increased salinity was associated with decreased terrestrial and freshwater plant species. **At medium and high salinity level plots, targeted saline species contributed to over 50% of the total plant abundance.**

It is recommended the slow addition of middle range (i.e. 26-30ppt) salinity groundwater in the soil surface would create favorable habitat to saline plant species. The seeding of saline species should be completed by April in Lancaster County, Nebraska (i.e. temperature range: min. 5°C, max. 20°C) to optimize the germination and growth of saline species.

ENDANGERED SPECIES

Efforts of the SWCP are to protect, restore, and manage the rare and unique saline wetland habitat and not just endangered species. The Salt Creek tiger beetle and Saltwort plant are indicator or bio species where their presence in Nebraska's eastern saline wetlands can indicate certain environmental conditions, such as soil type, pollution levels, etc. Therefore it is imperative the SWCP helps to monitor the endangered species of these wetlands for conservation efforts, as well as monitoring other indicator species.

The Salt Creek tiger beetle (*Cicindela nevadica lincolniana* Casey) was listed a state endangered species in 2000 and Federal endangered species on October 2005. It is endemic to the saline wetlands in Lancaster and southern Saunders counties. Saltwort (*Salicornia rubra*) is a state listed endangered species. In Nebraska, the Saltwort is only found in these saline wetlands.

The final revision to designate 1,110 acres of critical habitat for the Salt Creek tiger beetle was approved on May 5, 2014. Critical habitat is identified along four streams that still contain sufficient potential habitat to support viable populations of Salt Creek tiger beetle; Little Salt Creek, Rock Creek, Oak Creek, and Haines Branch Creek. The Little Salt Creek unit includes the three remaining populations, while the Rock, Oak, and Haines Branch Creek units are currently unoccupied. The designation consists of stream corridors with exposed salt seeps and salt flats that provide habitat for the species, and surrounding vegetative areas that provide food resources and shade. It is estimated the critical habitat can support at least six viable populations of Salt Creek tiger beetles and will ensure recovery of the species.

The critical habitat units include land under private ownership, lands owned by the Nebraska Game and Parks Commission, the City of Lincoln, the Lower Platte South Natural Resources District, and Pheasants Forever. Approximately 29 percent of the critical habitat is protected from future disturbance by conservation easements or fee title land acquisitions as a result of a conservation plan developed in 2003 by Nebraska Game and Parks Commission, City of Lincoln, Lancaster County, Lower Platte South Natural Resources District, and The Nature Conservancy.

Salt Creek Tiger Beetle Research

The following research information provided by:

Stephen M. Spomer
Entomology Department, University of Nebraska-Lincoln
Federal Permit #TE37351A-0, State Permit #552

Robert R. Harms
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service

2016 Salt Creek tiger beetle Surveys and Research

Field Collection and Rearing in 2016:

Recovery permits authorize pairing of male and female Salt Creek tiger beetles. Pairs originated from wild Salt Creek tiger beetle larvae that were produced and overwintered in 2015-2016; no pairs were collected from the wild in 2016. Male and female pairs were placed in rearing chambers at Omaha's Henry Doorly Zoo and Aquarium where they bred and later layed eggs. The adults were returned to the collection sites after mating and egg-laying had occurred in ten days. Progeny from these adults are being reared by Omaha's Henry Doorly Zoo and Aquarium, Lincoln Children's Zoo, and UNL.

Population Estimates for 2016:

Preliminary population estimates began on June 1, 2016. The first sighting of a Salt Creek tiger beetle adult was on June 7, 2016. Population estimates were conducted between June 20, 2016 and June 24, 2016. All adults had disappeared by the end of July. A total of 348 Salt Creek tiger beetles were counted, which nearly doubled the population in 2015. The number of beetles per sites surveyed ranged from 0 to 115.

Re-introduction Efforts

To assist with the re-introduction of Salt Creek tiger beetles reared in the zoos, data loggers, commonly referred to as HOBO units, are placed at locations where the beetles were released or locations which have future potential for release. The HOBO units monitor soil temperature at various depths and soil moisture just below the soil surface throughout the year.

In 2016, approximately 186 larvae of the Salt Creek tiger beetle reared in 2015 were released in the spring and another 80 in the fall. This was accomplished through a cooperative captive rearing program among the USFWS, NGPC, UNL, Omaha Henry Doorly Zoo and Aquarium, and the Lincoln Children Zoo. Researchers monitor the released larvae.

In order to monitor the beetle release locations and gather data from the HOBO units the U.S. Fish and Wildlife Service and Nebraska Game and Parks Commission worked with the Nebraska Master Naturalist program. Volunteers worked in pairs throughout the summer at each location; visiting the sites where releases occurred on a weekly basis and those sites with HOBO units monitoring saline wetland habitat for potential release on a monthly basis.

SUMMARY OF SALINE WETLANDS AND SOILS PROTECTED (2001-present)

In order to preserve and restore these wetlands, an Implementation Plan for the Conservation of Nebraska's Eastern Saline Wetlands was completed in 2003. This plan identifies four Landscape Objectives, which establish projection and restoration targets for the conservation of the Eastern Saline Wetlands. A summary of acres acquired through fee-title acquisition since 2001 by the SWCP is provided below. Acres of saline wetlands that have been acquired but have not yet been restored and conservation easements are not provided in the table summary.

LANDSCAPE OBJECTIVE	ACRES OF WETLAND PROTECTED OR RESTORED
1 – Permanently protect 100% (148 acres) of intact Category 1 saline wetlands and their associated conservation zones to ensure that the wetlands and their functions are sustained	43.3
2 – Restore and Protect 80% (1,412 acres) of unprotected degraded Category 1 saline wetlands and their associated conservation zones to ensure that the wetlands and their functions are sustained	288.5
3 – Restore (to intact Category 1 wetlands) and protect 50% (167 acres) of unprotected Category 3 saline wetlands and their associated conservation zones to ensure that the wetlands and their functions are sustained as intact Category 1 wetlands	62.0
4 – Restore (to intact Category 1 wetlands) and protect 50% (2,360 acres) of unprotected current non-wetland areas on saline hydric soils so that they become intact and sustained Category 1 saline wetlands	287.4
TOTAL	**681.2**

Source: Ted LaGrange and Rachel Simpson of the NGPC

EDUCATION

The Lower Platte South NRD provides opportunities for local schools to visit the saline wetlands to learn about saline wetland soils, vegetation, and hydrology. Students also examine invertebrate health within the wetlands and in streams to indicate stream health. In the spring and fall of 2016 the NRD hosted field trips with High School Biology students, Middle School 7th grade Environmental Studies students, and 5th grade students at the Lincoln Saline Wetlands Nature Center. Over 500 students enjoyed netting insects at the site, learning about the vegetation and potential wildlife and netting for macroinvertebrates in the water!

The Coordinator continues to present "saline wetland jeopardy" to fifth grade students attending the Earth Wellness Festival. Other presentations were given to local groups, UNL classes and conservation agencies.

RECENT FUNDING RESOURCES

- Federal Section 6 – In 2013, the NGPC through the U.S. Fish and Wildlife Service was awarded $190,300 for the acquisition of a property containing saline wetlands. The funding remains available for land acquisition of saline wetlands.

  In 2016, the NGPC through the U.S. Fish and Wildlife Service was awarded $206,536 for the acquisition of a property containing saline wetlands. The funding remains available for land acquisition of saline wetlands.

- A grant was submitted to the Nebraska Environmental Trust in 2011 for the "Eastern Saline Wetlands Project – 2012." The grant was approved in the amount $1.4 million for land acquisition, restoration, and planning activities for a three year grant period. The grant received two one year extensions to accommodate the Marsh Wren wetland restoration project. The grant funds have been expended and a Final Report will be submitted in July 2017.

- In 2012, The Nature Conservancy and the Lower Platte South Natural Resources District amended a previous grant agreement to specifically build, enhance and/or maintain effective ecological stewardship of the saline wetlands. Beginning June 30, 2012 and through July 1, 2019 The Nature Conservancy will disburse $7,500 annually contingent upon corresponding disbursement of matching funds from the Lower Platte South Natural Resources District for the Project.

- In 2002, the Nebraska Game and Parks Commission obtained a *2001 State Wildlife Grant* from the U.S. Fish and Wildlife Service entitled "Eastern Nebraska Saline Wetland Conservation Partnership". The grant award was for $620,000. The grant has been used to fund a variety of planning and implementation activities for the Partnership, including land acquisition, wetland restoration, wetland management, equipment purchases, and support for the Coordinator position. The grant funds have been spent and the grant was closed in 2015.

- A grant was submitted to the Nebraska Environmental Trust in 2015 for the "Eastern Saline Wetlands Project – 2016." The grant was approved in the amount of $795,000 primarily for wetland restoration/engineering/management and planning activities for a three year grant period. Year two of funding in the amount of $265,000 was recently approved.

SUMMARY OF OTHER COORDINATOR ACTIVITIES

- Participant of the U.S. Corps of Engineers Nebraska inter-agency wetland group.

- Attended meetings regarding City and County projects regarding construction activities scheduled near or on saline wetland areas

- Presentations on saline wetlands and the partnership to Nebraska Game and Parks Commission Habitat Partners, the LPSNRD Recreation, Forestry, and Wildlife sub-committee, and UNL classes

- Land management – Supervision of seasonal employees, annual saline wetland discussion with agency land managers, and noxious weed and woody vegetation control and GPS location identification at saline wetland sites.

- Toured saline wetland areas with Platte Basin time-lapse team, UNL Soils instructors, and Prairie Plains Resource Institute

- Youth education – presented and participated in the Earth Wellness Festival, UNL Career Day, Pioneers Park Nature Center nature camp tour to Frank Shoemaker Marsh, and assisted with State High School Land Judging competition

- Participated in several meetings and discussions regarding 27^{th} Street Right-of-Way widening project adjacent Frank Shoemaker Marsh with Lancaster County Roads, contractors, and the NGPC

- Attended NGPC Habitat Partners meeting, The Wildlife Society annual conference, Phragmites Management Webinar, North American Wetlands Conservation Act grant workshop, Nebraska Natural Legacy conference, and prescribed goat grazing webinar

- Provided site management for UNL Biogeochemical research project at Arbor Lake

- Worked with USFWS and NGPC on endangered species monitoring efforts, re-introduction site locations, accessibility issues for Master Naturalist teams to gather monitoring information, and participated in release of endangered species

- Toured saline wetland areas with several agencies and local zoos regarding endangered species recovery habitat for re-introduction and participated in monitoring discussions with the Master Naturalist and USFWS

- Marsh Wren restoration project - Provided assistance to LPSNRD, pre-bid meeting and bid opening, site visits with contractor and consultant, construction meetings, and final walk through

- Participant of Prairie Corridor technical advisory committee, core team representative of Nebraska Wetland Assessment grant project, and the Inter-agency wetlands group

- Miscellaneous grant administration and participation in grant applications through conservation agencies regarding wetland projects

- Worked with City legal counsel in the development of Waiver, Release, and Access Agreements for private grazing and cropping of City owned land; executed agreements with two cooperators

- Initiated and continued contractual discussions on the update of the "Last of the Least" and planning/engineering proposal for the Norder Tract.

