



# Patterns Over Time and Space in the Arrival and Spread of Aquatic Non-native Species in Illinois

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Loyola University Chicago

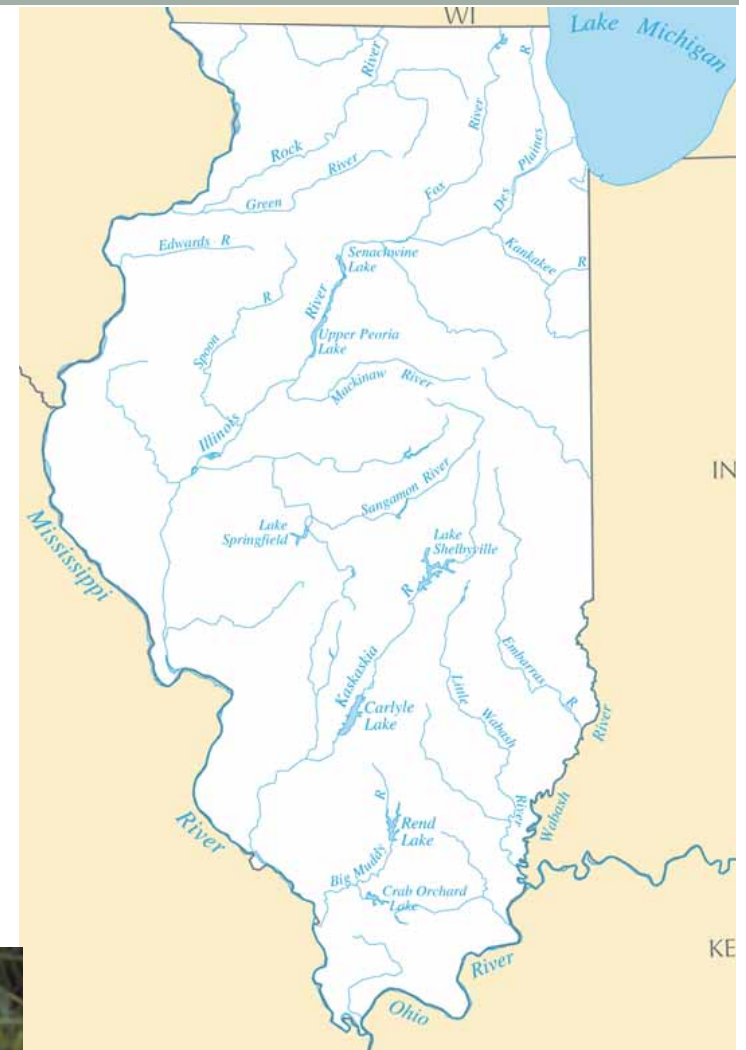
M.S. candidate in Biology

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# Introduction

- Freshwater ecosystems are highly invaded
- Increasing globalization and human population
- Illinois's artificial connection between Great Lakes and Mississippi River
  - conduit for aquatic non-native species
- Preventing spread is an important priority for conservation



Zebra Mussel



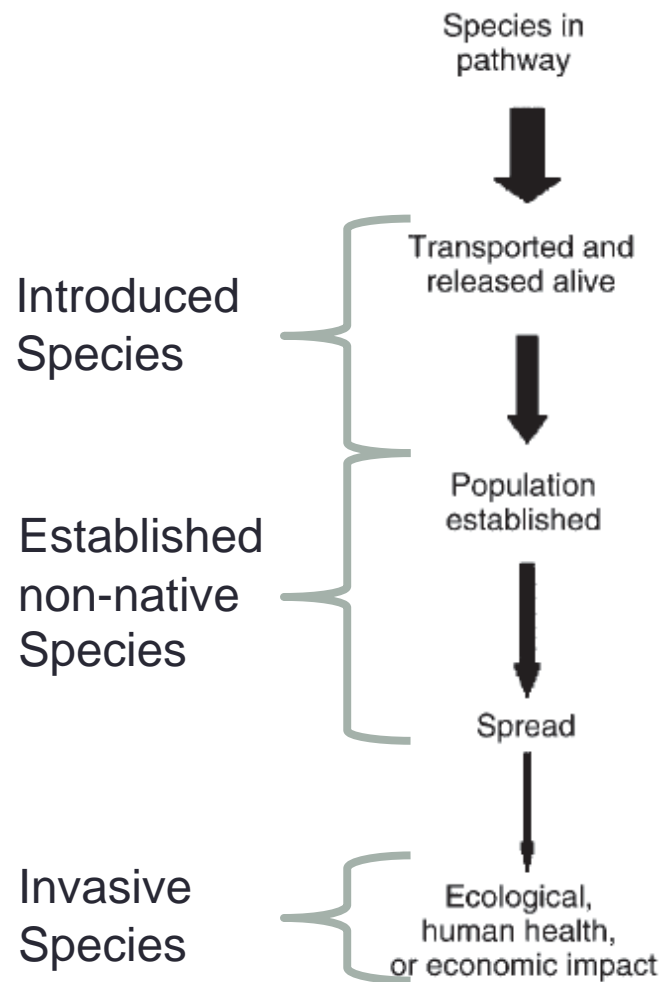
Eurasian Watermilfoil



# The Invasion Process

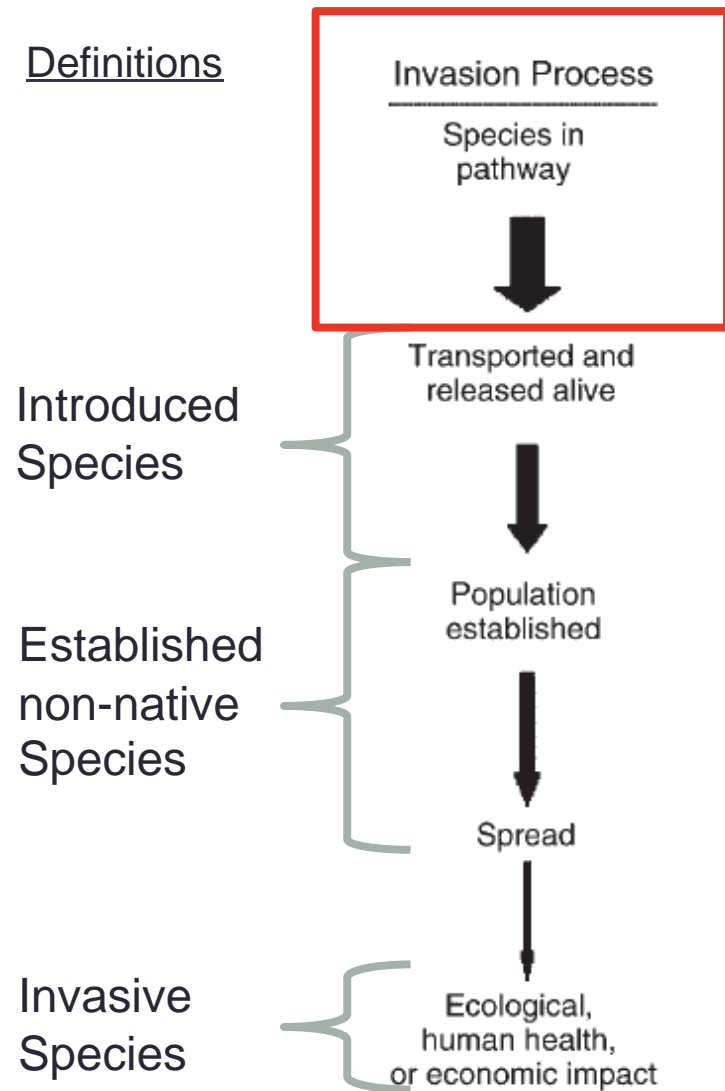
## Definitions

## Invasion Process

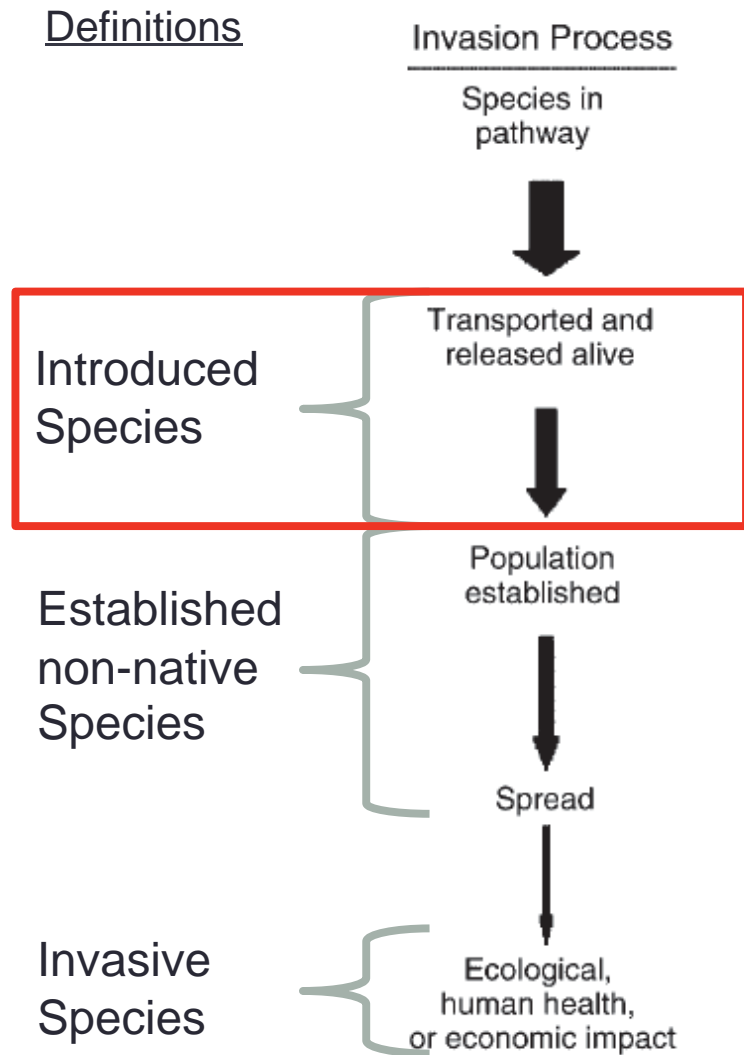


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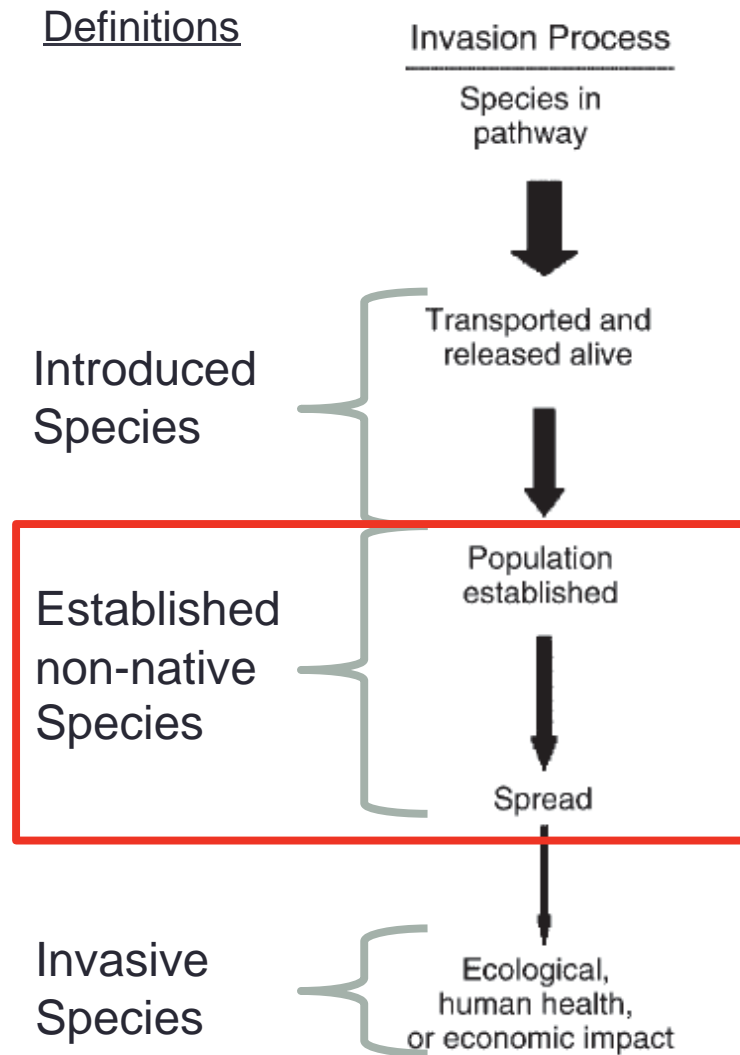
## Definitions