- Assisted with LJS articles and NET radio feature on saline wetlands

- Met and discussed with NGPC the digitalization of saline wetland historical slides and photos

- Completed 2012 NET extension request and submitted, on behalf of the LPSNRD a 2017 NET grant for the "Upper Little Salt Creek Saline Wetlands Conservation"

- Work with landowners, fund administrators and agency representatives regarding land acquisitions

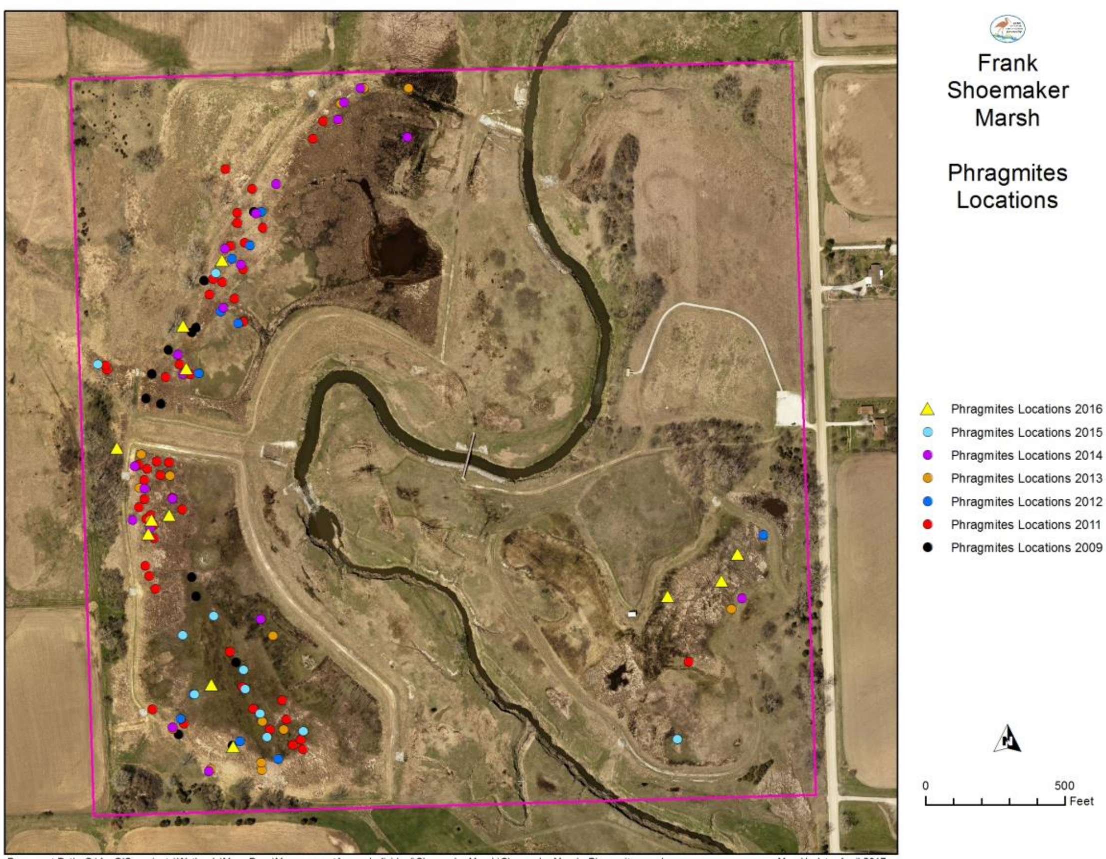
SALINE WETLAND PROPERTIES

- **Frank Shoemaker Marsh** – 27th Street and Bluff Road

Size:	160 acres
Purchase price and date:	$472,000 on June 12, 2003
Funding sources:	2001 State Wildlife Grant through the USFWS ($222,000) 2002 NET grant ($250,000)
Owner:	City of Lincoln

Activity summary – Noxious weed removal continued and included the documentation of several new plots of Phragmites. Upland area hayed and a concentrated effort on removing Cedar trees. Agreement with neighbors to control parking lot accessibility during closed hours.

Lancaster County Roads Department finalized agreement with the City of Lincoln for right-of-way acquisition along the east side of property on 27th Street. This includes tree removal and replacement, fence removal and re-installation, and parking lot modification. Construction work will be completed in 2017.



- **Dakota Springs** – South of Arbor Road and East of 27th Street

Size:	68.7 acres
Purchase price and date:	$204,700 in January 2004
Funding sources:	Federal Section 6 ($153,525)
	2002 NET grant ($51,175)
Owner:	City of Lincoln

  Dakota Springs Extension Purchase (Dial Realty, 7.45 acres)

Purchase price and date:	$48,500 on December 31, 2008
Funding source:	Federal Section 6

  Activity summary – Noxious weed and woody vegetation removal continued.

- **Warner Saline Wetlands -** 98th Street and Interstate 80

Size:	140 acres
Purchase price and date:	$298,580 on December 7, 2004
Funding sources:	Federal Section 319 ($179,148)
	LPSNRD ($43,043.20)
	SWCP ($76,388.80)
Owner:	LPSNRD

  Activity summary – Noxious weed control and woody vegetation removal continues with honey locust and cedars. Trees removed and piled for burning on North parcel.

- **Little Salt Creek Wildlife Management Area** – 1st Street and Raymond Road

Total Size:	256.5 acres
Purchase price and date:	$476,000 in June 2004 (original 156 acres)
Funding sources:	Federal Section 6 ($276,000)
	2004 NET grant through NGPC ($200,000)
Owner:	NGPC

  Noble Tract Extension (100.5 acres) - Along Little Salt Creek, between Mill Road and the southern boundary of the original Little Salt Creek Wildlife Management Area.

  Activity summary – Prescribed grazing and haying of upland was conducted. Cedar removal and noxious weed control continues. Platte Basin time lapse camera location.

- **Little Salt Creek West Wildlife Management Area –** South of Branched Oak Road between NW 12th and 1st Streets

Total Size:	220.0 acres
Purchase price and date:	$979,000 on October 9, 2009
Funding sources:	Federal Section 6 ($560,000)
	2005 NET Grant ($42,838.58)
	2008 NET Grant ($366,250.42)
	Ducks Unlimited ($10,000)
Owner:	Nebraska Game and Parks Commission

  Activity summary – Prescribed grazing was conducted. Cedar removal and noxious weed control continues. Food plots are established.

- **Arbor Lake Complex** – North of Arbor Road and east of 27th Street.

  Total Size: 132.5 acres
  Owner: City of Lincoln

  Arbor Lake Extension Purchase (Anderson Property, 69.2 acres)
  Purchase price and date: $361,710.67 on September 1, 2004
  Funding source: 2002 NET grant through City of Lincoln

  <u>Activity summary</u> –Wetland restoration construction was completed in May 2012. Post-restoration monitoring is continual. Noxious weed and woody vegetation removal continued. Upland area hayed. Research project completed and cleaned up.

- **Marsh Wren –** Between 40th and 56th Streets and north of Salt Creek

Total Size:	80.0 acres
Purchase price and date:	$320,000 on May 27, 2009
Funding sources:	Lower Platte South NRD ($25,000) SWCP ($25,000) City of Lincoln floodplain acquisition funds ($178,000 ($89,250 each from the City of Lincoln and the LPSNRD) 2005 NET Grant ($91,500)
Owner:	Lower Platte South Natural Resources District

  Marsh Wren addition (Anderson property) – East of 40th Street and immediately north of Salt Creek

Size:	49.4 acres
Purchase price and date:	$270,000 on June 19, 2012
Funding sources:	Federal Section 6 ($135,000) 2008 NET Grant ($130,000) SWCP ($5,000)
Owner:	Lower Platte South Natural Resources District

  <u>Activity summary</u> – Noxious weed and woody vegetation removal continued. Access easements and acquired and developed for entry to site. Construction commenced on wetland restoration project. Area closed to Public until construction completed.

- **Little Salt Fork Marsh Preserve addition (Allen property) –** Between Branched Oak Road and Raymond Road and west of 1st Street

Size:	66.6 acres
Purchase price and date:	$304,000 on February 17, 2010
Funding sources:	Lower Platte South NRD ($76,000) SWCP ($75,000) 2008 NET Grant ($153,000)
Owner:	Lower Platte South Natural Resources District

- **<u>Activity summary</u>** – Noxious weed and woody vegetation removal continued. Upland area was cropped with soybeans. After harvest, drainage areas were sprayed and terraces leveled in preparation for native seeding in 2017.

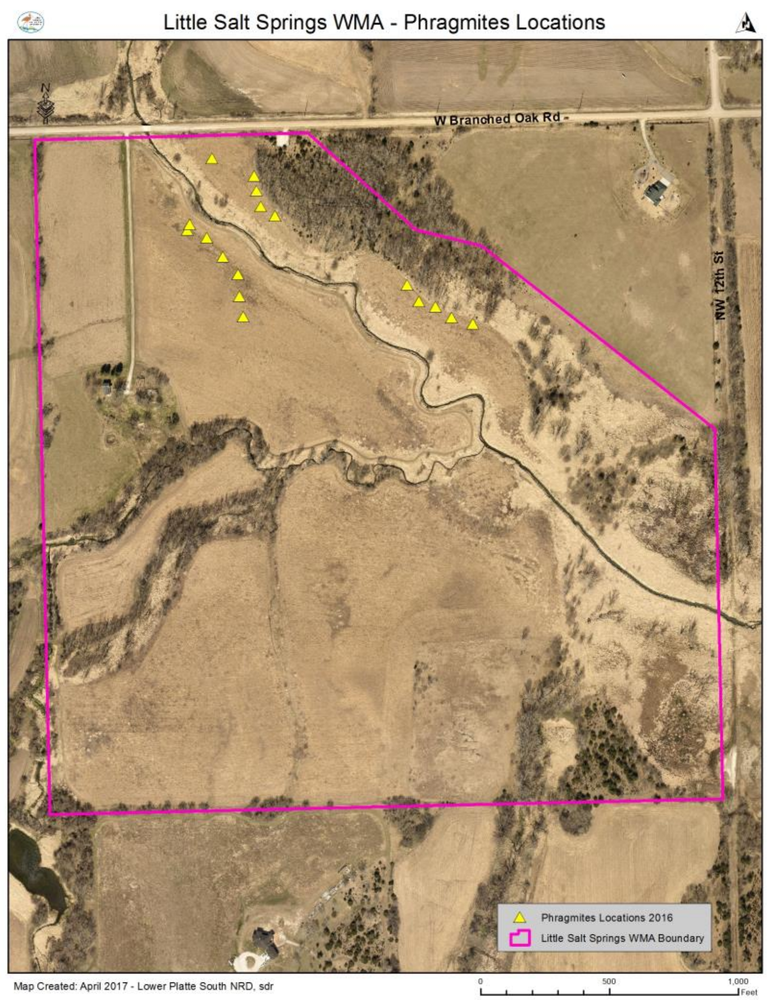
- **Little Salt Springs** – NW 12th Street and Branched Oak Road

  Size: 123 acres
  Purchase price and date: $472,188 on July 31, 2007
  Funding sources: Lower Platte South NRD ($187,960.35)
  2005 NET grant ($227,227.95)
  Partnership Funds ($57,000)
  Owner: Lower Platte South NRD

  Little Salt Springs Addition (Downs Property) – West Branched Oak Road between NW 12th and NW 27th streets

  Size: 13.3 acres
  Purchase price and date: $175,000 on October 15, 2015
  Funding sources: Lower Platte South NRD ($43,201.17)
  2012 NET Grant ($131,798.83)
  Owner: Lower Platte South NRD

  Activity summary – Continue to control noxious weeds and woody vegetation with emphasis on phragmites along west side of Little Salt Creek. The farmstead was gutted in preparation for a trial burn for the local fire department. The outbuildings were razed. Gate was installed at entrance off of west Branched Oak Road.



- **Helmuth Marsh –** South of Mill Road and west of 14th Street

  Size: 119.0 acres
  Purchase price and date: $630,000 on November 23, 2010
  Funding sources: Federal Section 6 ($275,000)
  2001 State Wildlife Grant through the
  U.S. Fish and Wildlife Service ($131,666.50)
  NGPC ($23,333.50)
  Donation from Helmuth family ($200,000)
  Owner: Pheasants Forever, Inc.

  <u>Activity summary</u> – Prescribed grazing and haying of upland was conducted. Cedar removal and noxious weed control continues.

- **Jack Sinn Wildlife Management Area (Kreitman addition) –** Between North 70th and North 84th streets and south of Ashland Road

  Size: 183.5 acres
  Purchase price and date: $375,000 on June 4, 2014
  Funding sources: Nebraska Game and Parks Commission ($225,000)
  2012 NET Grant ($150,000)
  Owner: Nebraska Game and Parks Commission

  <u>Activity summary</u> – Noxious weed control. Fencing plan developed to allow for prescribed grazing

- **Norder Tract –** Between North 14th and North 27th streets and south of Waverly Road

  Size: 78.9 acres
  Purchase price and date: $457,000 on September 15, 2014
  Funding sources: Federal Section 6 ($270,000)
  2012 NET Grant ($187,000)
  Owner: City of Lincoln

  <u>Activity summary</u> – 2016 Agreements for grazing (68.5 acres) and row crop (9.8 acres) were completed. Cooperators were responsible for land management activities.

- **Seacrest Range** (43 acres) – Located west of Folsom Street along both the north and south sides of Rosa Parks Way. The area is owned by the City of Lincoln. Efforts continued to remove woody vegetation and to control noxious weeds (Leafy spurge). Hex baskets to protect against flooding temporarily in place along east boundary and south of Rosa Parks Way.

- **Lincoln Saline Wetlands Nature Center** (92.7 acres) – Located near Capitol Beach in Lincoln. The area is owned by the LPSNRD. Management activities in 2016 included haying, noxious weed control (considerable phragmites) and woody vegetation.

- **Schleich Wetlands** (50.2 acres) – It is located southwest of Little Salt Creek near where it empties into Salt Creek and east of the Northridge subdivision in Lincoln. The area is owned by the LPSNRD. Management activities in 2016 were noxious weeds and removal of invasive trees.

- **Whitehead Wetlands** (98.8 acres) – It is located east of 27th street and a short distance south of Interstate 80. The area is owned by the LPSNRD. Management activities in 2016 were noxious weed control and removal of woody vegetation.

- **Little Salt Fork Marsh Preserve** (174.2 acres) – Located northwest of north 1st Street and Raymond Road and owned by the Lower Platte South NRD. Management activities in 2016 included control of noxious weeds. Discussion continues with Lancaster County regarding Raymond Road Bridge improvements.

- **Jack Sinn Wildlife Management Area** (1,352.3 acres) – Located south of Ceresco in Saunders and Lancaster counties. This area is owned by the NGPC. Management activities in 2016 were noxious weed control, woody vegetation removal, and prescribed fire and grazing.