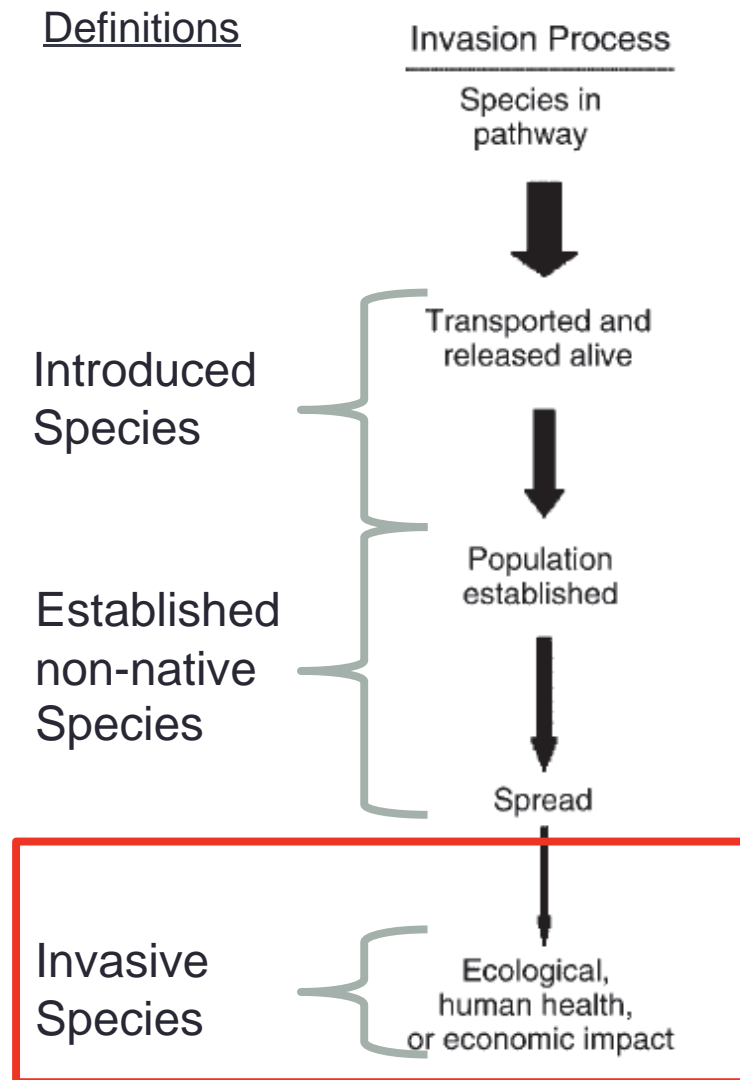
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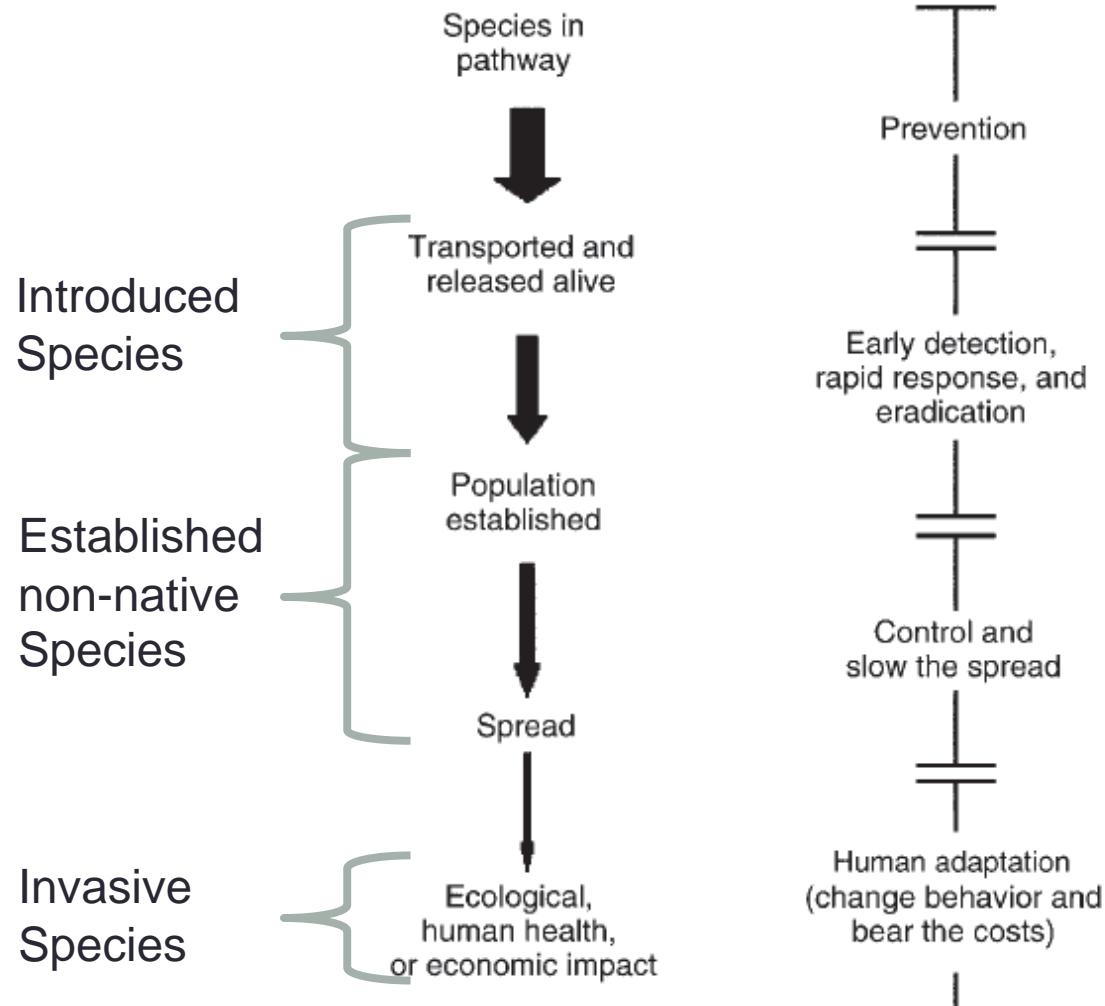


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## Definitions

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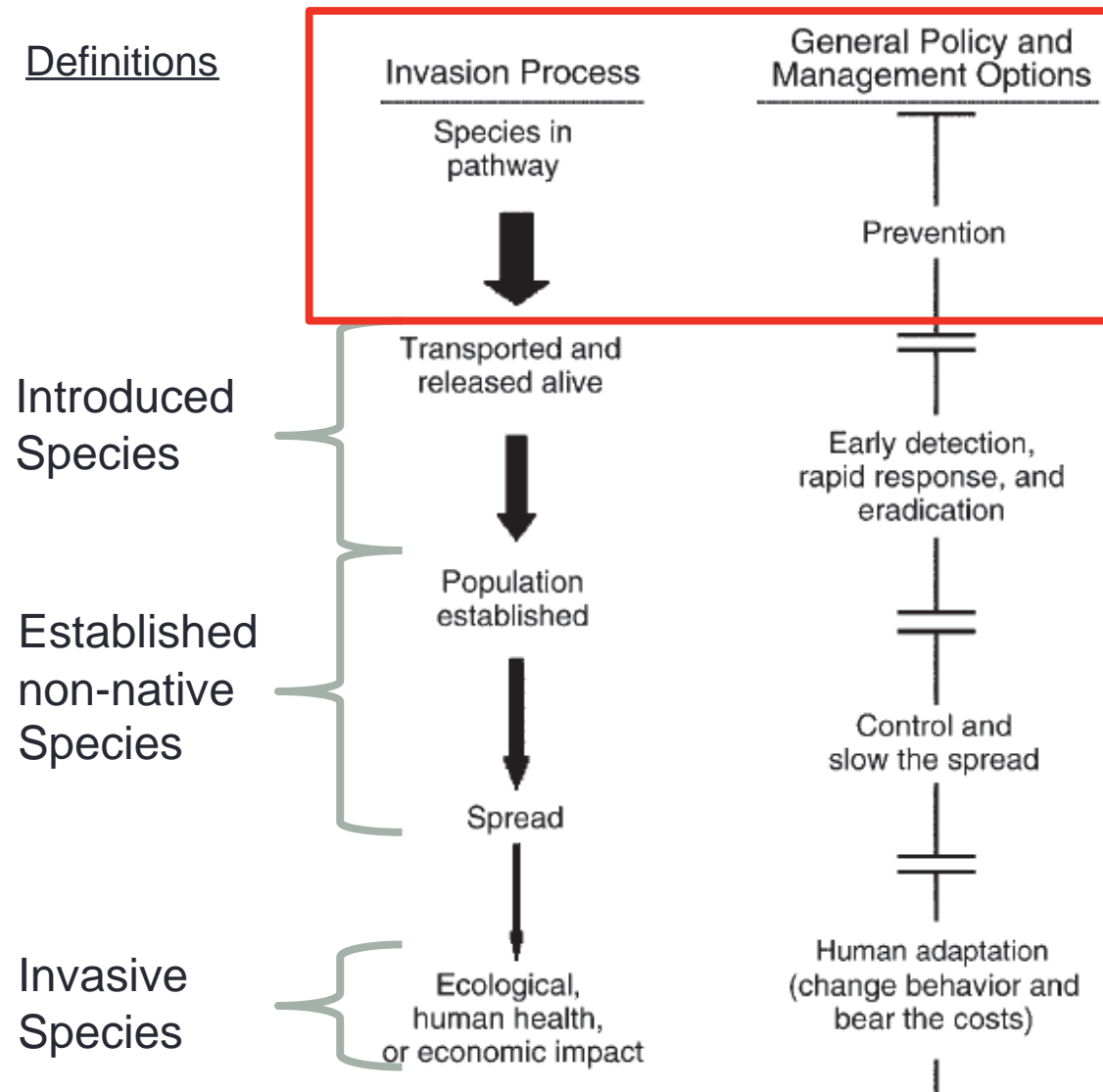
## General Policy and Management Options