The following Table provides a summary of the well distribution throughout the saline wetland management areas. Information gathered from the wells assist with the understanding of saline wetland hydrogeology of Nebraska's eastern saline wetlands.

Saline Wetland Management Area	**Wells # (depths)**			
	15-40 feet	41-90 feet	90 feet +	Other
Frank Shoemaker Marsh	3 (20', 25', 25')	3 (72.5, 75', 87.5')		1 (unknown depth)
Dakota Springs	3 (15', 25', 30')	2 (88', 79')	1 (98')	
Little Salt Creek WMA	2 (15', 15')	3 (77.5', 78', 83.5')	1 (182')	
Little Salt Fork Marsh Preserve	4 (9', 12', 25', 33')		2 (155', 201')	
Arbor Lake Complex	3 (14', 25', 28')	1 (41')	4 (113', 100', 120', 180')	
Little Salt Springs				1 (livestock)
Marsh Wren			2 6" (E. 216' and W. 155')	
Lincoln Saline Wetland Nature Center				1
Whitehead Saline Wetland	5 (15', 22', 23', 29'(?), 40')	1 (78')	2 (113', 188')	1 (unknown depth) 1 (Dial easement 30')
Jack Sinn WMA	1 (34.5')	4 (43', 45', 45', 63')	4 (93', 143', 143', 191')	2 (unknown depth)

Source: Saline Wetlands Conservation Partnership, 2017

This program has been very successful and continues to accomplish many of the goals of the Implementation Plan for the Conservation of the Eastern Saline Wetlands. Your continued support for the conservation of these natural areas is appreciated. If you have any questions, please contact me at 402-476-2729 or tmalmstrom@lpsnrd.org at the NRD or 402-441-7063 or tmalmstrom@lincoln.ne.gov at the City Parks and Recreation Department. You can visit the saline wetland website at http://lincoln.ne.gov/city/parks/ParksFacilities/wetlands/index.htm

APPENDICES

Appendix A

Nebraska's Inland Ocean: Restoring The Saline Wetlands

by Ariana Brocious, NET News

August 18, 2016 - 6:45am

The water that comes out of the ground around Lincoln can be almost as salty as the ocean. Historically, that created a rare environment for salt-adapted plants and animals. But much of that habitat was lost as the city has grown. A partnership is working to restore it.

Roughly seven miles northeast of Lincoln’s capitol building lies the confluence of Salt Creek and Little Salt Creek. From a high bank overlooking the water, Dan Schulz pointed to the clear water flowing below.

“That's actually base flow or salt water that's being discharged in the bottom of the creek,” he said. Before this property was farmed and used as a hunting club, that salt water made this land something else entirely – saline wetlands and salt marshes.

“Originally there was probably around 20,000 acres of these saline wetlands,” said Schulz, resources coordinator for the Lower Platte South Natural Resources District. “There were large expanses of bare ground that when it was dry enough it would actually be white and salt could accumulate on that.” Schulz said that unique landscape is part of why Lincoln is here.

“The first people that came here to settle the area were here to prospect mining salt that accumulated in these saline wetlands,” Schulz said. “The success of that was marginal at best.” There may not have been enough salt for a commercial industry, but salt-loving plants and animals flourished. So why is Lincoln’s groundwater so salty?

There are two main kinds of bedrock in eastern Nebraska, explained Dana Divine, survey hydrogeologist with Nebraska’s Conservation and Survey Division. The deeper, older limestone and shale contains a layer of evaporites, basically “thin beds of salt” said Divine. “Researchers now recognize that unit as very likely the source of the salt to the saline wetlands and the whole Lincoln area,” she said.

On top of that limestone sits the Dakota group, which contains layers of impermeable rock called mudstone. “And so that kind of acts like a cap to keep the saline water, the older saline water down,” Divine said.

But as groundwater moves downhill from the Rocky Mountains across the plains, it loses elevation and gains pressure. And in some places in eastern Nebraska that pressurized, saline water finds a way to the surface. Some of the water that comes out of the ground around of Lincoln is getting close to seawater, Divine said. “It's pretty salty.”

Researchers think the saline wetlands and salt marshes formed as that deep salty water repeatedly welled to the surface and spread out. But as the city of Lincoln grew, people changed the landscape.

“Years ago we used to just fill in wetlands, they were more of a nuisance,” said Tom Malmstrom, coordinator of the Saline Wetlands Conservation Partnership, which formed in 2003. He said people began to recognize the value of the saline wetlands in the 1980s, when some of the first saline land was set aside.

“They have been identified as one of most fragile ecosystems in the state of Nebraska. It also has an endangered species, the Salt Creek Tiger Beetle. It's the only location where it exists in the world,” said Malmstrom. The U.S. Fish and Wildlife Service has designated 1,100 acres along four streams in the Salt Creek watershed as critical habitat for the endangered beetle.

Today, only about a quarter of the original estimated acreage of eastern Nebraska saline wetlands remains. And many of those have been degraded by human development.

“We've built up the surface and we've lowered the water table, so now it's harder for our pressurized water to get up,” Divine said. Streams like Salt Creek have been channelized, which lowers the water table deeper. Sediment has accumulated on the land surface—from farming, road building, development, and freshwater runoff.

“And so our historic salty soil is now buried, and that salty soil is what the plants needed, what the beetles needed, and it’s buried under fresh new sediment,” Divine said.

Back on the edge of Little Salt Creek, a backhoe moves loads of dirt to lower the elevation of the bank. Schulz explained this is part of efforts to restore some of the natural hydrology.

“Historically little Salt Creek and Salt Creek would have had out of bank events rather regularly,” Schulz said. “So that salt water that was in the creek would spread out across the adjoining banks and the landscape and help accumulate the salt.”

The Saline Wetlands Conservation Partnership is working on restoring and preserving that unique habitat where they can, like this site called Marsh Wren. In addition to lowering the banks, they’ve scraped the ground to remove sediment and installed systems of pipes that allow them to control the flow of water on the entire site. By recreating the saltwater flooding, they hope to reestablish the saline soils that sustained the wetlands, Schulz said.

“I expect the vegetation to change, I hope that we eventually have enough salt accumulate in some of these cells that we can have salt flats again,” Schulz said. This restoration work is adaptive management, he added, “we're going to learn as we go along.”

Federal funding to protect the salt creek tiger beetle has helped conservation efforts, but many other groups have contributed land and money as well. Since the 1980s, the partnership has protected and restored more than 4,500 acres in the Salt Creek watershed. Once construction ends at the Marsh Wren site, it will be open to the public, like many of the wetland properties.

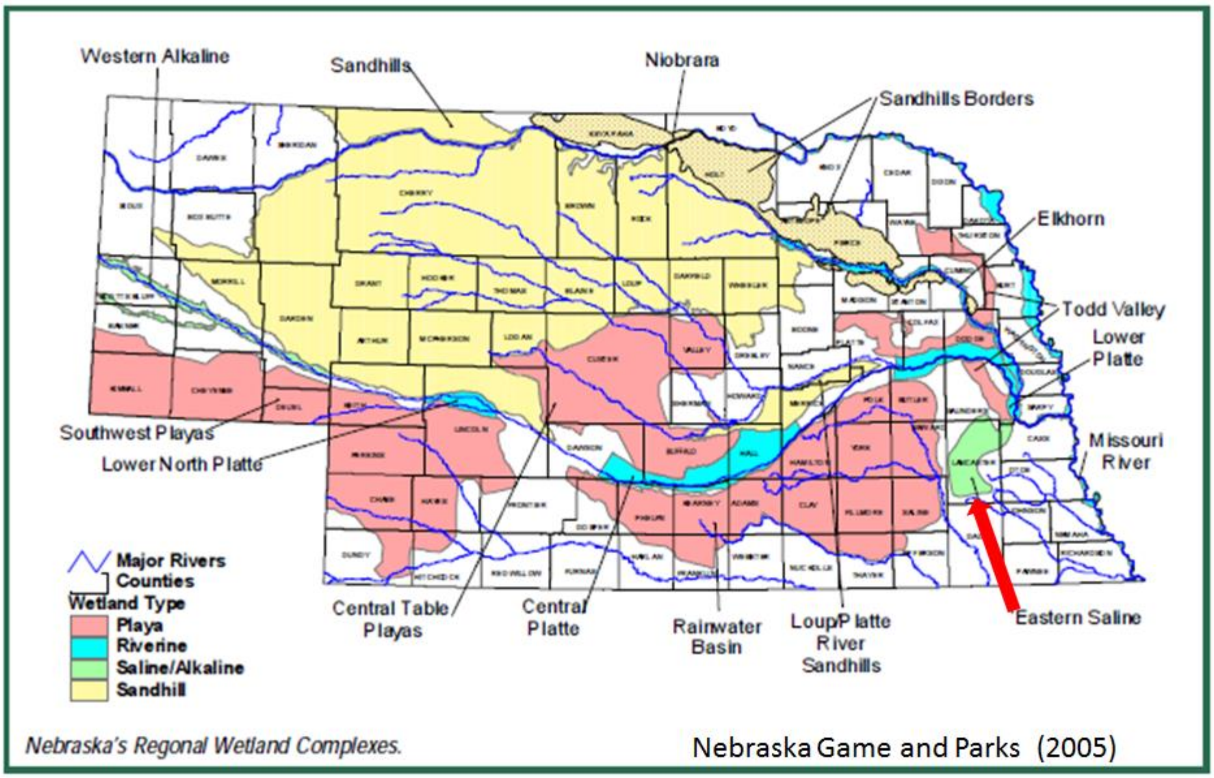
“As we develop more and more of this country for the things that we want to do, there's fewer and fewer places like this that people can access,” said Schulz. “And [that’s] what's great about the saline wetlands--it's in Lincoln's backyard.”

Appendix B

Biogeochemical controls on saline wetland plant establishment in Nebraska's Eastern Saline Wetlands

A Final Report

submitted to the Nebraska Game and Parks Commission on March 15, 2016



Nebraska's Regional Wetland Complexes. Nebraska Game and Parks (2005)

Submitted by

Keunyea Song[1,2] and Amy Burgin[1,2]

[1]School of Natural Resources, University of Nebraska-Lincoln

[2]Current affiliation: Kansas Biological Survey, University of Kansas

Table of Contents

1. Executive Summary

Nebraska's eastern saline wetlands are unique ecosystems that provide habitat for wildlife and salt-tolerant plant communities. However, urban and agricultural development and related activities have degraded over 80% of saline wetlands in Nebraska; now they are considered an endangered ecosystem.

The goal of our study was to determine whether continuous saline groundwater addition to the soil surface would create a more favorable saline condition for saline plant species and other wetland ecosystem services. Under this overarching goal, we sought to understand how soil and water biogeochemistry respond to saline groundwater addition (a proposed saline wetland restoration practice), as well as whether this practice would shift plant communities to a saline-obligate dominant community.

We implemented the groundwater addition practice in the experimental restoration site and measured: 1) soil physicochemical changes, 2) biogeochemical process rate changes and 3) plant community and diversity changes in relation to salinity and water addition methods (slow vs. fast water addition). The experimental restoration site was located immediately north of Lincoln, Nebraska and it contained 32 plots divided into four replicates of the following water additions: 1) fresh water, 2) low salinity (3 ppt), 3) mid-level salinity (12 ppt), and 4) high salinity (27 ppt), respectively in addition to two control plots. The treatment gradient was drawn from naturally occurring a variation in groundwater at the site. Using water, soil and gas samples collected from the experiment site, we measured changes in pore water chemistry and rates of biogeochemical processes like greenhouse gas flux.

Biotic responses were determined with two separate surveys: 1) a germination experiment and 2) measurements of plant growth rate and diversity changes in the experimental site. The germination experiment was conducted in a temperature and light-controlled incubation lab-setting. Six saline wetland species were used as indicators of a healthy saline wetland plant community: Saltwort (*Salicornia rubra),* Saltgrass *(Distichlis spicata),* Spearscale *(Atriplex patula),* Seablite (*Sueada depressa),* Marshelder (*Iva annua)*, and Saltmarsh Aster (*Aster subulatus).* We identified all plants in the experimental plots using a quadrat (1 ×1m) and calculated the relative abundance of each species.

Key findings:

1) Continuous saline groundwater addition increased the interaction and connections between soil and saline groundwater, which created more saline pore-water conditions in the experimental restoration site. **Slow groundwater addition was more effective** in creating saline conditions and generating salt crusts in the surface soil.
2) Saline groundwater addition increased CO_2 fluxes likely due to physical and chemical dissolution and desorption of inorganic carbon from the soil particles. Thus, **alteration of soils by increasing salinity will affect carbon cycling (reduce C storage)** in addition to altering the saline characteristics.
3) Salinity and temperature affected the germination rates. **Salinity inhibited germination rates of all six targeted species**. High salinity (26-30ppt) suppressed the germination rates significantly and highest germination rate reached only 8%. We found that the **April thermo-period (5°C night-20°C day) stimulated germination rates** for most saline species in this study. It was particularly favorable to Seablite germination.
4) Plant species richness decreased as salinity increased at the experiment site, mainly due to suppressed growth of terrestrial and freshwater wetland species. **At Mid and High salinity treatments, target saline species became dominant** in the plant communities. **Spearscale and Seablite** were the most abundant saline species in all salinity treatment plots, which is consistent with the results of germination experiment. Saltwort emerged only in the Mid-salinity level plots.