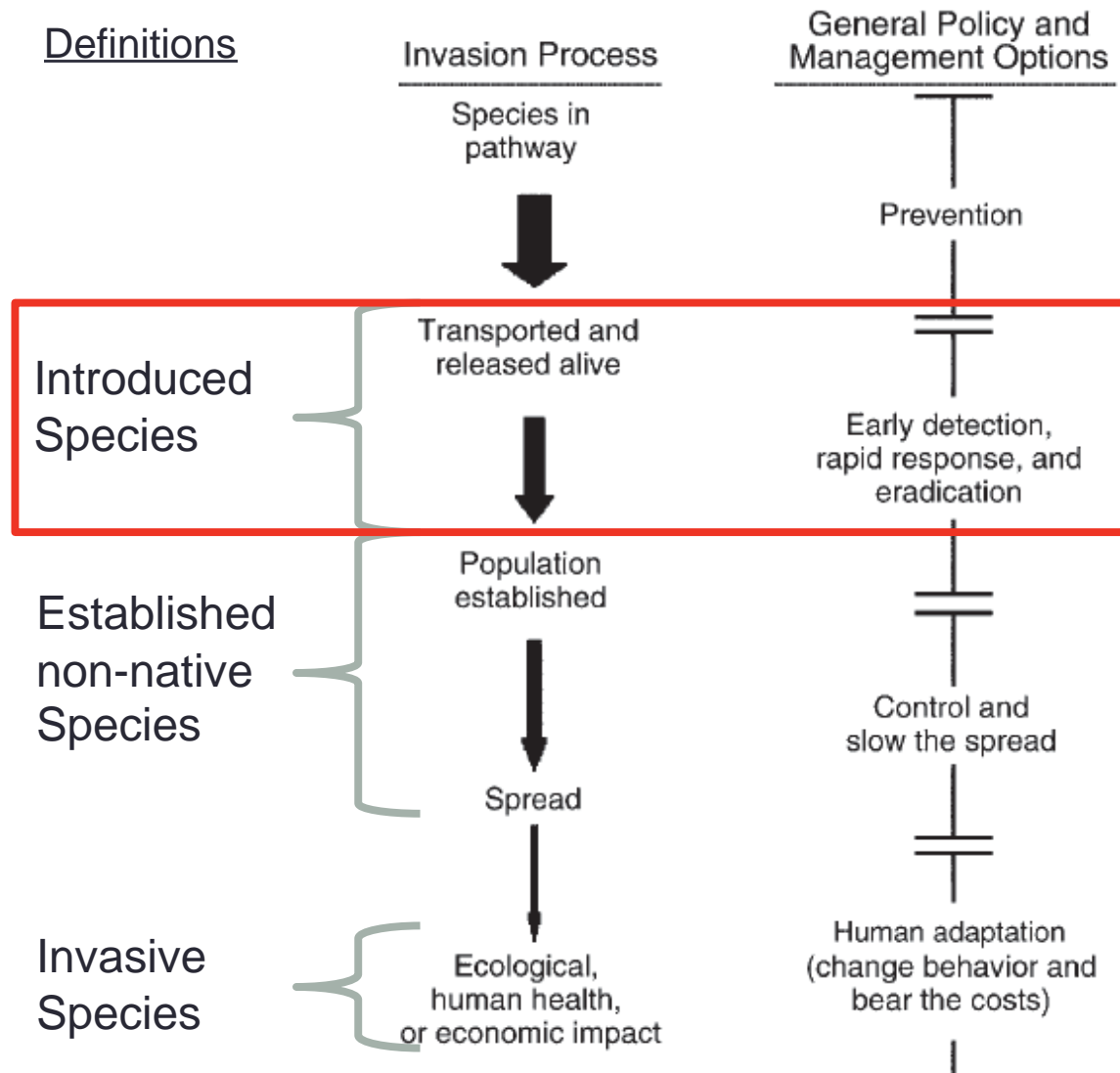


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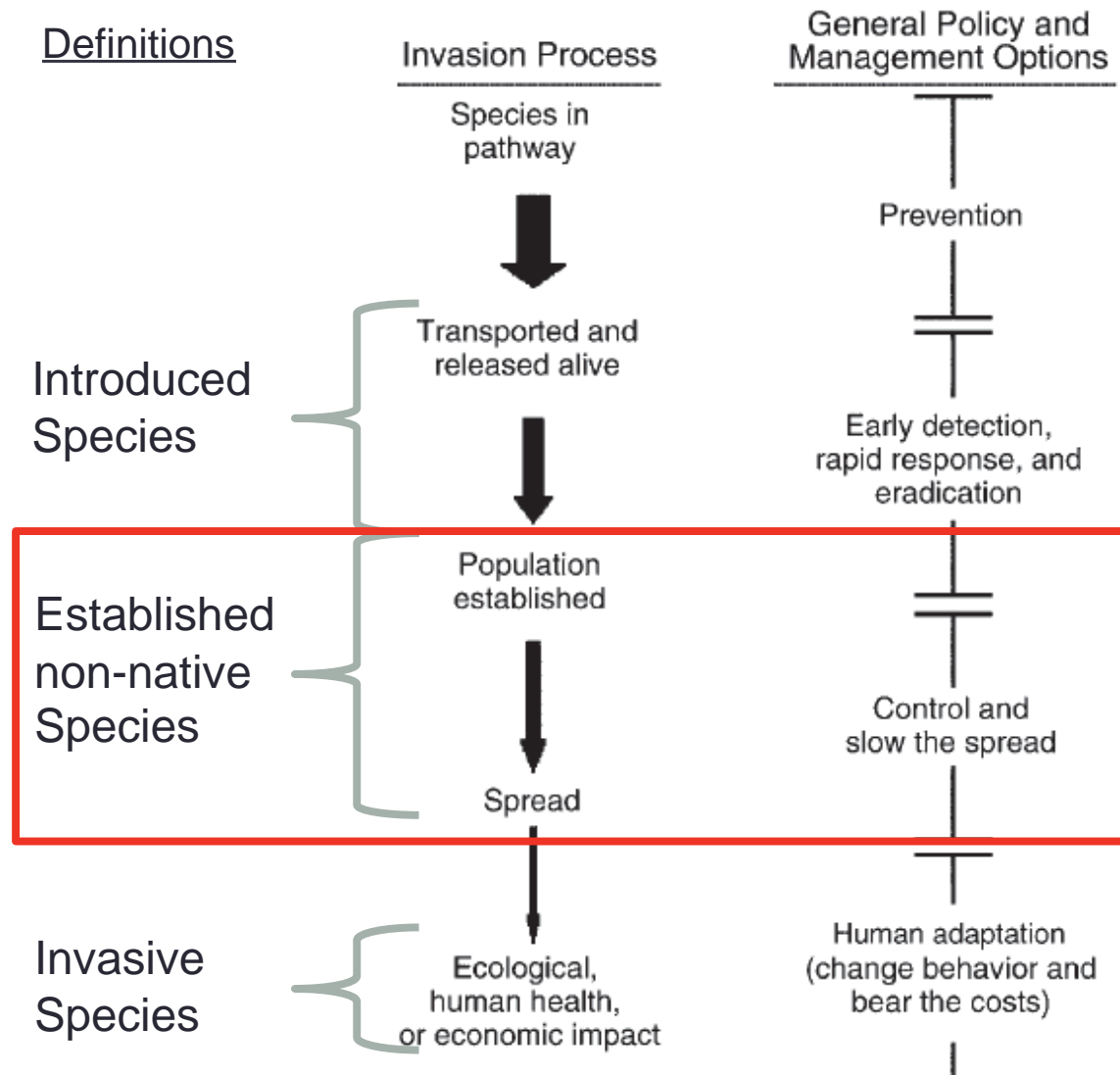
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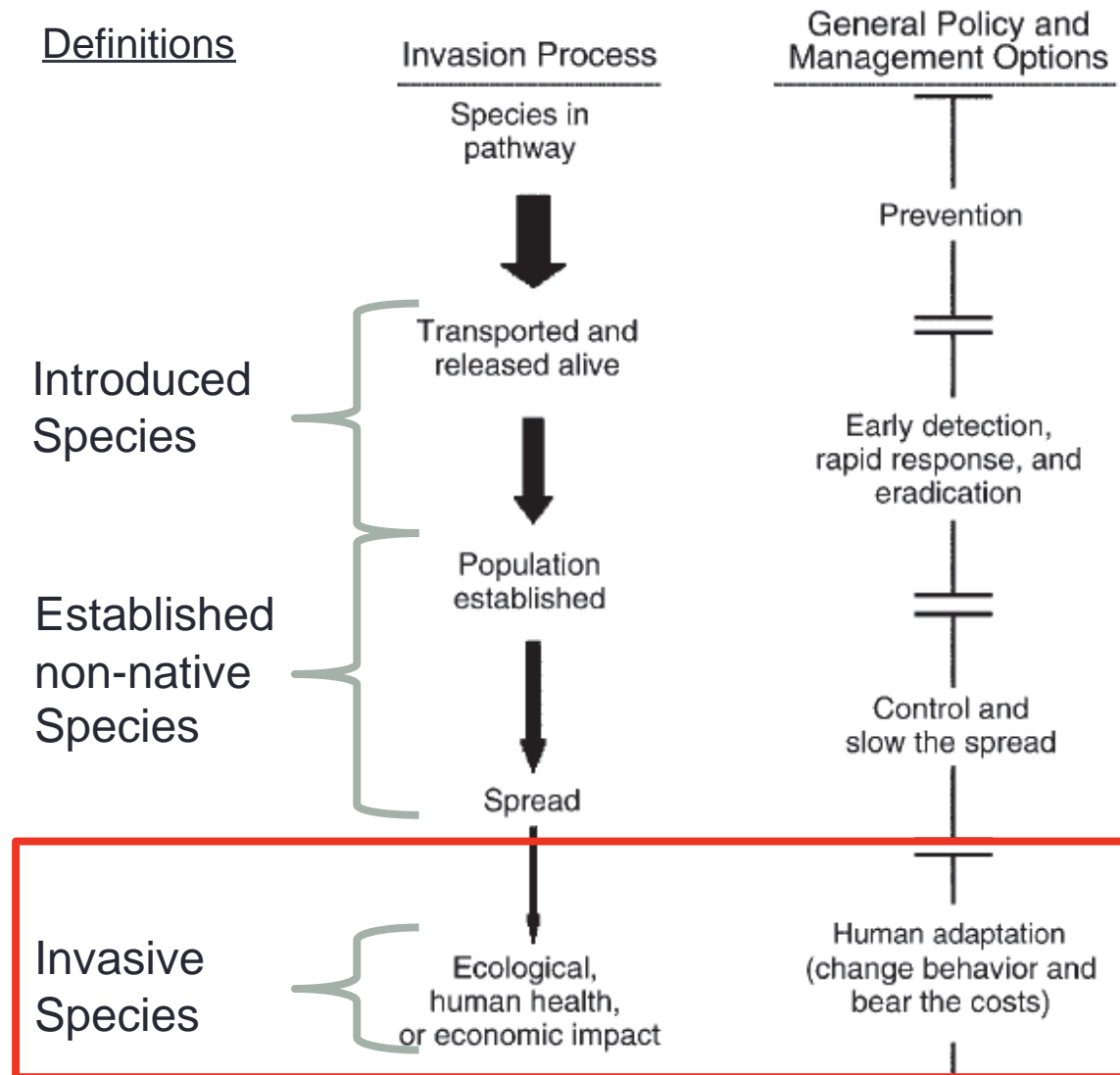
# The Invasion Process



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# The Invasion Process



# Goals

- Compile comprehensive database of aquatic non-native species introduced to Illinois
- Determine establishment status and vectors of arrival
  - Spread throughout IL counties
- Assess ecological impact of established species

## Definitions

Introduced Species

Established non-native Species

Invasive Species

## Invasion Process

Species in pathway

Transported and released alive

Population established

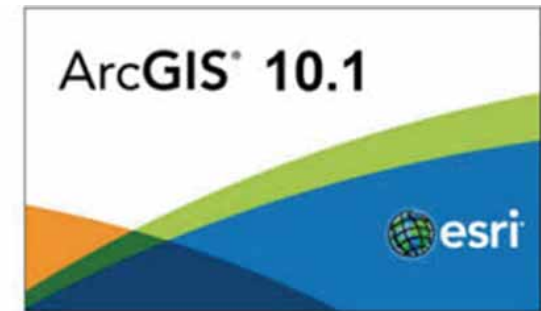
Spread

Ecological, human health, or economic impact

Lodge et. al. 2006

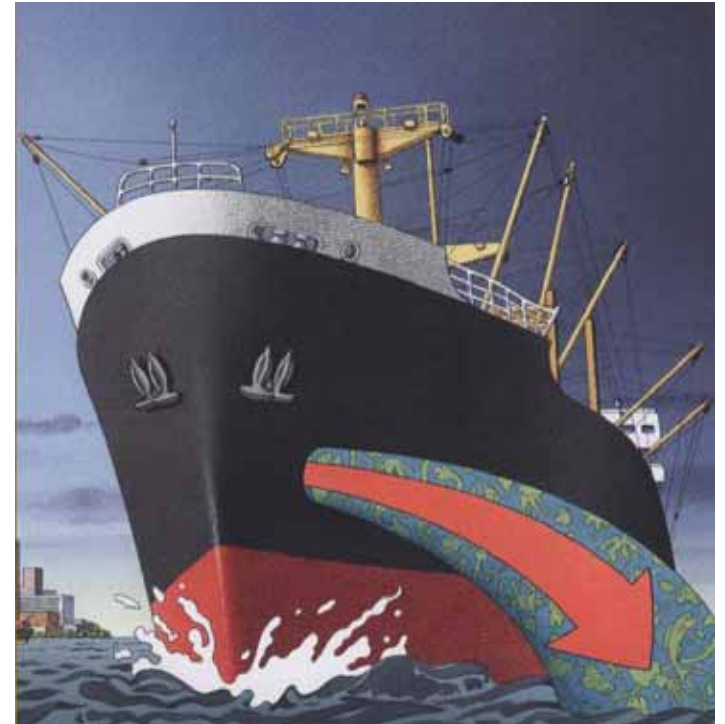
# Methods

- Searched for aquatic non-native species Occurrence records
  - Contacted experts
  - Collected records from 13 dataholders
- Data include:
  - Species
  - Date
  - Location
  - Establishment status
  - Collector's ID
- Imported into ArcGIS 10.1
- Constrained analysis to:
  - Established aquatic non-native species
  - Illinois and its borders within Lake Michigan



# Methods

- Examined vectors
  - Initial carrier to freshwaters of US
- Considered spread within US
  - Direction a species came to Illinois
    - Great Lakes Basin
    - Lower Mississippi River Basin
    - Unknown/ Other





# Database Sources



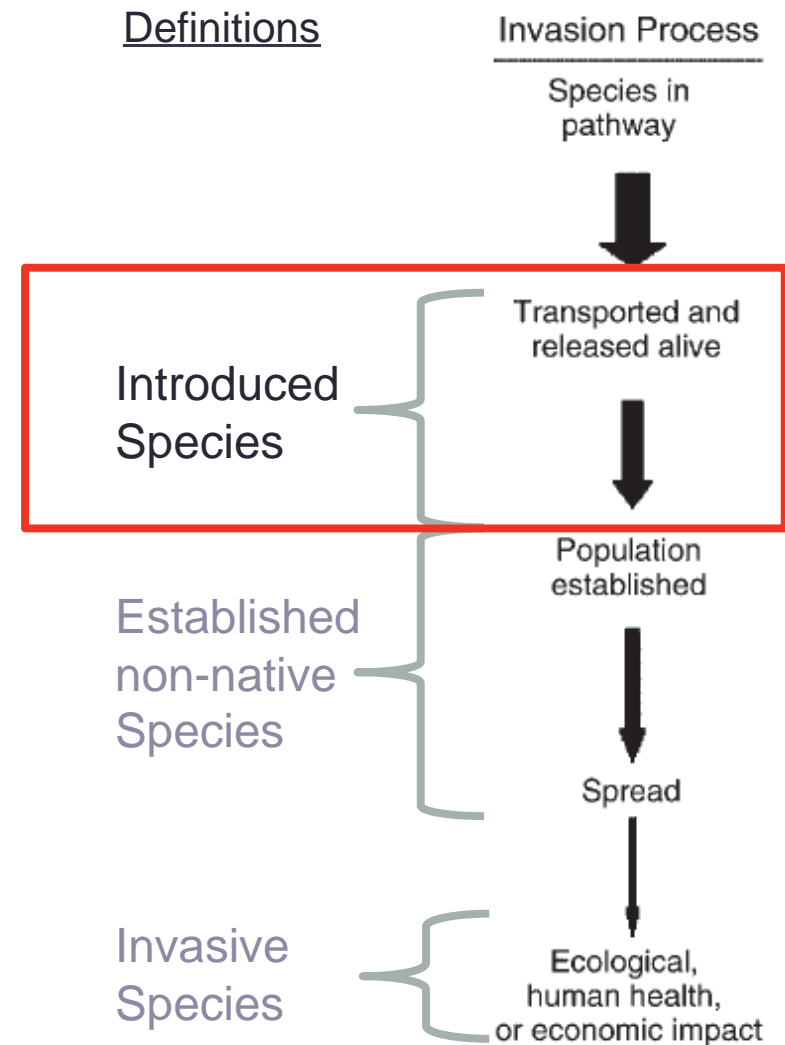
ILLINOIS  
NATURAL  
HISTORY  
SURVEY





# Introduced Species

- 112 aquatic non-native species
  - 34 species represented by 209 records
    - Not established
      - Found only a handful of times
      - Some stocked
      - Cannot survive in Illinois
      - Incomplete

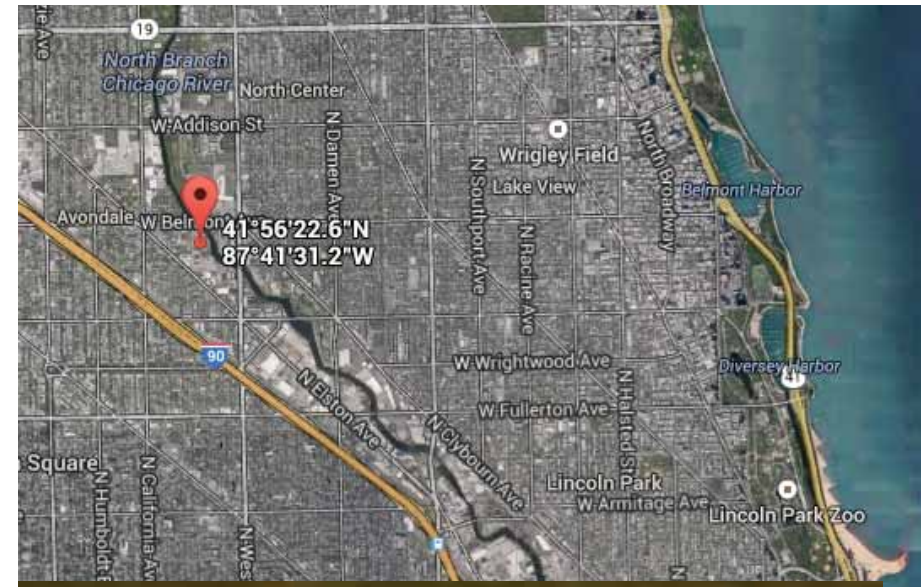


Lodge et. al. 2006

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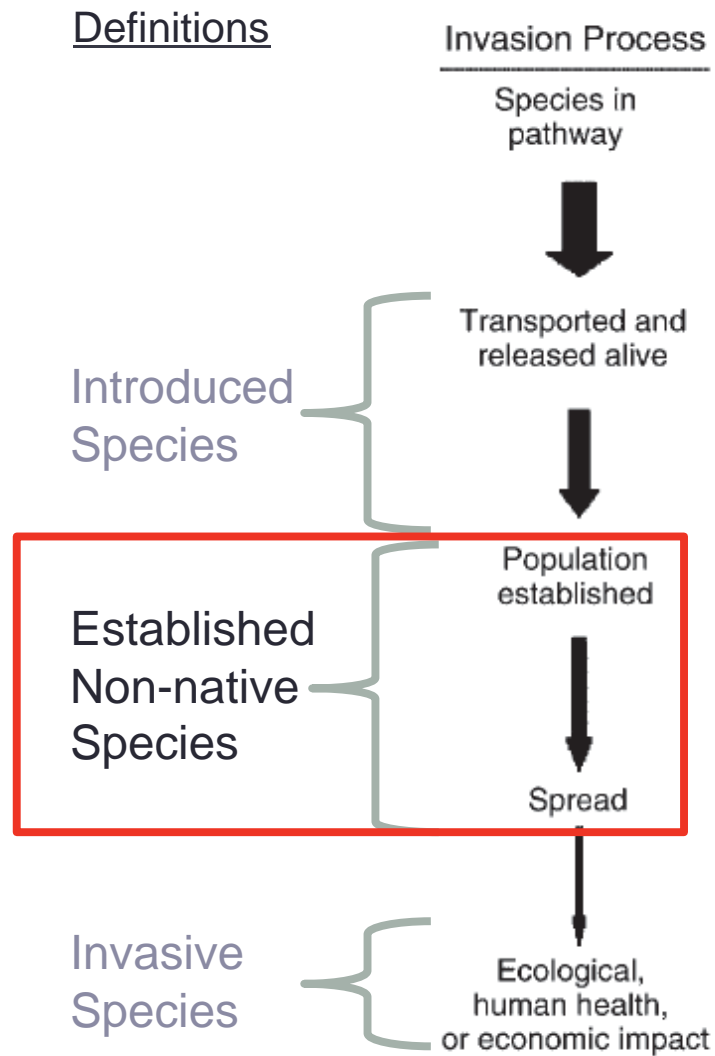
North Branch Chicago River



American Alligator



# Established Species



# Established Species by Taxonomic Group

Phylum or Division	Number of Records	Number of Species	Comments
Arthropoda	283	9	All Crustaceans
Bacillariophyta	11	5	Diatoms
Chordata	15,906	21	All Fishes
Cnidaria	2	1	Hydroid
Mollusca	2,355	8	Bivalves and Gastropods
Tracheophyta	5,168	34	Vascular Plants
<b>Total</b>	<b>23,725</b>	<b>78</b>	

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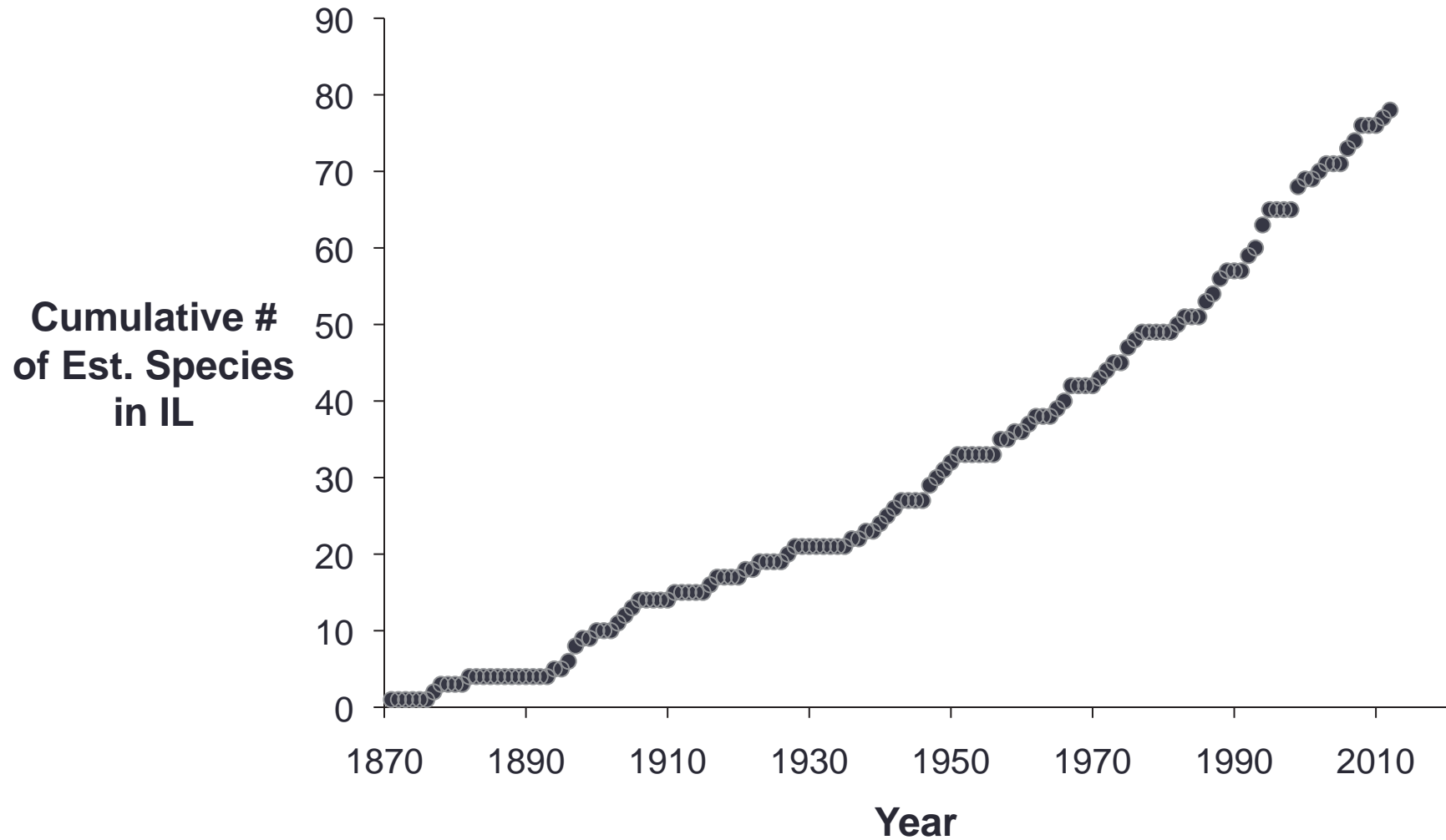
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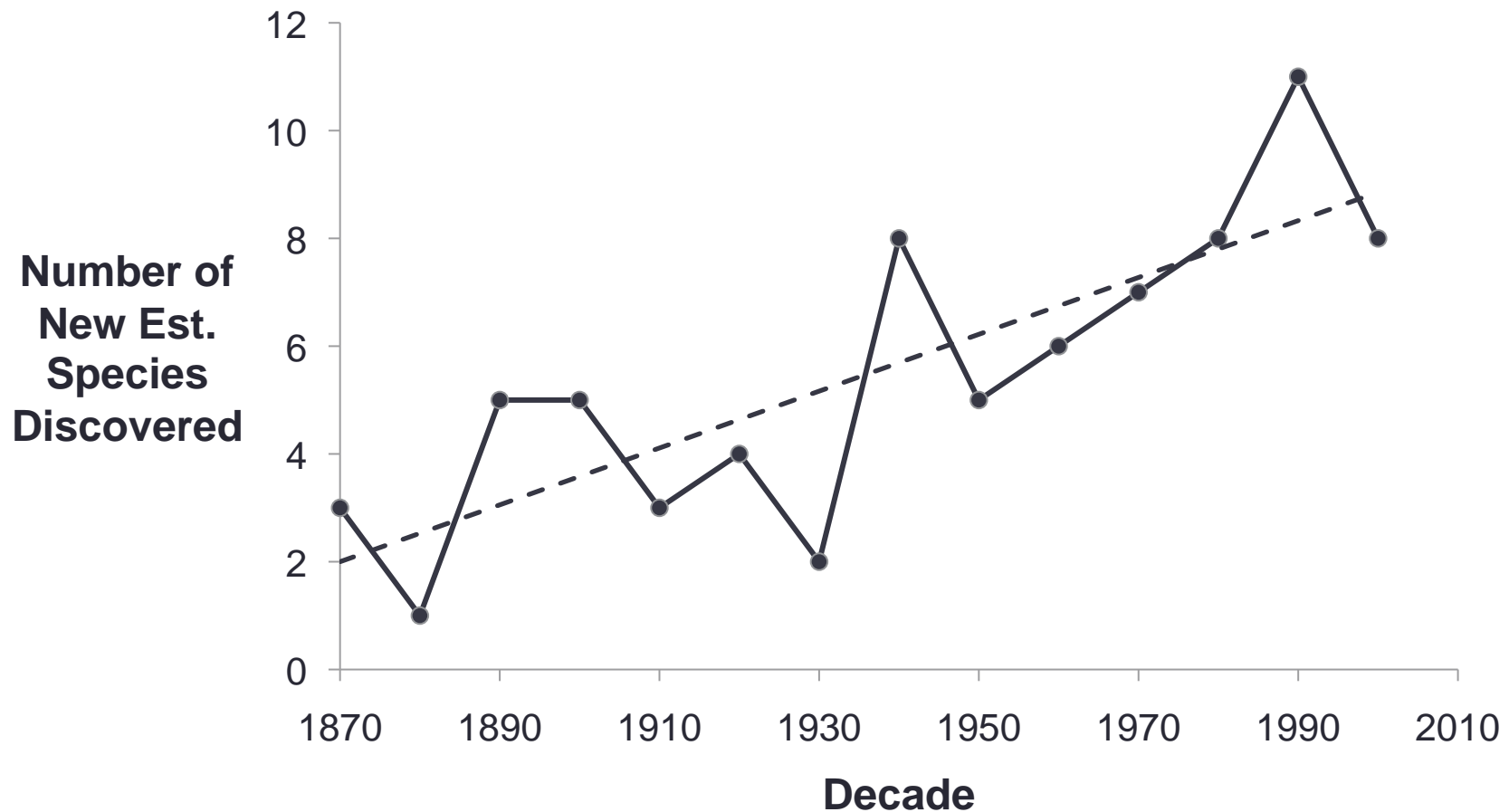
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# Cumulative Number of Species Over Time



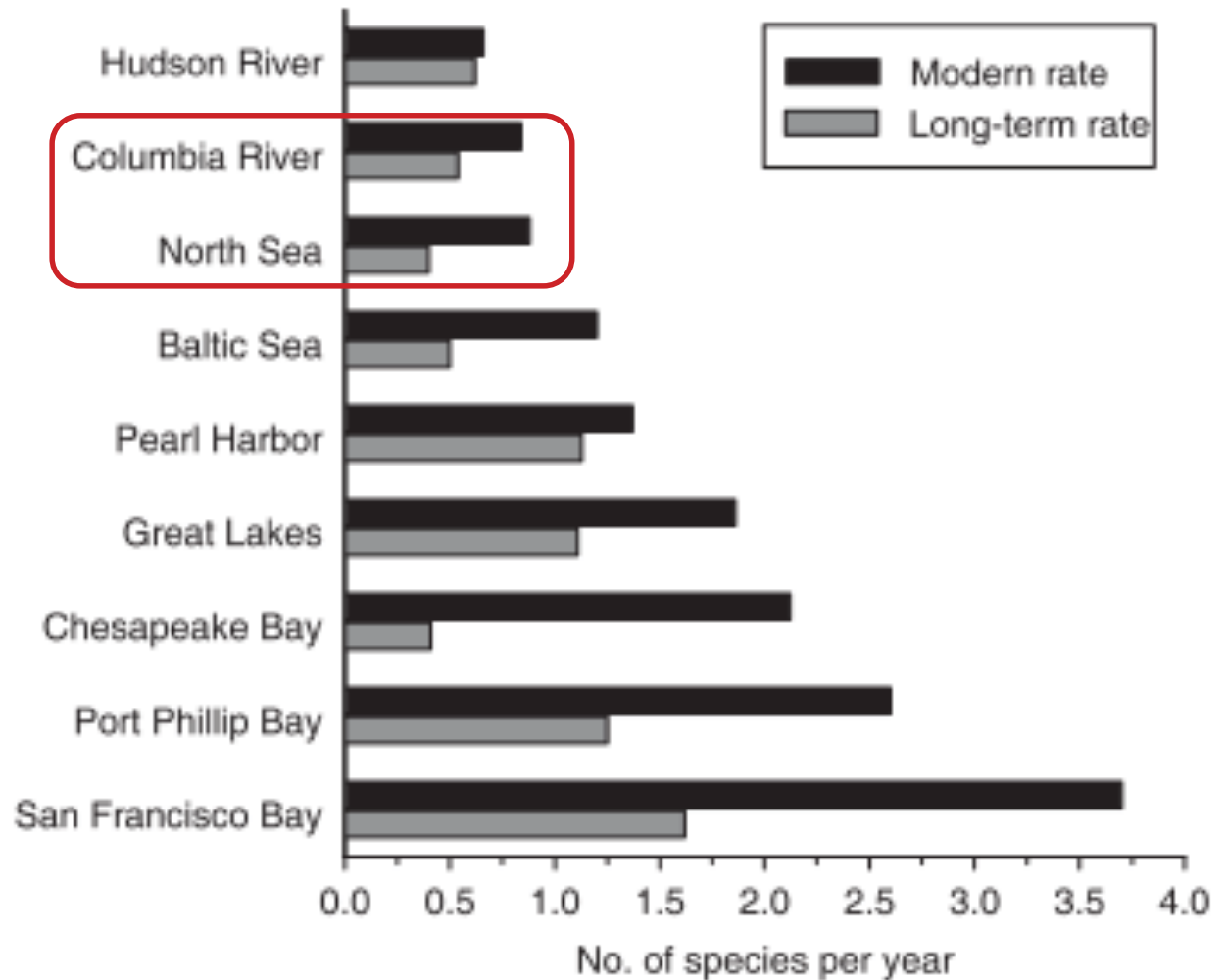
# Exponential Increase in Discovery Rate



$p < 0.001, n = 14$   
 $y = 0.0527x - 96.637, R^2 = 0.64$

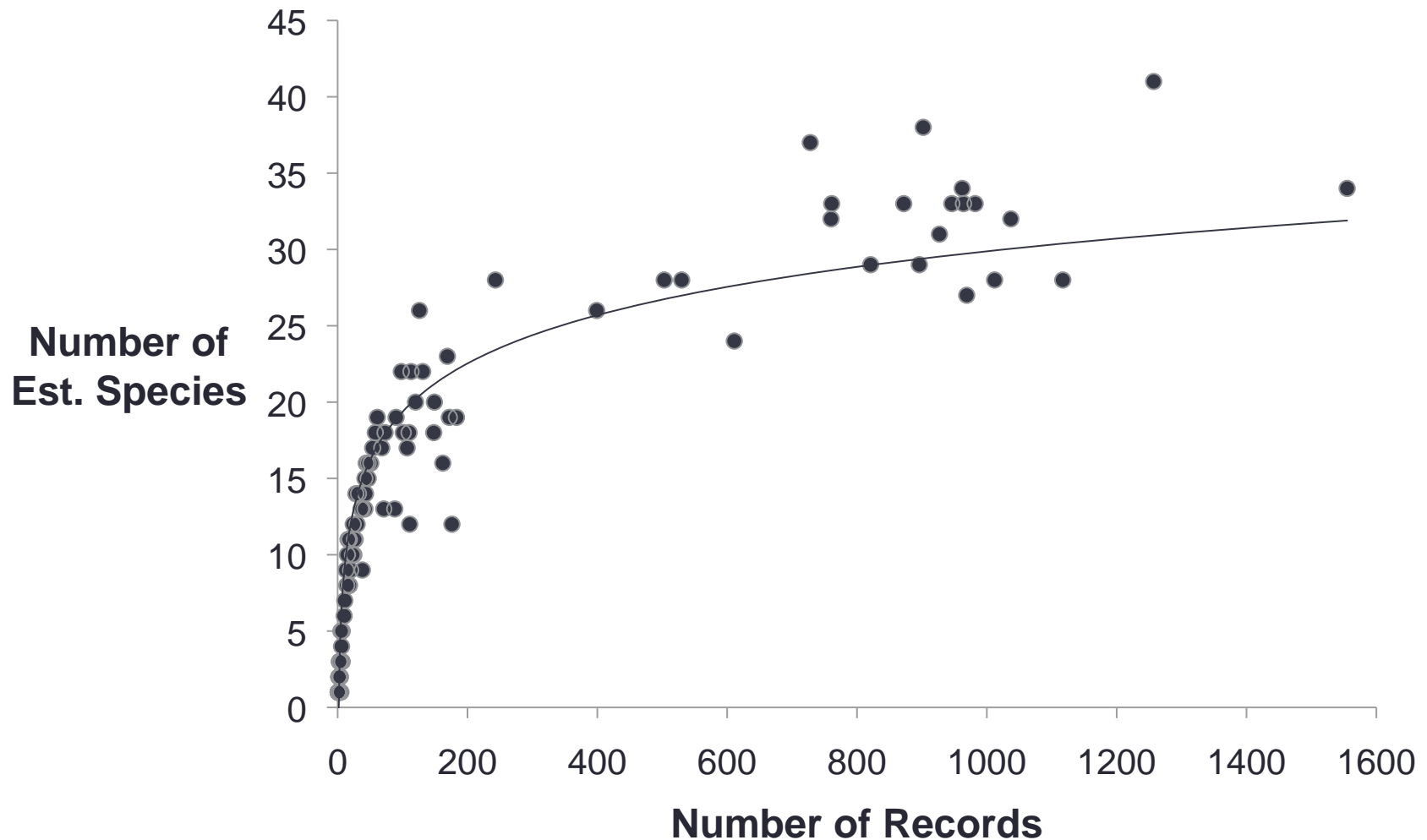
# Discovery Rate for Illinois

- Modern Rate of Discovery (1960-2012):
  - **0.81 species/year**
- Long Term Rate of Discovery (1870-2012):
  - **0.55 species/year**