Based on our research findings, we conclude that continuous addition of middle range salinity (i.e. 26-30ppt) in the soil surface would create favorable habitat to saline species. For best results, we also recommend slow application of middle salinity range groundwater and saline species seeding by April in Lancaster County, Nebraska (i.e. temperature range: min. 5°C, max. 20°C).

2. List of Tables

3. List of Figures

4. Project Background

Nebraska's Eastern Saline Wetlands are inland saline wetland ecosystems endemic to the Salt Creek, Little Salt Creek, and Rock Creek watersheds in Lancaster and Saunders counties near Lincoln, Nebraska (Fig. 1A). This unique ecosystem is fed by deep groundwater from the Dakota formation layer, or deeper layers, which contains high salt concentrations originated from ancient ocean salt deposits.

These saline wetlands provide unique habitat for salt-tolerant species including the state endangered saltwort (*Salicornia rubra*) and the state and federally endangered Salt Creek tiger beetle (*Cicindela nevadica lincolniana*) (Fig. 1 B/C). However, extensive agricultural and residential development in the Lincoln area has degraded over 80% of the saline wetlands. Now it is considered an endangered ecosystem type with only 3,200 acres remaining (LaGrange et al., 2003).

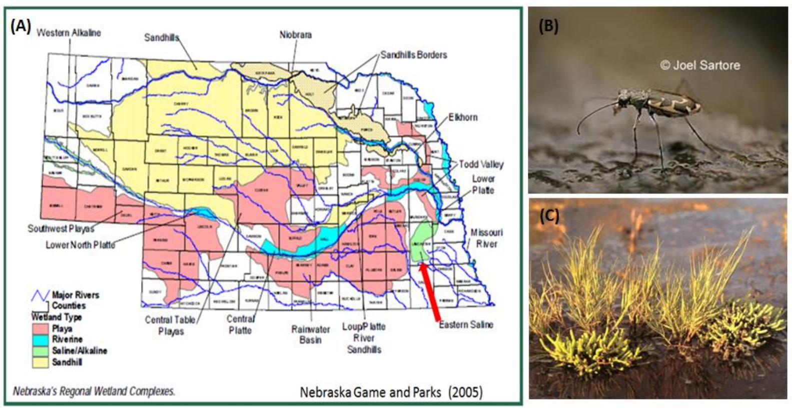


Fig. 1. Nebraska's Eastern Saline Wetlands (in green; A), Salt Creek Tiger Beetle (*Cicindela nevadica lincolniana;* B) and Saltwort (*Salicornia rubra;* C).

The Saline Wetland Conservation Partnership (SWCP) was organized to conduct restoration and conservation of this endangered ecosystem. The goal of SWCP is "No net loss of saline wetlands and their associated functions with a long-term gain in sustaining wetland functions through the restoration of hydrology, prescribed wetland management, and watershed protection" (La Grange et al., 2003). One main restoration goal for Nebraska's Eastern Saline Wetlands is the restoration of native saline plants as many salt-tolerant plants found in these ecosystems are rare or endangered in Nebraska, including saltmarsh aster and saltwort. Despite the attempts to conserve and restore the remaining saline wetland fragments, there is limited scientific understanding of Nebraska's Eastern Saline Wetlands and effective restoration strategies. Given that groundwater and soil surface interactions and connections play key roles in maintaining saline wetland conditions (Harvey et al., 2007), the Partnership proposed a restoration technique: introducing deep saline groundwater to surface soils to mimic groundwater upwelling and improve soil-groundwater interactions. Ideal outcomes of this restoration practice would be improving the conditions for saline plant species as well as recovering wetland ecosystem services by creating more saline areas.

5. Project Objectives

The overall goal of this research was to test the feasibility of the proposed practice to maintain or improve the saline condition by adding saline groundwater to the soil surface. The objectives of this project were specified into three components (Fig. 2):

1) ***Soil Physicochemical Responses***: Improve our understanding of the interactions and connections among artificial groundwater intrusion and soil physicochemical characteristics.

2) ***Soil Biogeochemical Responses***: Understand changes in biogeochemical process rates (e.g. gas exchange rates or microbial metabolism) resulting from this wetland restoration technique.

3) ***Biotic Responses*:** Determine if saline groundwater additions can shift plant communities to a saline-species dominant community.

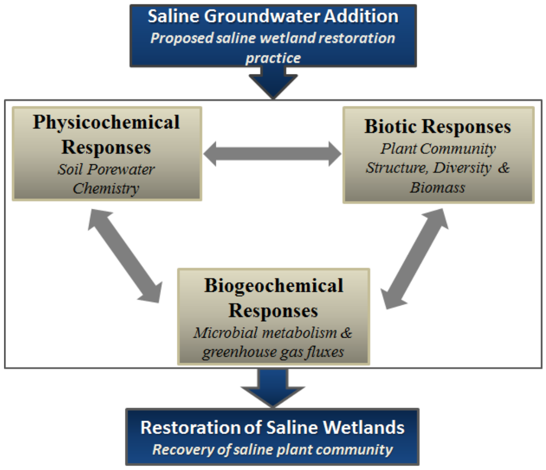


Fig. 2. Conceptual diagram of research objectives in relation to the impact of saline groundwater addition to the restoration sites.

6. Materials and Methods

6.1. Experimental Restoration Site

6.1.1. Site Description

The experimental site is located north of Lincoln, Nebraska at the northeast corner of the intersection of 27th Street and Arbor Road and near Frank Shoemaker Marsh; a saline wetland restoration site(Fig. 3). The major research activities started in April 2014. The final experimental design included four salinity levels (Fresh: 0.2 ppt, Low: 2-3 ppt; Middle: 18-20 ppt and High: 26-30 ppt) and two hydrologic regimes (Slow and Flush) with four replications (4 × 2 × 4 +2 control=total 34 plots, Fig. 4, 5). The 34 plots were randomly assigned in three dredged experimental areas. The plots (2m ×1.5 m) were established in the existing soils at the site. The soil was categorized as Salmo Silty Clay Loam, and the site was in crop production prior to 2004. There was likely a plant seed bank present in the soils.

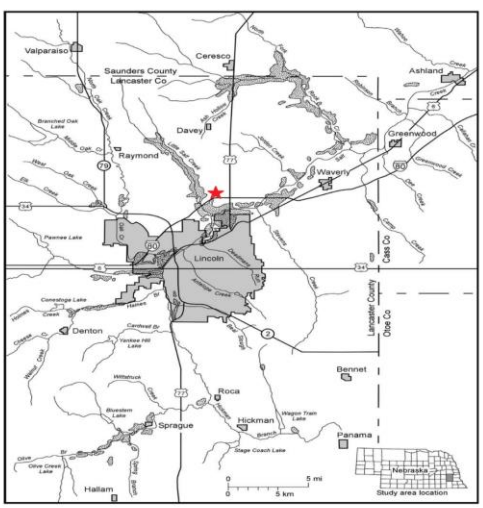


Fig. 3. Distribution of Nebraska Eastern Saline Wetland and Experimental Site (Red Star). (Modified from Harvey et al., 2007)

6.1.2. Experimental Design

The salinity treatment gradient was drawn from naturally occurring variations in groundwater at the site. Saline groundwater with three different salinity levels was supplied from the groundwater wells installed at the experimental site (the wells were screened at 20ft, 90ft and 180ft deep), referred to as **Low**, **Mid**, and **High** salinity water sources, hereafter (Fig. 5).

We used Lincoln tap water as a freshwater source to differentiate the effects of salinity and water addition. In addition to determining an environmentally relevant salinity gradient, we also had to consider how to realistically apply groundwater to the surface soil. Therefore, we applied two different hydrologic patterns to create different intensities of salt water intrusion (Fig. 6): 1) **SLOW** water addition: 55 gallons of water were released at an approximate flow rate of 4 L/ hr. for 2 days through the use of rain barrels and drip tapes. 2) **FLUSH** water addition: Rapid flooding was simulated by applying the same amount of water (i.e. 55 gallons) at a rate of 4L/min. This is similar to the rate at which groundwater is pumped from wells. The two control plots did not receive any water addition.

Fig. 4. Saline wetland restoration experimental site

Plastic covered barriers were inserted 15 cm deep into the soil to minimize water exchange between plots. All measurements were conducted in the center of the plots and at the soil surface. Saline groundwater and freshwater were added into the experiment plots weekly from July 2014 to October 2015 except on rainy and cloudy days. A weather station was installed in Jun. 2014, and solar radiation, air temperature, relative humidity, precipitation, wind speed, and wind direction were recorded hourly basis until Oct. 2015.

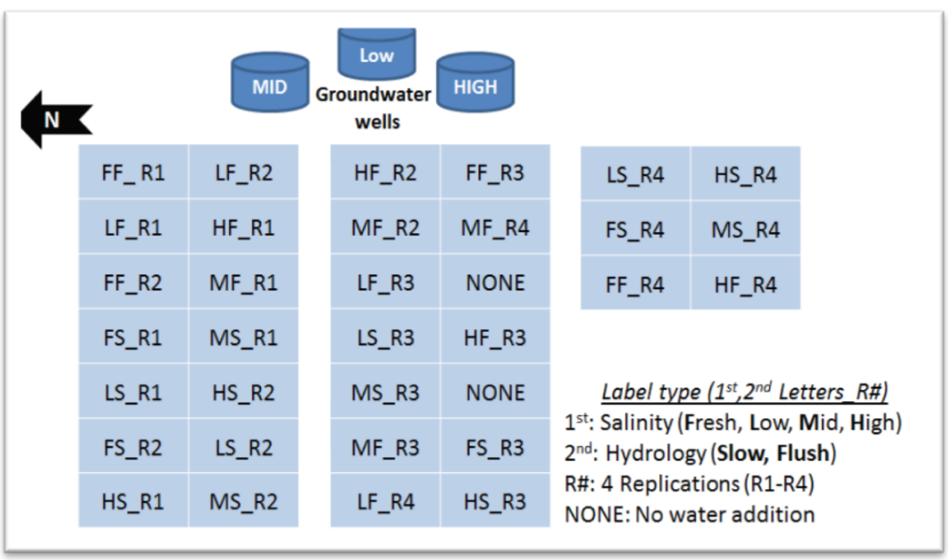


Fig. 5. Field experimental design and the layout of the site: salinity gradient (Fresh, Low, Mid and High) × hydrology patterns (Slow-S and Flush-F) × 4 replications

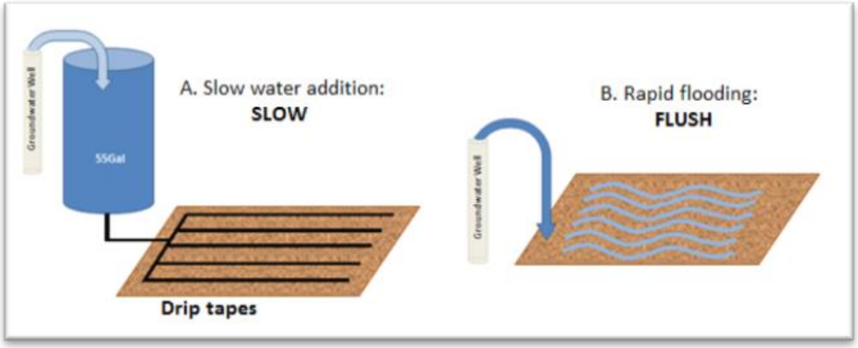


Fig. 6. Simplified conceptual demonstration of the hydrologic patterns: (A) Slow water addition vs. (B) rapid flooding Flush treatment.

6.2. Biogeochemical and Physical Responses-2014

In the first year of the study (2014), we focused on the physicochemical and biogeochemical responses to saline groundwater addition. To separate these from the biotic responses, mainly mediated by plant communities, we kept the experimental restoration site plant-free in 2014. Mechanical removal (mowing) followed by chemical treatment (i.e. glyphosphate) were conducted two months before the experiment, and any minor plant emergence was controlled by hand or spot chemical treatment during the experiment.

6.2.1. Field Sampling and Biogeochemical Analysis

To measure the change of pore water chemistry over time in relation to saline groundwater and freshwater addition, we installed a pore water sampler in each plot and collected pore water 1-2 times per month. Pore water sampling was generally conducted 1-2 days after each water addition. Sampled pore water was then filtered within 24 hours and stored in a freezer until the subsequent analysis. The concentrations of chloride (Cl^-), nitrate (NO_3^-), and sulfate (SO_4^{2-}) were measured using Ion Chromatogrphy (DIONEX-IC). Cl^- and SO_4^{2-} are indicators of increased salinity as both are abundant in salt water.

Greenhouse gas flux was measured biweekly using a closed chamber method. Headspace gas was collected five times at 10 min intervals from closed greenhouse gas chambers (Fig. 7). CO_2 and CH_4 concentrations were analyzed from the headspace samples using Gas Chromatography (HP-6890), then concentration changes over time were used to calculate gas flux rate (µg m^2 hr^{-1}).

Fig. 7. Experimental plot set up with greenhouse gas chamber and pore-water sampler

6.2.2. Soil Core Incubation-Lab Experiment

We collected three replicated soil cores collected from 10cm deep surface soil at each plot bimonthly from July 2014 to October 2015 for lab scale soil incubation experiments. At the lab, we measured microbial-driven ecosystem processes such as denitrification, iron reduction, and sulfate reduction rates as well as extracellular enzyme activities. Given that these microbial processes occur under anaerobic condition, all soil biogeochemical processes were done in an anaerobic glove bag (Fig.8). Data from the lab incubation experiment is still under chemical and data analysis. The final results will be reported in manuscript format to SWCP.

Fig. 8. Sediment core incubation experiment in the lab setting (Anaerobic glove bag and soil incubation for denitrification measurement)

6.3. Biotic Responses-2015

The second year's (2015) research objective was to understand the interaction of saline groundwater addition and subsequent biogeochemical changes with native plants growth rates. For this, we collected native target saline species seeds and conducted: 1) a germination experiment, 2) seeding in the experimental sites, and 3) plant growth rate and diversity surveys. We also continued physicochemical and biogeochemical measurements at the experimental site and in the lab as described above. The germination experiment and plant survey at the field restoration site were particularly important given that there is little information on effective seeding time and salinity level to improve saline plant communities.

6.3.1. Seed Collection

Seven saline wetland plant species were selected based on their relative value and scarcity of species (Fig. 9, Table 1). For example, saltwort (*Salicornia rubra*) is a high salt-tolerant species and state endangered species. The targeted species were *Salicornia rubra* (common name: Saltwort), *Sueada depressa* (Seablite), *Atriplex patula* (Spearscale), *Hordeum jubatum* (Foxtail barley), *Aster subulatus* (Saltmarsh Aster), *Iva annua* (Marshelder), and *Distichilis spicata* (Saltgrass). We collected the seeds for these species in September-November 2014 with help from the Prairie Plains Resource Institute (Mike Bullerman). Seeds were collected in saline wetlands near the experimental site (Fig. 10). Collected seeds were hammer-milled and went through a purification process. The purification process included hand picking, sequential sieving, and gentle air-blowing to separate the seeds from remaining plant materials. Purified seeds were cold-stratified for a month for the subsequent lab-scale germination experiment. Field seeding took place in March, 2015.

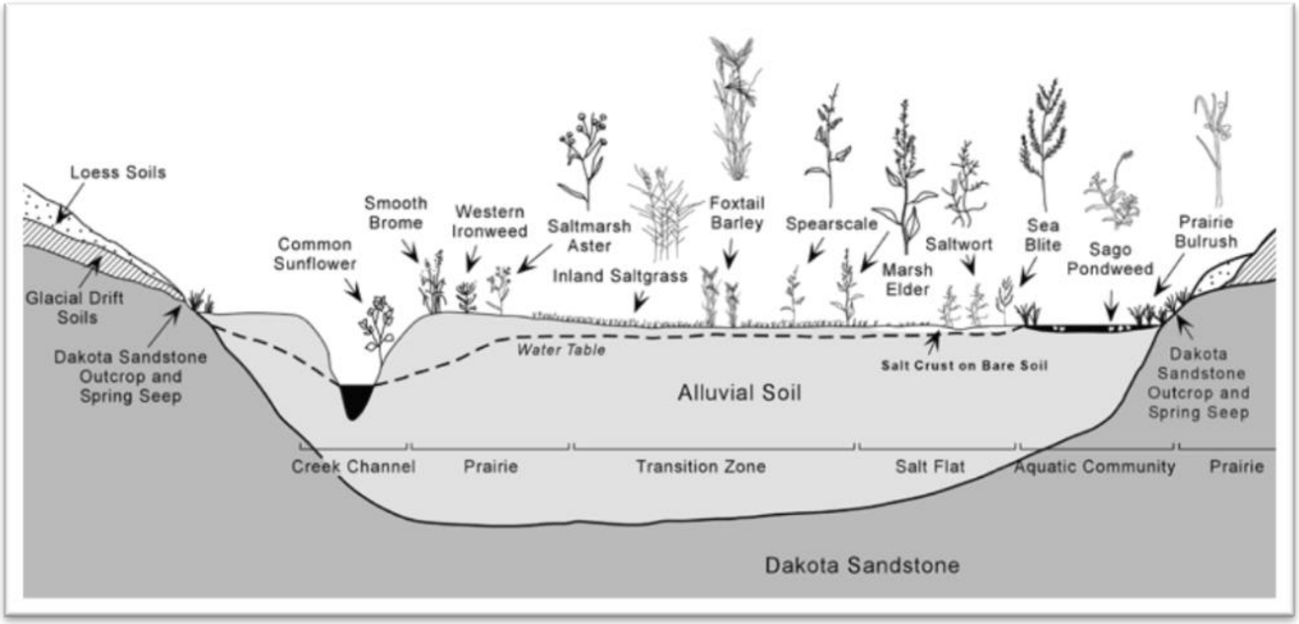


Fig. 9. Conceptual diagram of vegetation distribution along the salinity level (Harvey et al., 2007)

Table 1. Relative values of saline wetland plant species (modified based on Taylor et al., 1997 and Harvey et al., 2007)

Relative values	Species
4	Saltwort (*Salicornia rubra*)
4	Seablite (*Sueada depressa*)
3	Spearscale (*Atriplex patula*)
3	Saltgrass (*Distichlis specata*)
2	Foxtail barley (*Hordeum jubatum*)
2	Saltmarsh Aster (*Aster subulatus*)
2	Marshelder (*Iva annua*)
1	Other freshwater wetland plants
0	Upland plants

Fig. 10. Seed collection locations for Spearscale (ATSU), Foxtail barley (HOJU), Saltmarsh Aster (ASSB), Saltwort (SARU), Seablite (SUCA), Marshelder (IVAN), Saltgrass (DISP).

6.3.2. Germination Experiment

The germination experiment was conducted in a temperature and light-controlled incubation setting. Six saline wetland species (Saltwort, Spearscale, Seablite, Saltgrass, Marshelder, and Saltmarsh Aster) are indicators of a healthy saline wetland and are targeted species for this project and for the Saline Wetland Conservation Partnership. Foxtail barley seeds were not used in the germination experiment as we had a limited amount available for the field seeding.

The overall objective of the germination experiment was to find the best germination conditions (i.e. temperature and salinity levels) for each species and the optimal seeding time (i.e. optimal temperature) for the best restoration outcomes (Fig. 11). This information can be useful to identify the optimal conditions that improve inhabitation of native saline wetland species as means of saline wetland restoration practice.

We varied temperature and salinity based on environmentally relevant ranges. Three temperature levels of low-high temperature ranges that represent March (5-10°C), April (5-20°C) and May (10-20°C) conditions in Lincoln, Nebraska were used were used to find an optimal seeding time for each species. The low-end temperature for each month temperature was set with dark (night condition) whereas high-end temperature was with light (day time condition). This thermo-light treatment was cycled every 12 hours. Four salinity levels representing the groundwater salinity gradient and freshwater in Lincoln were used. We obtained saline groundwater from the wells located at the experimental site, and tap water was used for the freshwater source. All germination experiments were done in Petri dishes (5 ×1.5 cm) with two sheets of Whatman No. 2 filter paper. We placed 10 seeds of each species between the filter sheets and then 1 mL of saline or fresh water was in each petri dish. Each treatment had five replications.

Detailed experimental design: 3 thermo-light cycles (5-10°C, 5-20°C, 10-20°C) × 4 salinity level (Fresh, Low, Mid, High) × 6 saline species × 5 replicated dishes (each dish contained 10 seeds).

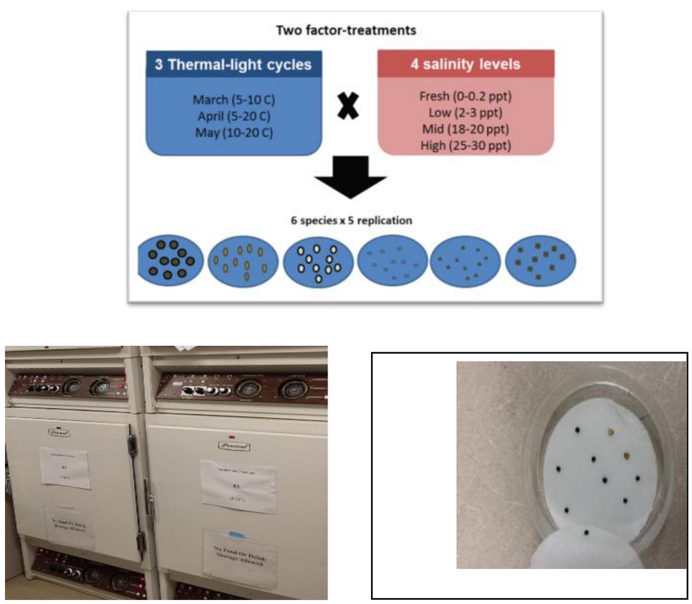


Fig. 11. Germination experiment set up (Top) and temperature/light controlled incubation chambers (Bottom)

The germination experiment was conducted in 2015 from February-May. The germinated seeds were counted and recorded every other day for 20 days. The percentage of seed germination of each dish at 2-day intervals was calculated as the germination rates over time. Germination rate measurement and analysis were modified based on a previous germination experiment (Ungar and Hogan, 1970; Khan et al., 2000).

6.3.3. Experimental Site Seeding and Vegetation Survey

We placed the stratified seeds of seven species into the experimental site in Feb. 2015. To understand the interaction of biogeochemistry with the growth rates of native plants under different salinity levels, we measured aboveground net primary productivity (NPP) at the surface using peak biomass measurement from experimental sites during September and October. We identified all plants in the experimental plots using a quadrat (1m ×1m) (Fig. 12). All plants in the quadrat were identified by species and measured for height. The number of stems or branches on the each plant was counted. The number of species and plants were used to calculate the relative abundance of each species and the plant diversity index per plot and per treatment. After completing the plant surveys for each plot, 10-20 samples of each species present in the experimental site were collected for biomass sampling. These samples were measured and counted using the same methods as used in the field. The plant samples were then placed in paper bags and oven dried at 65 °C for 14 days. The dry weight of each plant sample will be used to create an allometric regression to estimate peak biomass of each species and total biomass for each plot. Plant biomass and subsequent data analysis are still underway.

Fig. 12. Field vegetation survey quadrat (1m ×1m)

7. Results and Discussion

7.1. Soil Physicochemical Responses (Objective 1)

Groundwater pumped from wells at the experimental site showed a clear salinity gradient with salinity levels of 2-3 ppt for the shallow well (Low treatment), 18-20 ppt for middle (Mid) salinity treatment and 26-30 ppt for the high salinity. Freshwater used as the control exhibited salinity of 0.2-0.3 ppt. This salinity gradient in the groundwater created the Cl^- and SO_4^{2-} concentration gradients of pore-water samples (Fig. 13). This salinity gradient indicated by Cl^- and SO_4^{2-}concentrations was more distinctive in the plots with slow water application than those receiving water by flush method (Fig. 14). Cl^- and SO_4^{2-}concentrations in the Mid and High-level treatment with slow water application were significantly higher than those in groundwater-flushed plots. We observed the salt crust formation only on the surface sediment layer of Mid and High plots with Slow groundwater applied plots (Fig. 15). This result indicates that slow application of saline groundwater in the soil surface was effective in creating a saline condition with higher pore water salinity and visible salt crust formation on the surface soil. NO_3^- concentrations did not show any pattern between treatments.