# Records vs. Established Species

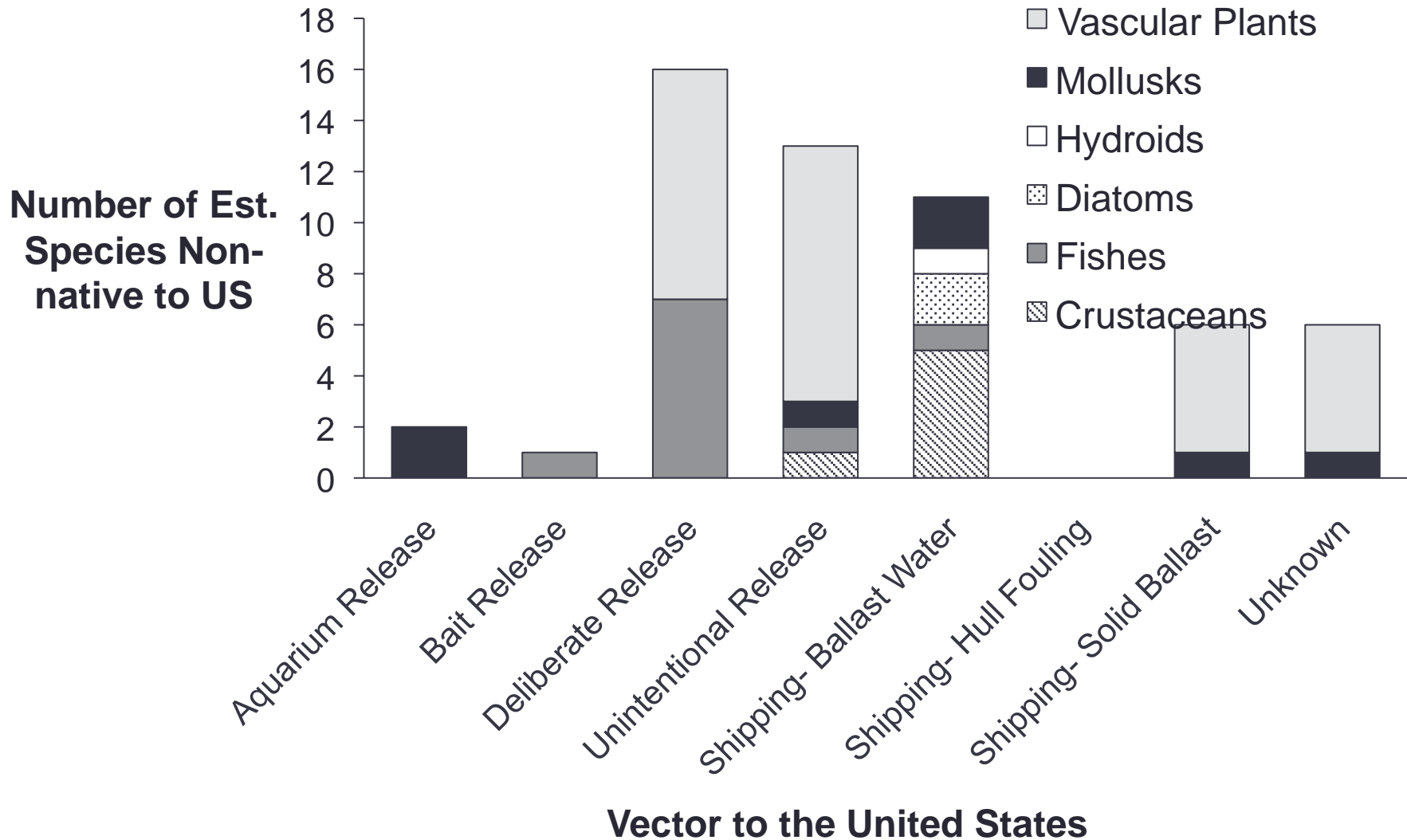


Line fitted by logarithmic regression:  $y = 4.5648\ln(x) - 1.6535$  ( $R^2 = 0.93$ ).

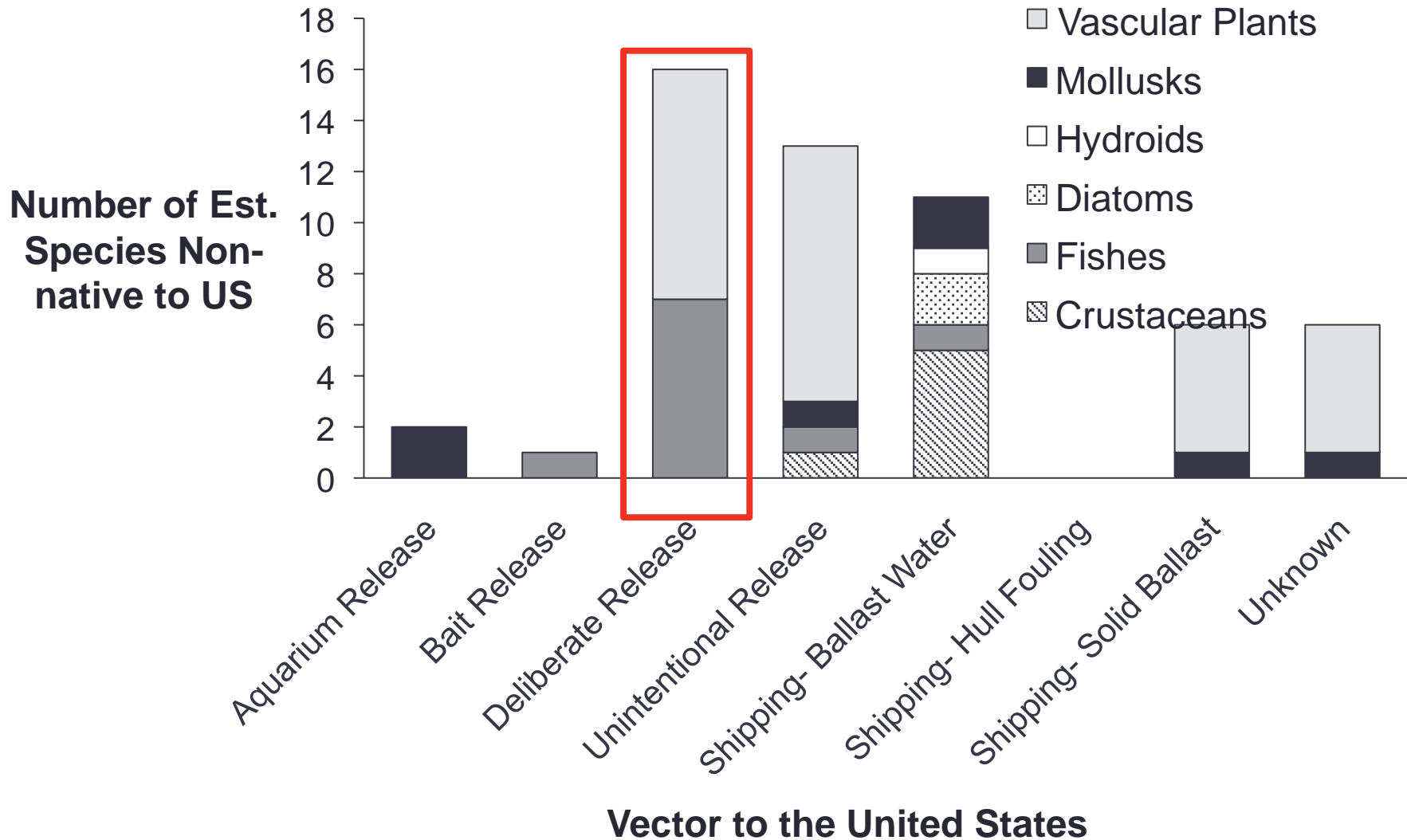
# Vectors of Species Non-native to US

- How did these aquatic non-native species arrive in freshwaters of the US?
  - Is there a dominant vector?