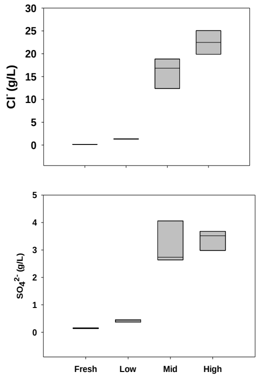


Fig. 13. Cl^- and SO_4^{2-} concentrations in the water source (n=5; tap water-Fresh; Low, Mid, High-groundwater from the wells at the

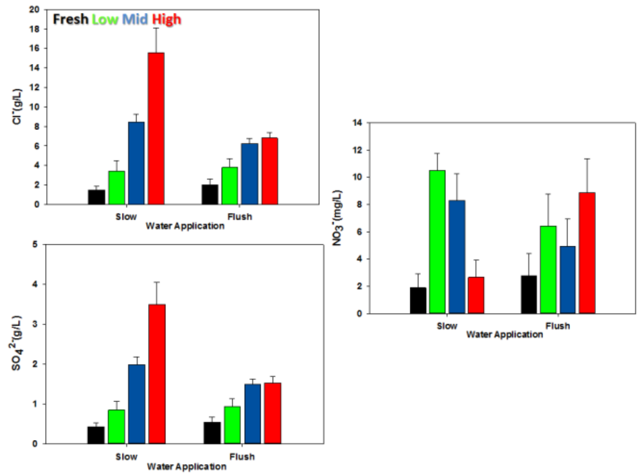


Fig. 14. Cl^-, SO_4^{2-} and NO_3^- concentrations in the pore water collected at the experimental sites (n=16)

Fig. 15. Formation of salt crust in Mid and High Slow plots

7.2. Soil Biogeochemical Responses (Objective 2)

CO_2 fluxes responded instantly and remained high at Mid and High salinity plots with up to 10^4 times higher values than those in Freshwater and Low plots (Fig. 16). Given that the experimental sites in 2014 did not have any plants, this CO_2 pattern is likely a physicochemical response to increased salinity (Herbert et al., 2015). One possibility would be desorption and exchange of inorganic carbon with high salt from saline groundwater (Mid and High levels). These physical effects may dissipate over time as salt groundwater addition continues. Water addition pattern did not have a significant influence on CO_2 fluxes. CH_4 concentrations and fluxes were low and variable regardless of salinity and water treatments. Negative CH_4 fluxes indicate that CH_4 oxidation was more predominant than CH_4 production at the sites.

We measured other biogeochemical process rates including denitrification, iron reduction, sulfate reduction and extracellular enzyme activities. These processes are still under chemical and statistical analysis.

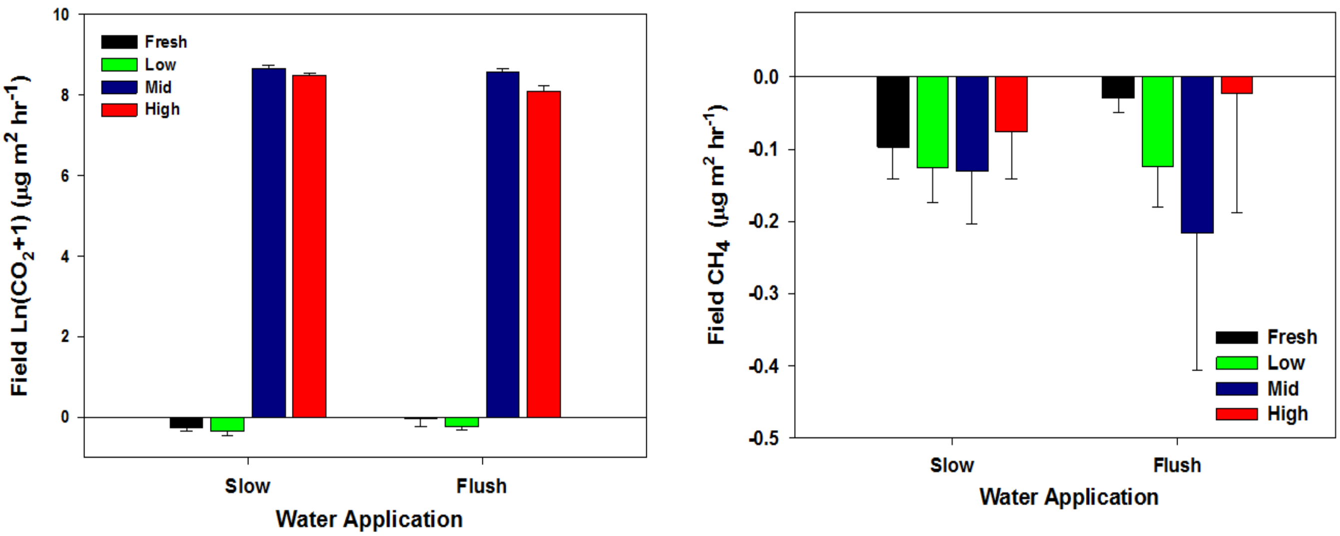


Fig. 16. CO_2 and CH_4 fluxes measured at the experimental site

7.3. Biotic Responses (Objective 3)

Biotic responses were determined with two separate surveys: 1) a germination experiment in a greenhouse, and 2) measuring plant growth rate and diversity in the field.

7.3.1. Germination rates of native saline species in different salinity and temperature levels in a greenhouse

Seed germination rates increased over time for 20 days of the experiment at all temperature and salinity treatments. Salinity decreased the germination rates significantly regardless the temperature differences. Highest germination rates were observed in the Freshwater treatment.

In the March temperature condition (i.e. 5°C - 10°C), Spearscale (labeled as ASSB in the figure) showed the highest germination rates in Fresh, Low and Mid salinity treatments. At the highest salinity level, Seablite (labeled as SUCA) germination reached the highest rate, 7% compared to others including Spearscale with 1-4% germination rates (Fig. 17).

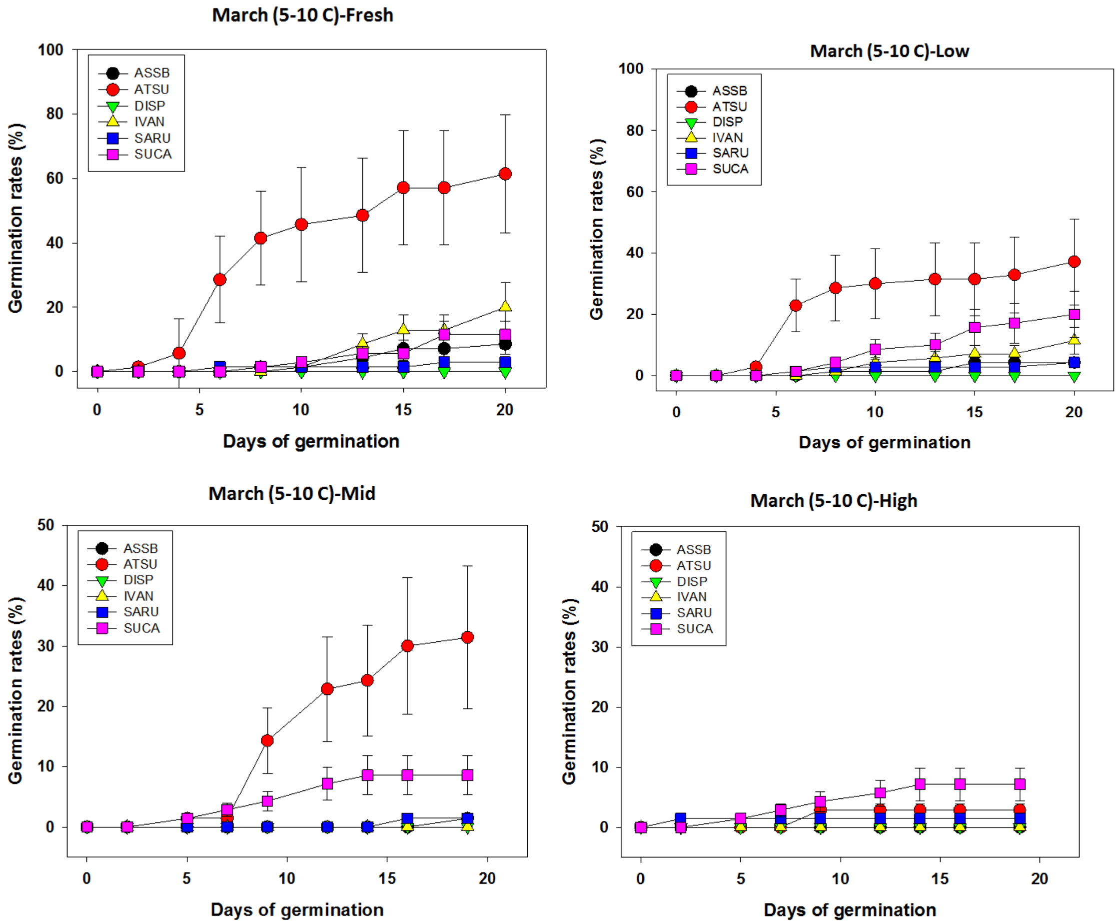


Fig. 17. Germination rates of six saline species seeds in different salinity level at the 5°C night-10 °C day thermal-period that represent March temperature in Lincoln, Nebraska. (ASSB-Saltmarsh Aster, ATSU-Spearscale, DISP-Saltgrass, IVAN-Marshelder, SARU-Saltwort, SUCA-Seablite)

Salinity inhibited the germination rates under the April temperature condition (Fig. 18). More interestingly, we found that increasing the day-time temperature (from March to April) stimulated the germination rates of seablite while it suppressed Spearscale's germination. When comparing the germination rates and patterns between Seablite and Spearscale at the April temperature set up, the final germination rate of Seablite exceeded Spearscale in all salinity levels. In addition, the overall germination rates of Spearscale in the April set up was lower than those under the March temperature. Seablite germination rates were an average 2.5 times higher in both Fresh and Low salinity levels, and it was 1.8 times higher for Mid salinity level compared with those in March temperature condition. Spearscale continued to show the second highest germination rates among studied species at the April condition. We also observed a slight increase of germination rates for other species, including Marshelder (IVAN), Saltmarsh Aster (ASSB) and Saltwort (SARU) with the April temperature condition. This result suggests that increasing temperature, or the April temperature range is likely optimal for the saline plant species we studied; it is especially favorable to Seablite germination.

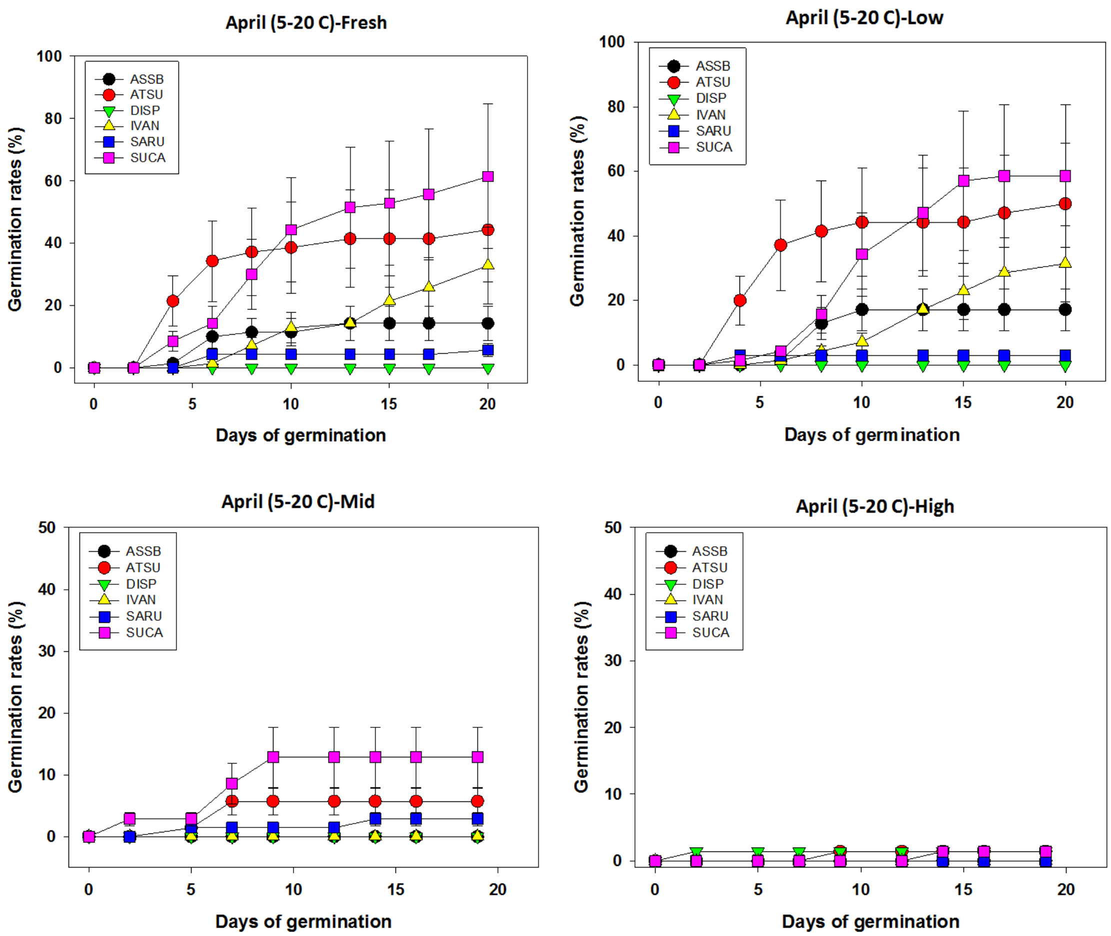


Fig. 18. Germination rates of six saline species seeds in different salinity level at the 5°C night-20 °C day thermal-period that represent April temperature in Lincoln, Nebraska. (ASSB-Saltmarsh Aster, ATSU-Spearscale, DISP-Saltgrass, IVAN-Marshelder, SARU-Saltwort, SUCA-Seablite)

At May temperature condition, 10-20°C, germination rates showed similar patterns with salinity and species sensitive germination rates. Spearscale and Seablite continued to have higher germination rates than others. However, germination rates for all species at the May temperature were lower than we observed at the April temperature regime (Fig. 19). This suggests that increasing minimum temperatures (Average min. temperature at night: 10°C) have either no or negative impacts on germination rates of Nebraska's Eastern Saline Wetland species.

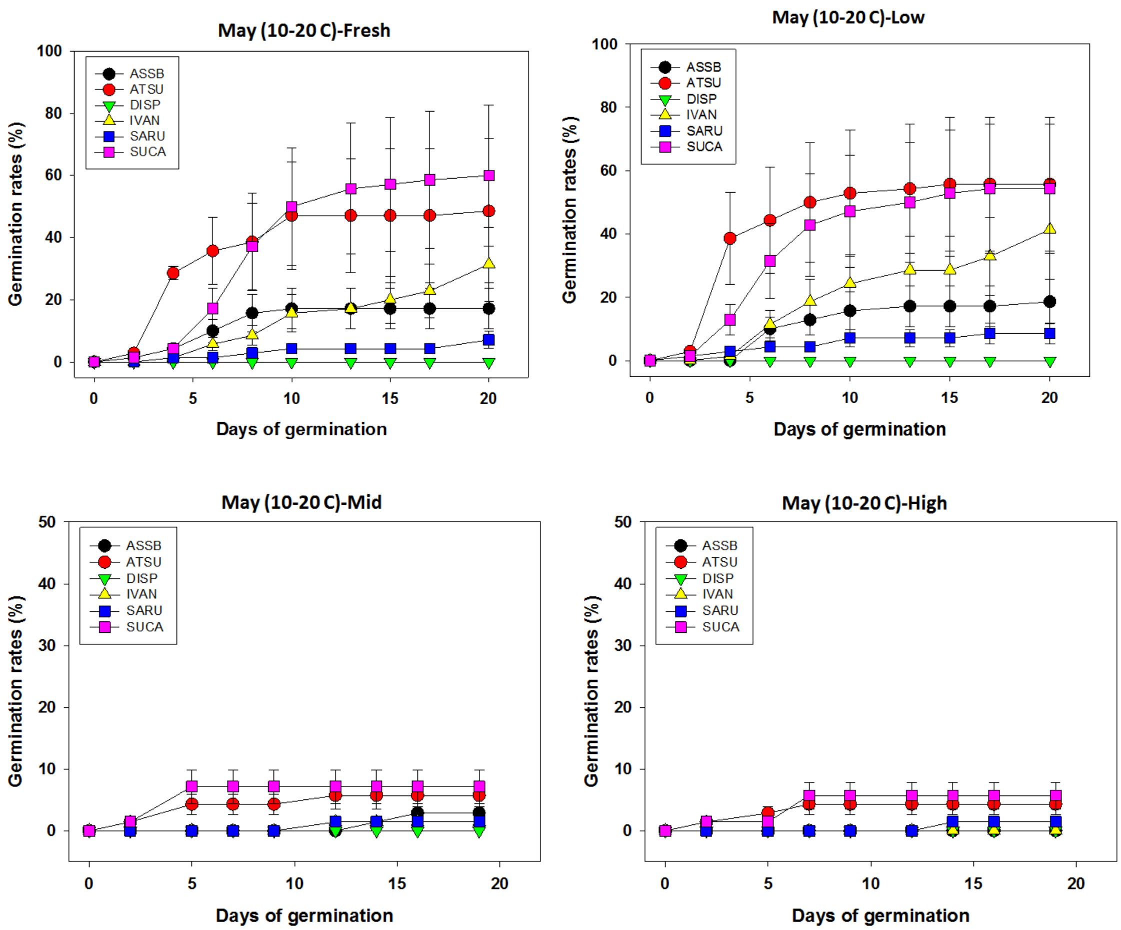


Fig. 19. Germination rates of six saline species seed in different salinity level at the 10°C night-20 °C day thermal-period that represent May temperature in Lincoln, Nebraska. (ASSB-Saltmarsh Aster, ATSU-Spearscale, DISP-Saltgrass, IVAN-Marshelder, SARU-Saltwort, SUCA-Seablite)

7.3.2. Plant survey in the experimental site

Plant communities became dense in all experimental sites, especially in freshwater treated plots. Based on the peak biomass measurements and the plant identification survey, we found that species richness decreased with salinity (Table 2). Please see Appendix for the scientific names of the plants. We identified a total of 20 species in freshwater treated plots whereas only 6 species were found in high saline water treated plots.

Table 2. List of species identified in the experimental site (Bold letter represents target species in the project)

Salinity	# of species	Species
Fresh	22	Burr Sunflower, Bushy Knotweed, Common Ragweed, Common Sunflower, Curly Dock, Fall Panicum, **Foxtail Barley**, Giant Foxtail, Goldenrod, Kochia, Marestail, **Marshelder**, Plantain, Saltbush, **Saltmarsh Aster**, **Salt Grass, Seablite**, **Spearscale**, Tall Thistle, Thistle, Western Ragweed, Witchgrass
Low	17	Bushy Knotweed, Common Ragweed , Common Sunflower, Curly Dock, **Foxtail Barley**, Kochia , **Marshelder**, Plantain, Red Foxtail, Reed Canary, Saltbush, **Saltmarsh Aster, Seablite**, **Spearscale**, Thistle, Western Ragweed, Witchgrass
Mid	11	Bushy Knotweed, Common Ragweed, Common Sunflower, **Foxtail Barley**, Kochia, **Marshelder,** Saltbush, **Saltgrass , Saltwort , Seablite, Spearscale**
High	5	**Foxtail Barley**, Kochia, Saltbush, **Seablite**, **Spearscale**, Western Ragweed

In the Fresh plots, common ragweed, thistle, kochia and giant foxtail were predominant, accounting for 60% of plant communities. These widespread plants are often considered weeds or invasive plants. Saline wetland indicator species such as seablite, marshelder and foxtail barley, which are also the project target species as well as saltbush were found in the Fresh plots (Fig .20). Saline wetland species contributed up to 20% of the plant communities in Fresh plots.

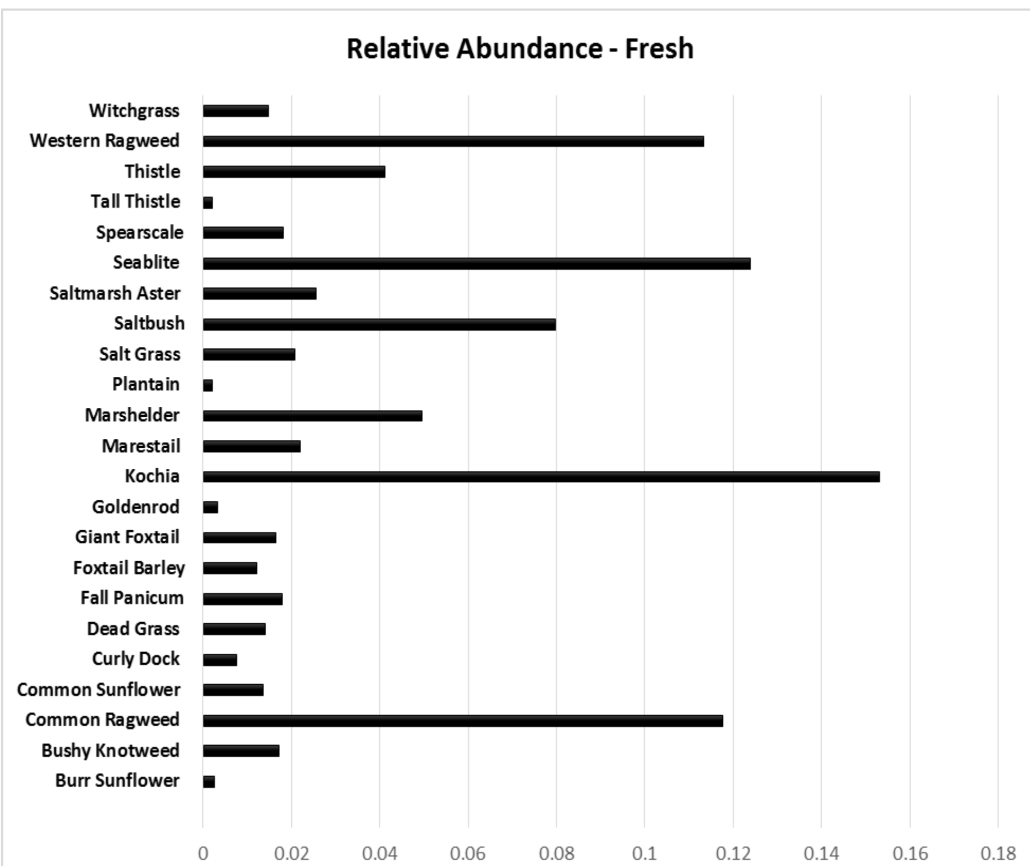


Fig. 20. Averaged relative abundance of species monitored in Fresh plots (FreshSlow and FreshFlush plots combined; n=6)

In the Low plots, western ragweed, water plantain and kochia dominated in both Low-Slow and Low-Flush plots, accounting over 40% of plant communities (Fig. 21). These are freshwater wetland or terrestrial plant species, but kochia and ragweed are also considered by some to be invasive plants, often growing in the disturbed area. The same terrestrial or freshwater wetland plant communities were observed in Fresh plots as well. More saline species emerged in the Low plots compared to Fresh plots. Spearscale, seablite, saltmarsh aster, marshelder and foxtail barley species were found and contributed to 25% of plant communities on average in the Low plots.

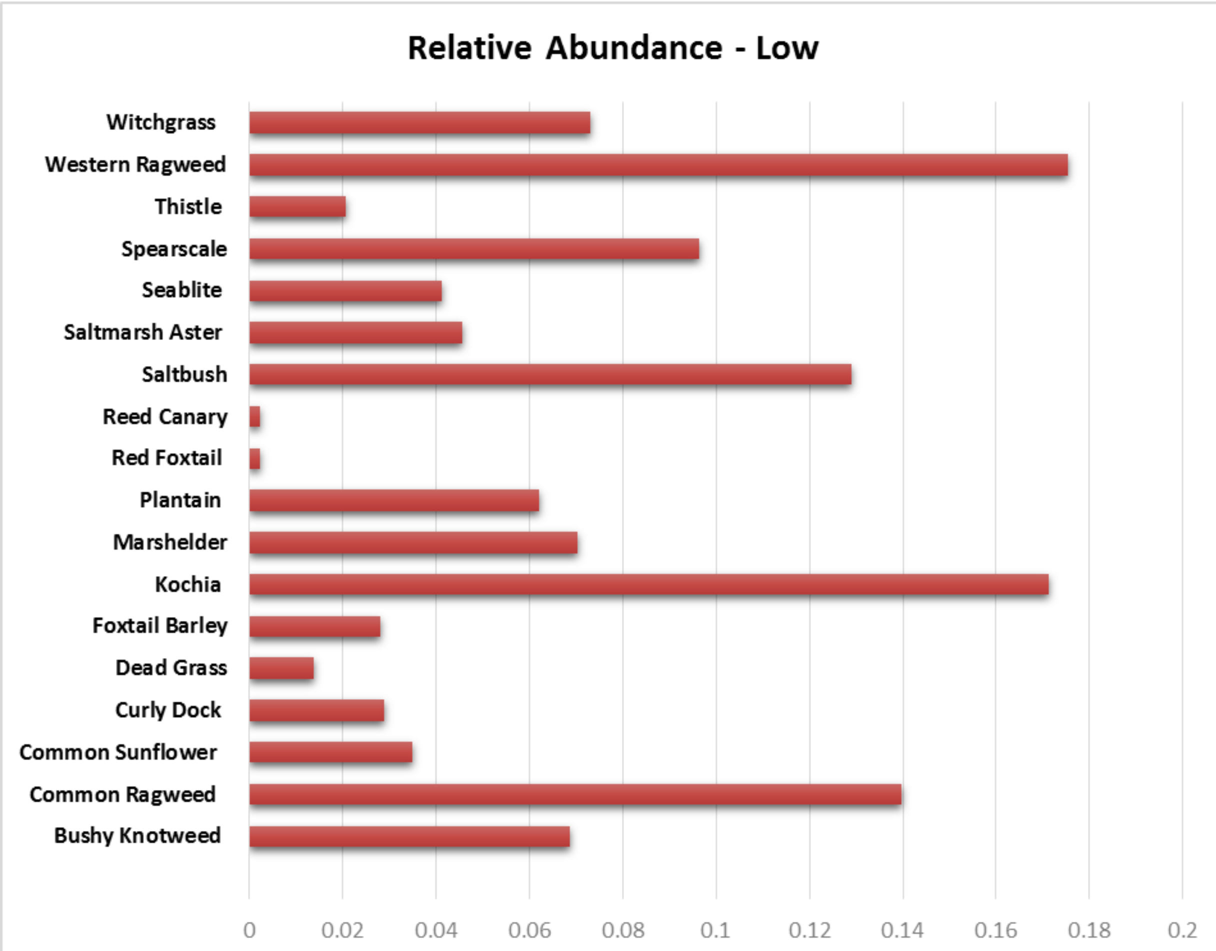


Fig. 21. Averaged relative abundance of species monitored in Low plots (Low-Slow and Low-Flush plots combined; n=6)

We continued to observe a gradual decrease of species richness as salinity increased. The decline in richness in the Mid plots was associated with the decrease of terrestrial and freshwater wetland species, although kochia remained the most abundant species on average. Relative abundance of the 7 target saline species reached over half of the total plant community. Saltwort was only found in the Mid plots (Fig. 22). In High salinity treatment plots, we only observed 6 species, and 4 of them were saline species (Fig. 23). The relative abundance of target species reached 59%. Non-target species were dominant with Fresh and Low salinity treatments, and plant communities shifted to include target saline wetland species (i.e. salt-tolerant species) with Mid and High treatments (Fig. 24).