# Vectors of Species Non-native to US

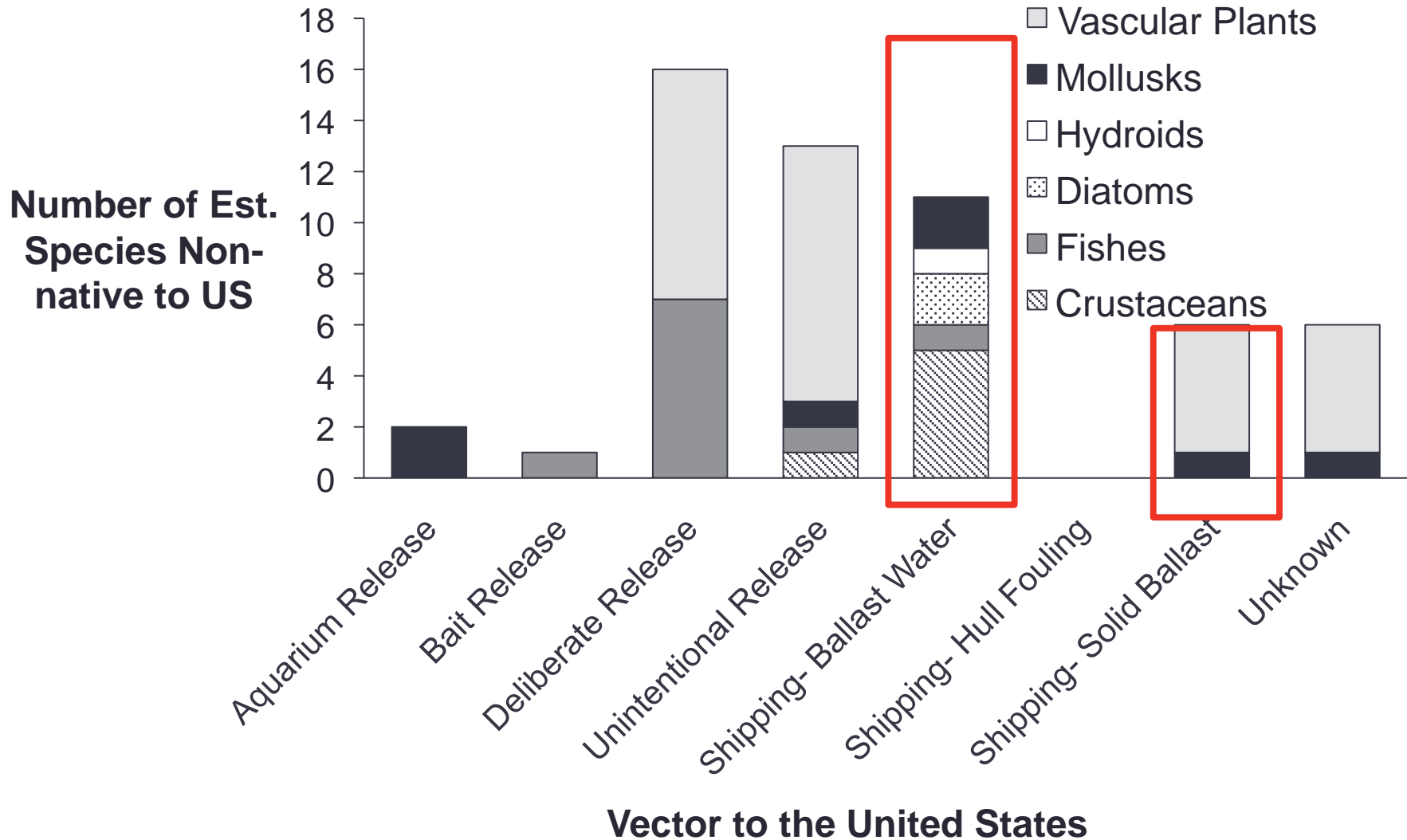


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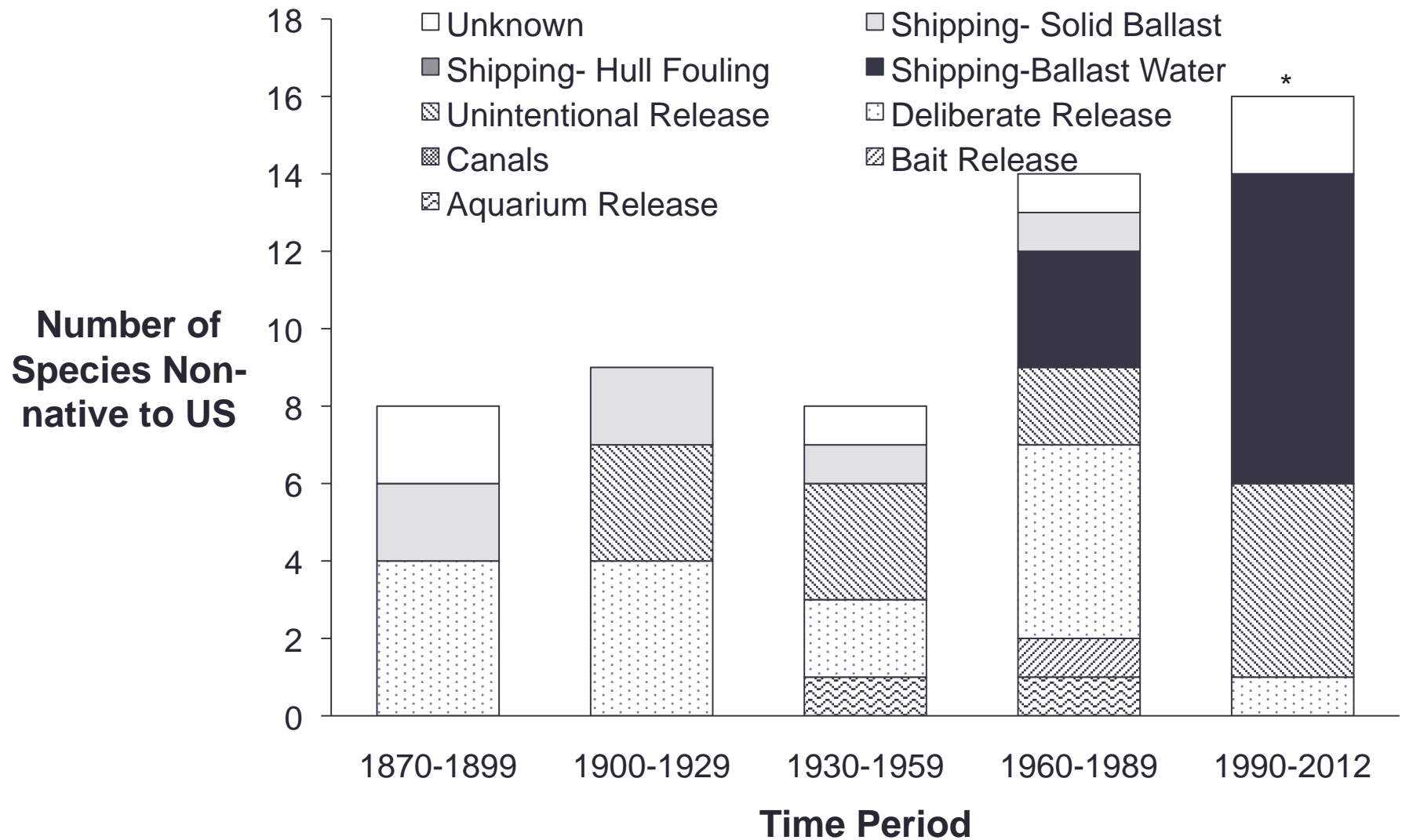




# Vectors of Species Non-native to US



# Vectors of Species Non-native to US Through Time

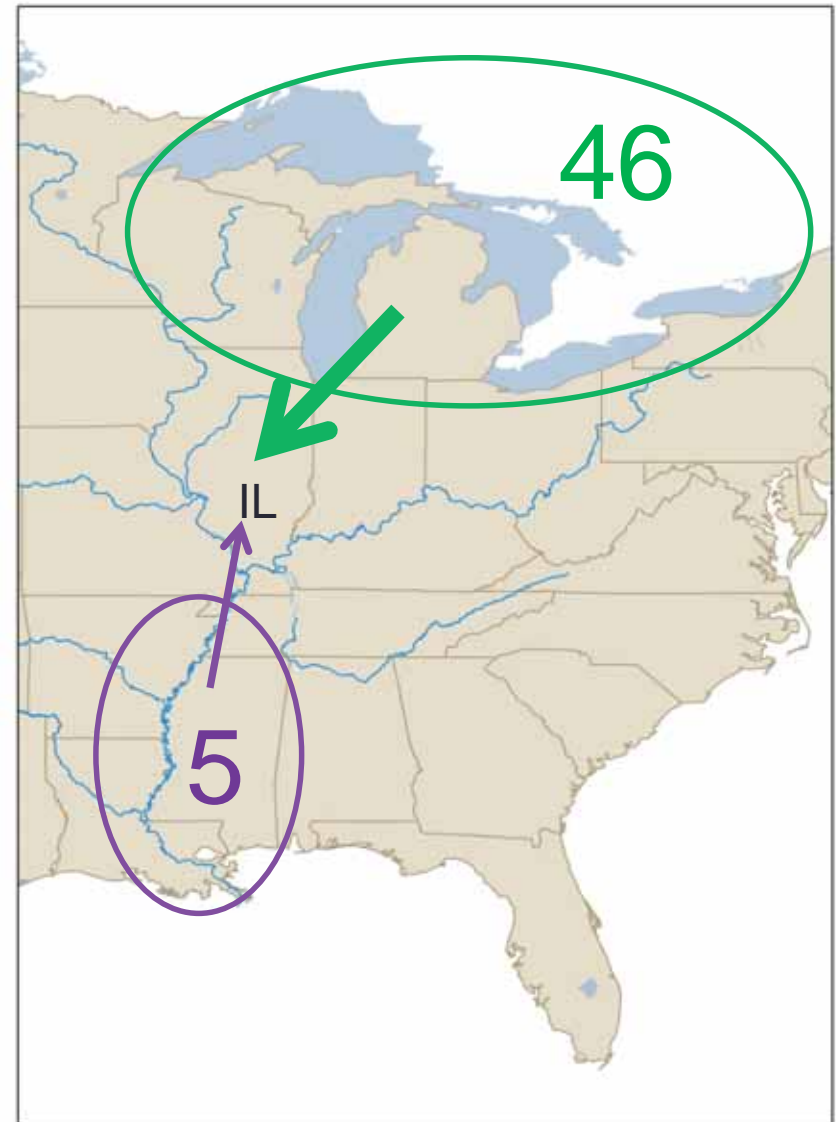


# Spread within US to Illinois

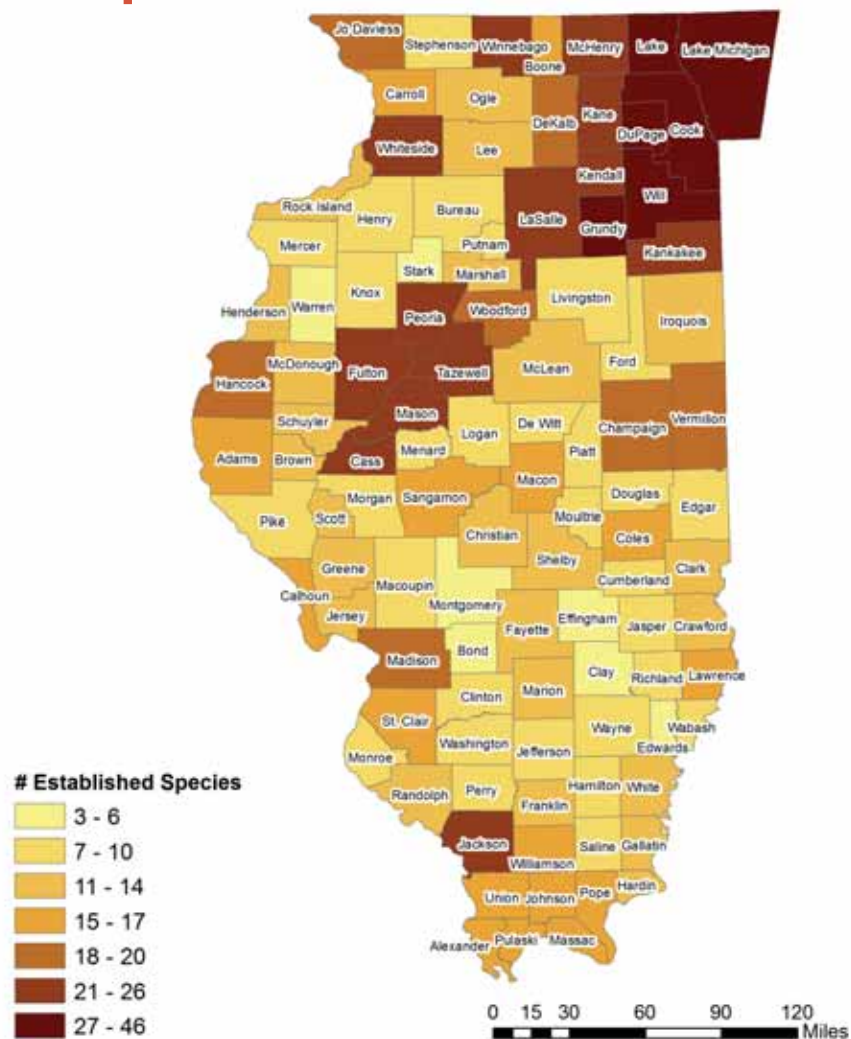
- How many species are crossing into Illinois from the Great Lakes Basin and from the Lower Mississippi River Basin?
- Methods:
  - From the Great Lakes or Mississippi River Basin
    - Discovered there before Illinois

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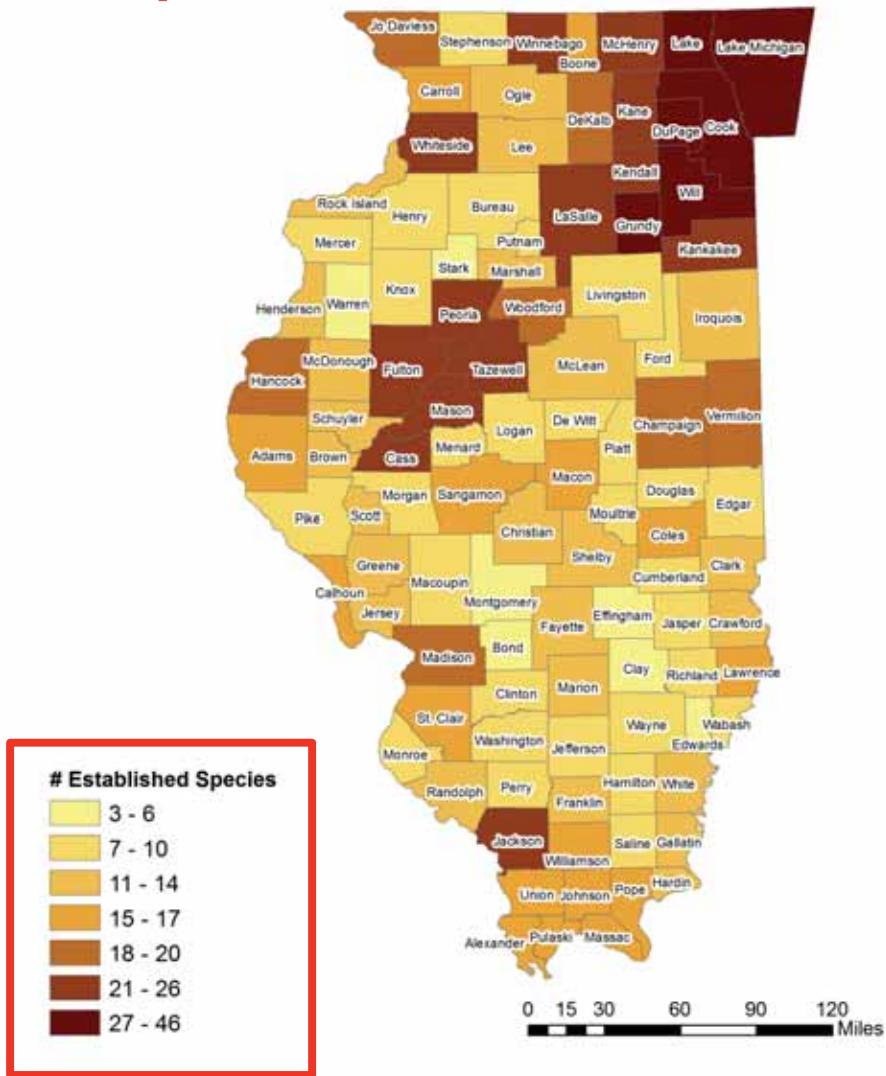
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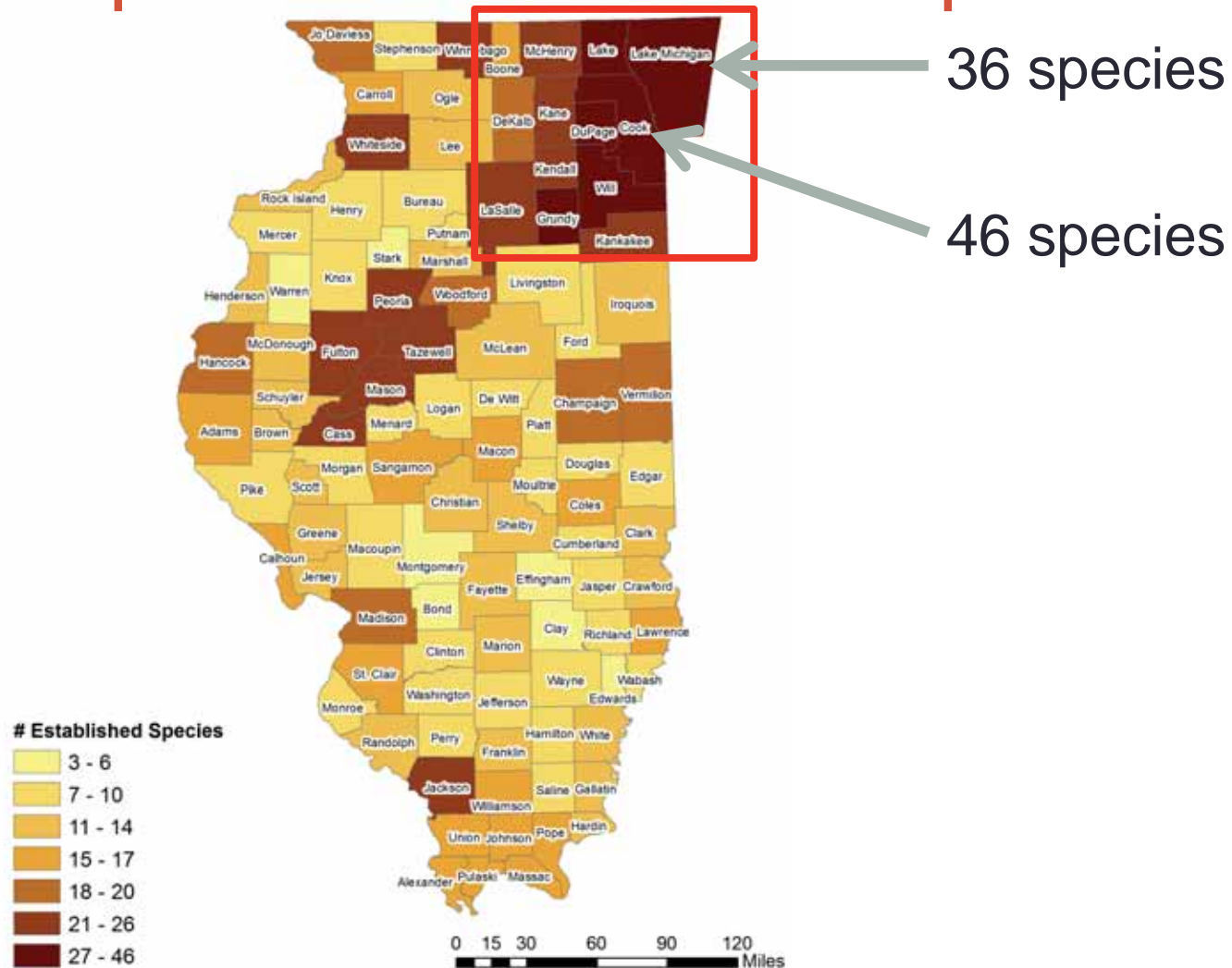
# Spread of Established Species by County