These results indicate that salinity gradients induced by saline groundwater addition shifted plant community structure from a terrestrial or freshwater wetland species dominant community to a saline species dominant community. Plant species richness decreased with the salinity gradient.

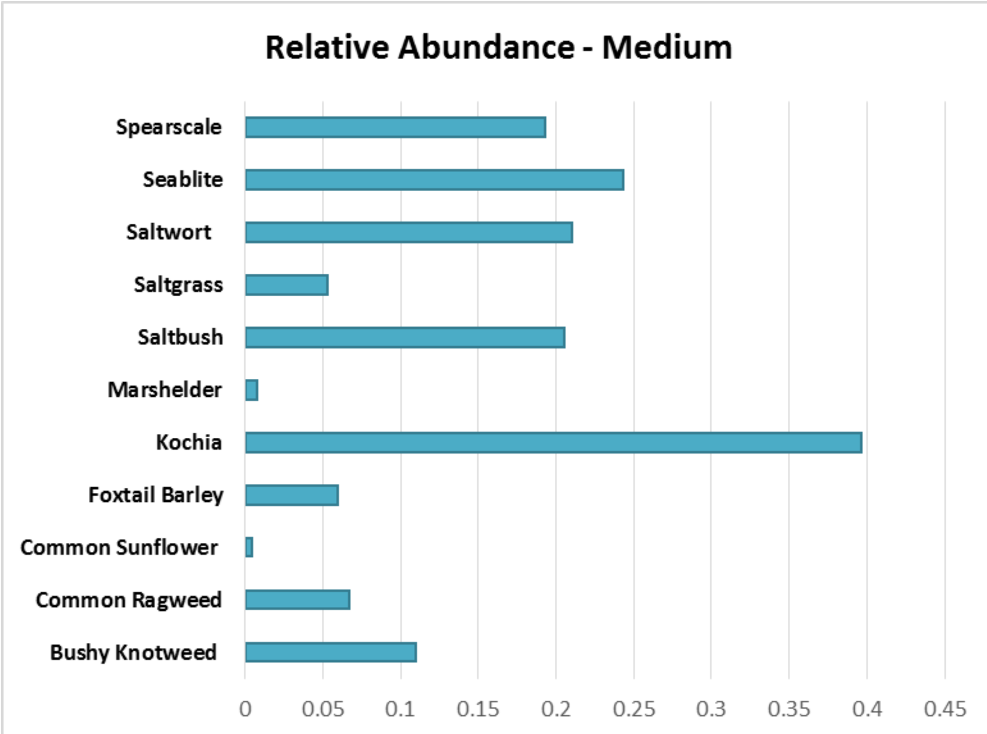


Fig. 22. Averaged relative abundance of species monitored in Mid plots (Mid-Slow and Mid-Flush plots combined; n=6)

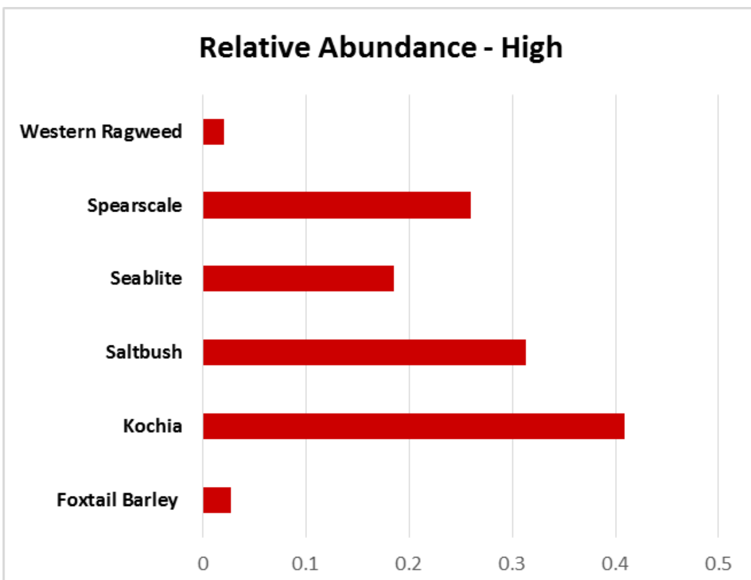


Fig. 23. Averaged relative abundance of species monitored in High plots (High-Slow and High-Flush plots combined; n=6)

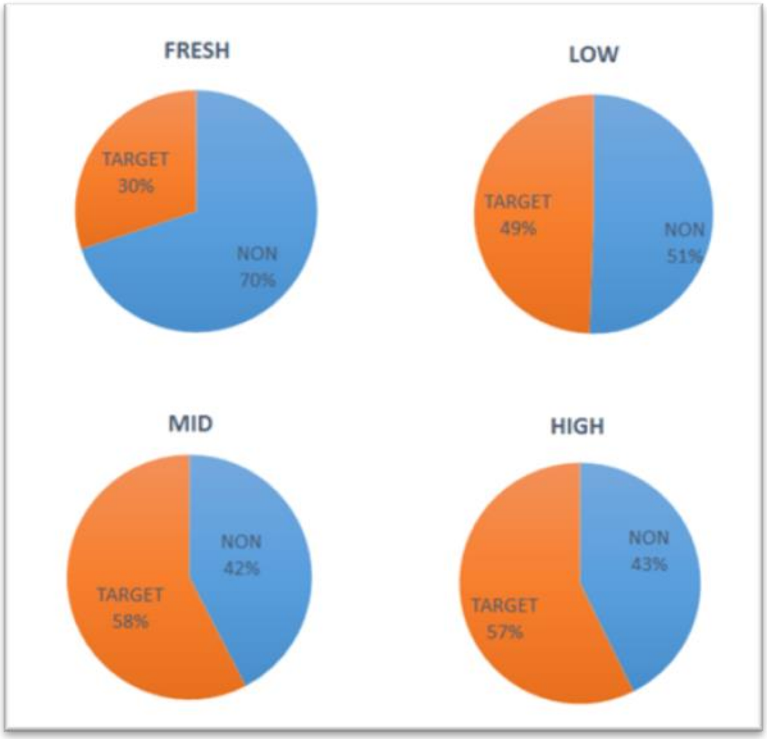


Fig. 24. The changes of relative distribution of non-target and target species between different salinity treatment (Fresh, Low, Mid and High salinity) plots.

8. Conclusions and Restoration Recommendations

The interactions between saline groundwater and soil are an important feature of Nebraska's Eastern Saline Wetlands. **Our project results imply that slow and continuous saline groundwater application holds a high potential as an effective saline wetland restoration strategy.**

The continuous saline groundwater addition (Fig. 6) increased pore water salinity in the experimental site (Fig. 13, 14). The addition of a medium and high range of salinity groundwater (i.e. 18-20 and 26-30ppt in this study) induced the distinctive pore water salinity differences from those in freshwater and low salinity (2-3ppt) plots (Fig. 14).

Slow groundwater application prolonged the connections between saline groundwater and soil, therefore, maximized the effects of saline groundwater addition on the soil surface. Slow application of medium and high salinity groundwater generated salt crusts in the soil surface (Fig. 15).

Medium and high salinity groundwater addition (18-30ppt in this study) increased CO_2 fluxes (Fig. 16). This suggests that the alteration of soil salinity level by saline wetland restoration activities affects carbon cycling and storage.

Salinity regulated the germination rates of saline species. Increased salinity inhibited the germination rates of all six targeted species (Fig. 17-19). Seablite and Spearscale appeared to be tolerant to medium (18-20ppt) level salinity. Warmer temperature stimulated germination of most saline species under the same salinity conditions (Fig. 17 vs. 18). **We suggest that the April thermos-period (5°C night-20°C day) would be the optimal condition for better germination rates of targeted saline species as well as to avoid competitions with terrestrial/freshwater wetland species.**

Spearscale and Seablite were the most abundant species at all saline groundwater treated plots at the experimental site (Fig. 20-23), which is consistent with the germination results. **Saltwort emerged only in the medium salinity level plots (Fig. 22).** Decreased plant species richness with increased salinity at the experimental site was associated with decreased terrestrial and freshwater plant species (Fig. 20-23). **At medium and high salinity level plots, targeted saline species contributed to over 50% of the total plant abundance (Fig. 24).**

We recommend that continuous slow addition of middle range salinity (i.e. 26-30ppt) groundwater in the soil surface would create favorable habitat to saline plant species. We also suggest saline species seeding by April in Lancaster County, Nebraska (i.e. temperature range: min. 5°C, max. 20°C) would be optimal to enhance the germination and growth of saline species.

9. References

Harvey, F.D., Ayers, J.F., Gosselin, D.C., 2007. Ground water dependence of endangered ecosystems: Nebraska's Eastern Saline Wetlands. Ground Water 45: 736-752.

Herbert, E.R., Boon, P., Burgin, A.J., Neubauer, S.C., Franklin, R.B., Ardon, M., Hopfensperger, K.N., Lamers, L.P.M., Gell, P., 2015. A global perspective on wetland salinization: ecological consequences of a growing threat to freshwater wetlands. Ecosphere 6: 206. http://dx.doi.org/10.1890/ES14-00534.1

Khan M.A., Gul, B., Weber, D.J., 2000. Germination responses of Salicornia rubra to temperature and salinity. Journal of Arid Environments. 45: 207-214.

LaGrange, T., Genrich, T., Johnson G., Schulz, D., Lathrop, B., 2003. Implementation plant for the conservation of Nebraska's Eastern Saline Wetlands. Saline Wetland Conservation Partnership.

Taylor, T., Krueger, L., Gilber, M., Gersib, D., LaGrange, T., Stutheit, R., Hickman, T., Wilson, E., 1997. Mitigation guidelines for Nebraaska's Eastern Saline Wetlands (Cooperative project report by USEPA, US Army Corps of Engineers, Nebraska Game and Parks Commission, Nebraska Department of Environmental Quality, US Fish and Wildlife Service).

Ungar, I.A., Hogan, W.C., 1970. Seed germination in Iva Annua L., Ecology 51: 150-154.

10. Acknowledgements

We thank Tom Malmstrom, Ted LaGrange, Randy Stutheit, Dan Schulz for stimulating the ideas and the support on this project. Mike Bullerman collected saline wetland seed for the research. We appreciate his help and advice on germination experiment and seeding in the field station. Craig Adams, David Moscicki, Cain Silvey, Carrie Adkisson, Valerie Schoepfer, Ellen Dolph, Blaise Weaver, Tanner Zlab helped field and laboratory work.

11. Appendix

Common name and the scientific name for the all identified plants during the field survey. Target saline wetland species were indicated in bold.

Common name	**Scientific Name**
Bushy Knotweed	*Polygonum ramosissimum* Michx
Common Ragweed	*Ambrosia artemisiifolia* L.
Common Sunflower	*Helianthus annuus* L
Curly Dock	*Rumex crispus* L
Fall Panicum	*Panicum dichotomiflorum* Michx
Foxtail Barley	*Hordeum jubatum* L.
Giant Foxtail	*Setaria faberi* Herrm
Goldenrod	*Solidago missouriensis*
Kochia	*Kochia scoparia* (L.) Schrad.
Marestail	Conyza canadensis
Marshelder	*Iva annua*
Plantain	*Plantago rugelii* Dcne.
Red Foxtail	*Setaria sp.*
Reed Canary	*Phalaris arundinacea*
Salt Grass	*Distichlis spicata* (L.)
Saltbush	*Atriplex wrightii S.*
Saltmarsh Aster	Aster subulatus Michx
Saltwort	Salicornia rubra
Seablite	*Sueada calceoliformis*, also referred to as Sueada depressa
Spearscale	*Atriplex subspicata*
Tall Thistle	*Cirsium altissimum* (L.) Spreng
Thistle	*Cirsium arvense* (L.) Scop.
Western Ragweed	*Ambrosia psilostachya* DC.
Witchgrass	*Panicum capillare* L.