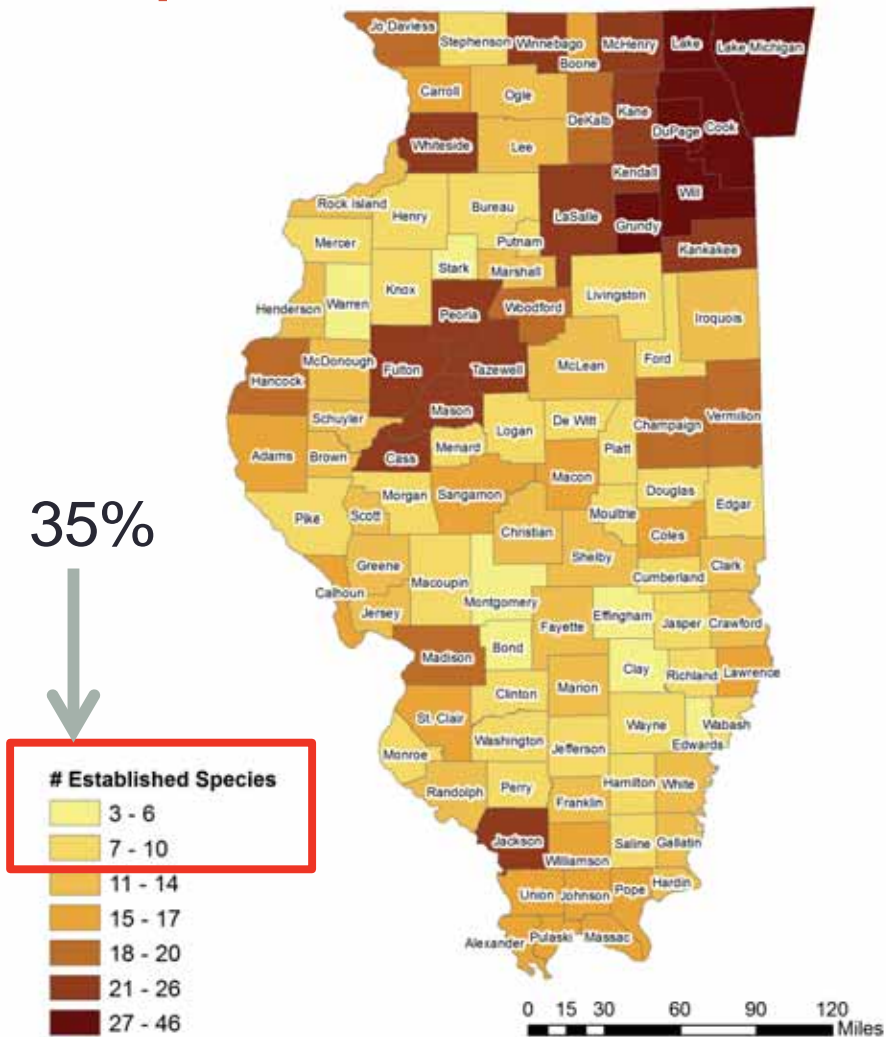
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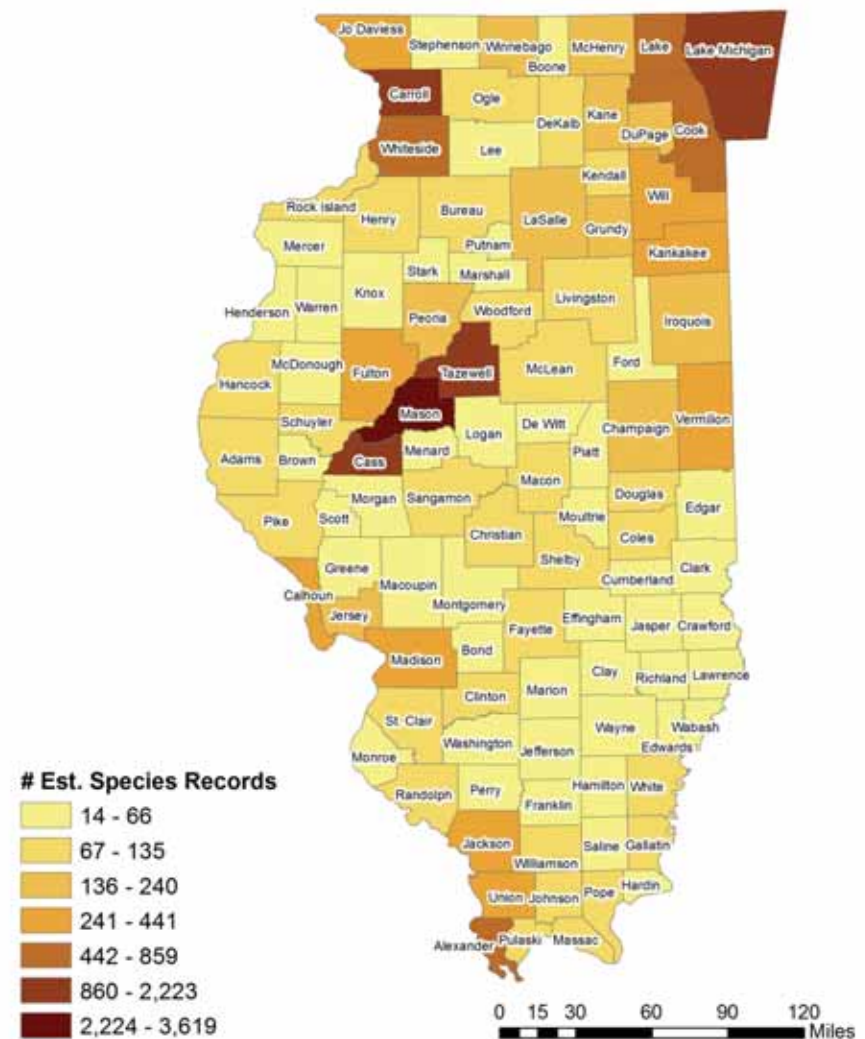
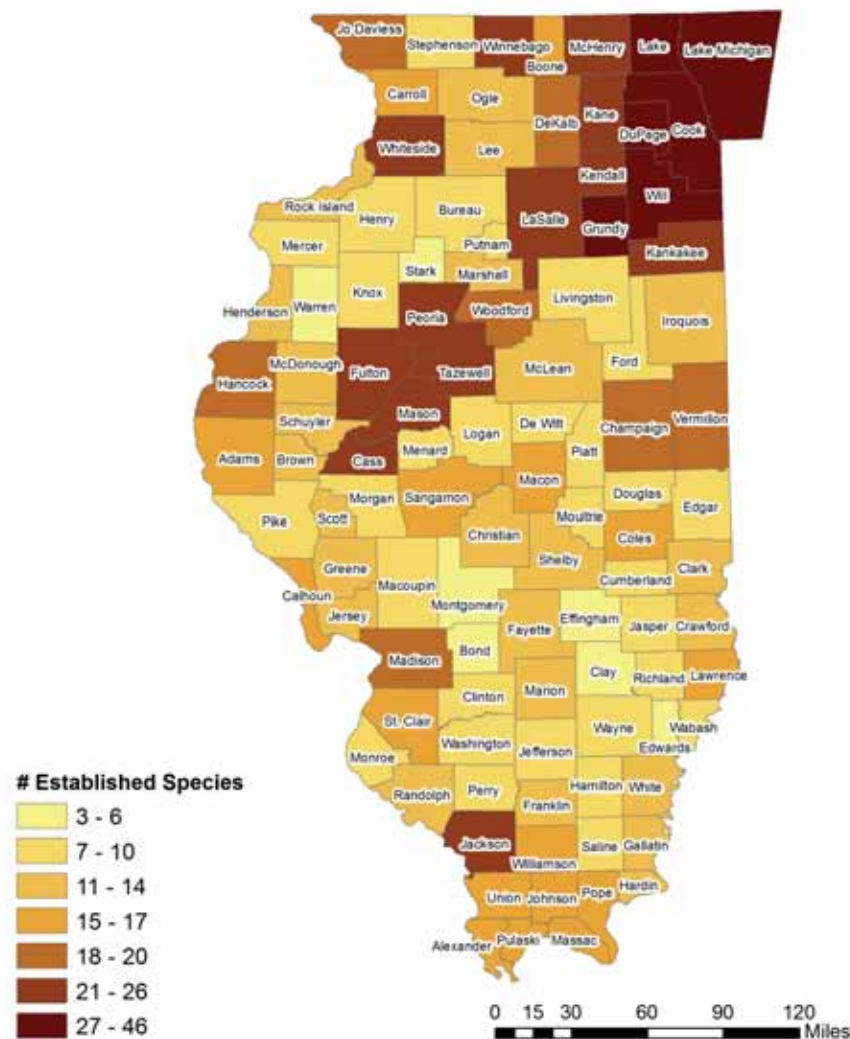


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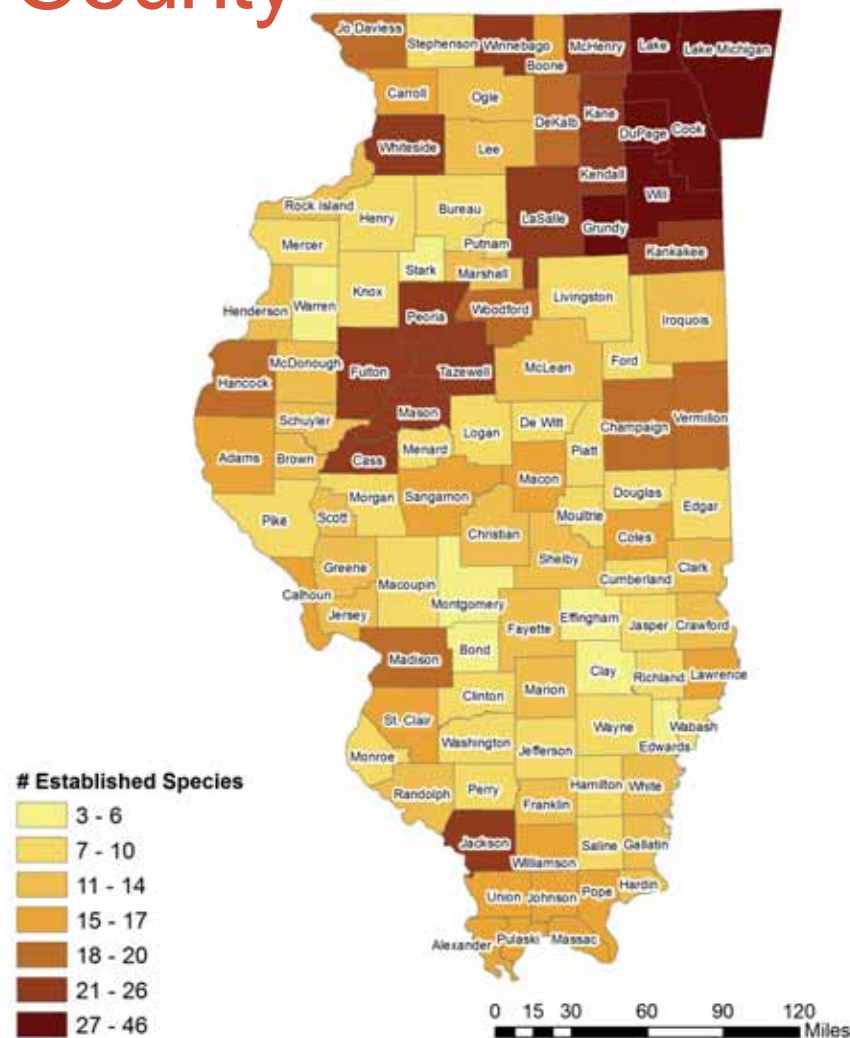




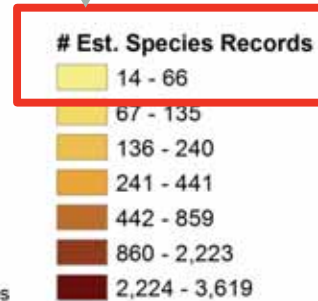
# Number of Est. Species vs. Records per County



# Number of Est. Species Records per County

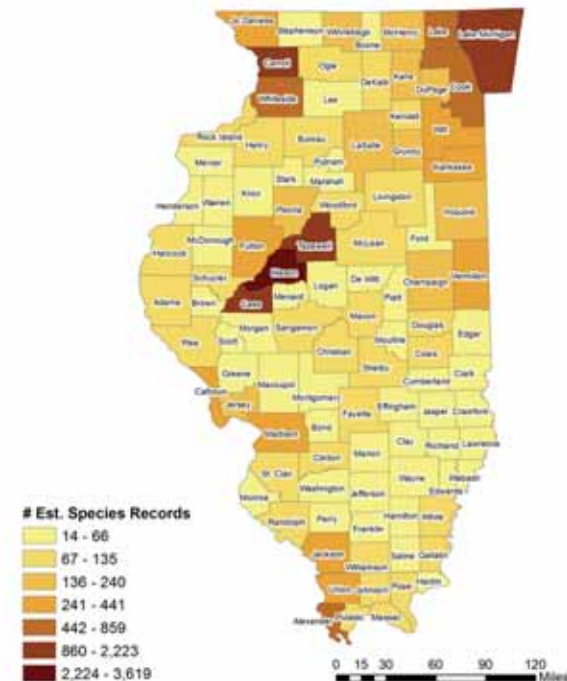
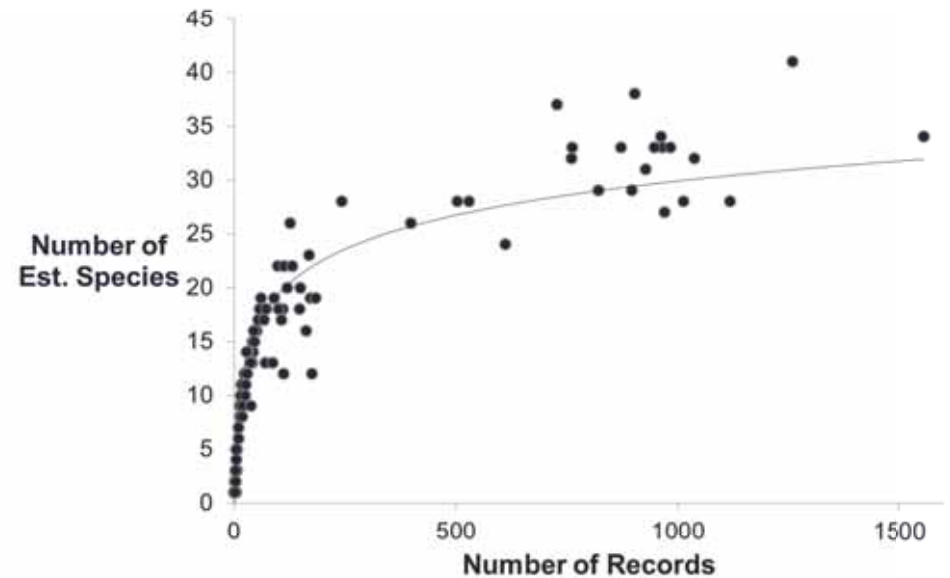


44%



# Interpretations

- We now know how many species and which aquatic non-native species are found in Illinois as a whole
- At a smaller level, knowledge is incomplete
  - Need to increase sampling effort spatially

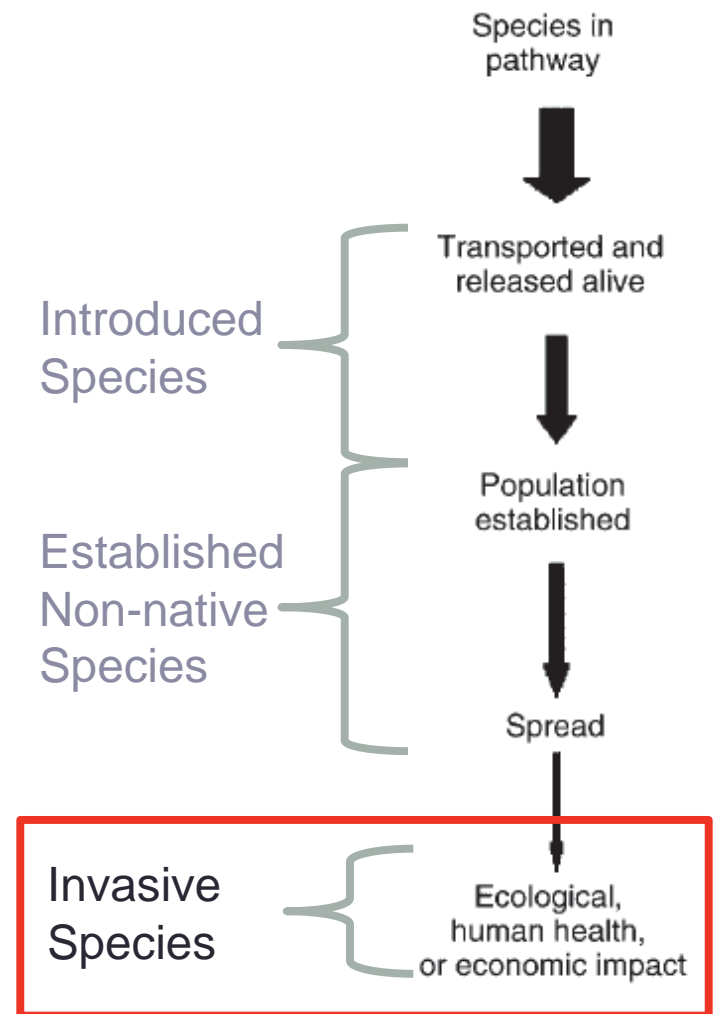


# Ongoing Research

- Ecological impacts of established species in Illinois inland waters questionnaire
  - Contact experts to determine which established species have higher ecological impacts and may be considered invasive species
    - Rank from low to very high impact
    - Includes aquatic vascular plants, fishes, mollusks, and crustaceans

## Definitions

## Invasion Process



# Conclusions

- Non-native species are arriving faster than ever before
- Species currently established in Illinois came from a variety of vectors and directions
  - Shipping largest factor recently
  - Many have crossed the basin divide between the Great Lakes and the Mississippi River
- Invasions will continue into the future
  - State and federal government need to be prepared
    - National approach to controlling invasive species

# IDANS Online Database



**GISIN**  
Global Invasive Species Information Network

GISIN.org

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## Occurrences where: the provider is 'Illinois Database of Aquatic Non-native Species, Loyola University Chicago'

Provider:

Addition:

Scientific Name:

Kingdom:

Country:

Order By:

Submit

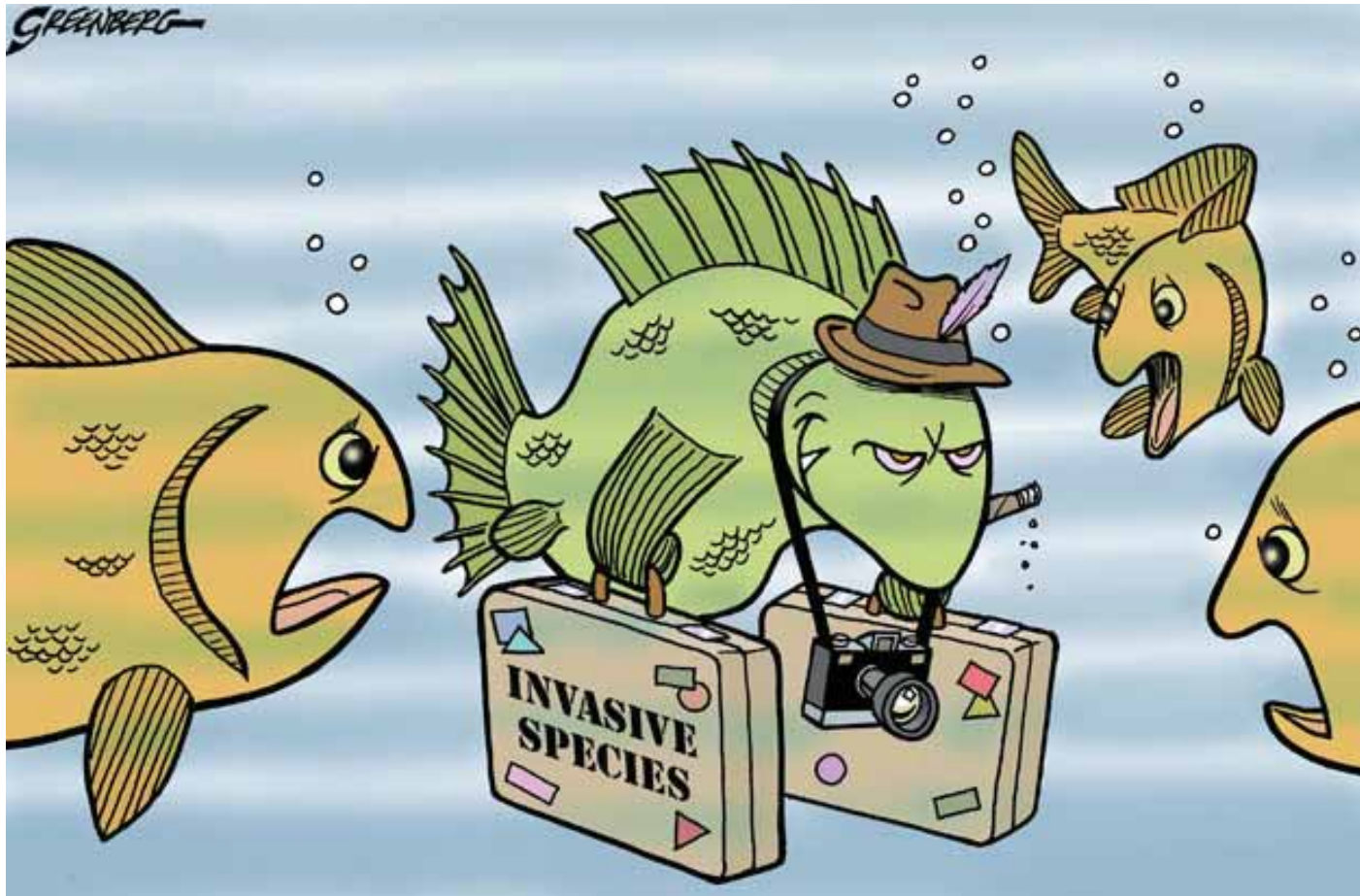
Rows 1 through 20 of 26362

Row Details	Provider Information	Kingdom	Scientific Name	Latitude	Longitude	Country
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<a href="#">Details</a>	<a href="#">Illinois Database of Aquatic Non-native Species, Loyola University Chicago</a>	Animalia	<a href="#">Cipangopaludina chinensis malleata</a>	41.784	-87.581	United States
<a href="#">Details</a>	<a href="#">Illinois Database of Aquatic Non-native Species, Loyola University Chicago</a>	Animalia	<a href="#">Corbicula fluminea</a>	37.756	-88.513	United States
<a href="#">Details</a>	<a href="#">Illinois Database of Aquatic Non-native Species, Loyola University Chicago</a>	Animalia	<a href="#">Corbicula fluminea</a>	41.221	-87.973	United States
<a href="#">Details</a>	<a href="#">Illinois Database of Aquatic Non-native Species, Loyola University Chicago</a>	Animalia	<a href="#">Oncorhynchus kisutch</a>	42.358	-87.821	United States
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# Thank you!

- LUC: Dr. Timothy Hoellein, Dr. Martin Berg, Kevin Scheiwiller, Ellen Cole, David Treering, John Belcik,
- ILDNR: Mike Garthaus, Kevin Irons, Dan Makauskas, Steve Robilliard, Steve Shults, Chris Bickers, Trent Thomas
- INHS: Kevin Cummings, Chris Mayer, Rick Phillippe, Chris Phillips, Jeff Stein, Chris Taylor, Stephen Butler, Jeremy Tiemann
- USGS NAS: Amy Benson,
- ISM: Hong Qian, Robert Warren,
- FMNH: Jochen Gerber, Susan Mochel, Christine Niezgodna,
- USDA APHIS: Scott Blackwood,
- EDDMapS: Chris Evans, Rebekah Wallace,
- NIIPP: Cathy McGlynn,
- BMNH: Andrew Simons,
- ILEPA: Laura Lovgrin, Diane Tancl
- SIU: James Garvey, Greg Whitledge,
- Chicago Botanical Gardens: Bob Kirschner,
- ILM Inc.: Gregg Zink

# Questions?



[www.vjmovement.com](http://www.vjmovement.com)

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# References

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## Table S1- Established Species

Group	Scientific Name	Common Name	Year of First Discovery	Number of Records	Found in IL and/or Lake Michigan	Number of IL Counties Present
Crustaceans	<i>Apocorophium lacustre</i>	A Scud	2003	6	IL Only	5
Crustaceans	<i>Bythotrephes longimanus</i>	Spiny Water Flea	1986	6	LM Only	0
Crustaceans	<i>Cercopagis pengoi</i>	Fishhook Waterflea	1999	3	LM Only	0
Crustaceans	<i>Daphnia lumholtzi</i>	Water Flea	1992	28	IL Only	16
Crustaceans	<i>Echinogammarus ischnus</i>	An Amphipod	1999	1	LM Only	0
Crustaceans	<i>Eubosmina coregoni</i>	Water Flea	1966	1	LM Only	0
Crustaceans	<i>Eurytemora affinis</i>	A Calanoid Copepod	1972	3	Both	1
Crustaceans	<i>Hemimysis anomala</i>	Bloody Red Shrimp	2007	2	LM Only	0
Crustaceans	<i>Orconectes rusticus</i>	Rusty Crayfish	1906	234	Both	23
Diatoms	<i>Cyclotella cryptica</i>	Diatom	1995	1	LM Only	0
Diatoms	<i>Cyclotella pseudostelligera</i>	Diatom	1994	4	LM Only	0
Diatoms	<i>Discostella pseudostelligera</i>	Diatom	1994	4	LM Only	0
Diatoms	<i>Stephanodiscus binderanus</i>	Diatom	1995	1	LM Only	0
Diatoms	<i>Stephanodiscus subtilis</i>	Diatom	1994	1	LM Only	0

## Table S1- Established Species Cont

Group	Scientific Name	Common Name	Year of First Discovery	Number of Records	Found in IL and/or Lake Michigan	Number of IL Counties Present
Fishes	<i>Alosa pseudoharengus</i>	Alewife	1949	290	Both	3
Fishes	<i>Ameiurus catus</i>	White Catfish	1965	12	IL Only	11
Fishes	<i>Carassius auratus</i>	Goldfish	1917	657	Both	43
Fishes	<i>Ctenopharyngodon idella</i>	Grass Carp	1971	977	Both	48
Fishes	<i>Cyprinus carpio</i>	Common Carp	1894	10,050	Both	102
Fishes	<i>Cyprinus carpio</i> x <i>Carassius auratus</i>	Common Carp X Goldfish	1959	419	IL Only	40
Fishes	<i>Gasterosteus aculeatus</i>	Threespine Stickleback	1988	36	Both	3
Fishes	<i>Hypophthalmichthys molitrix</i>	Silver Carp	1983	1,221	IL Only	48
Fishes	<i>Hypophthalmichthys nobilis</i>	Bighead Carp	1986	690	IL Only	47
Fishes	<i>Misgurnus anguillicaudatus</i>	Oriental Weatherfish	1987	29	IL Only	2
Fishes	<i>Morone americana</i>	White Perch	1988	293	Both	16
Fishes	<i>Morone americana</i> x <i>Morone mississippiensis</i>	White Perch X Yellow Bass	2000	6	IL Only	1
Fishes	<i>Morone saxatilis</i>	Striped Bass	1977	71	IL Only	22
Fishes	<i>Neogobius melanostomus</i>	Round Goby	1993	286	Both	7
Fishes	<i>Oncorhynchus gorbuscha</i>	Pink Salmon	1973	1	LM Only	0
Fishes	<i>Oncorhynchus kisutch</i>	Coho Salmon	1967	242	Both	2
Fishes	<i>Oncorhynchus mykiss</i>	Rainbow Trout	1950	153	Both	13
Fishes	<i>Oncorhynchus tshawytscha</i>	Chinook Salmon	1940	212	Both	3
Fishes	<i>Osmerus mordax</i>	Rainbow Smelt	1923	56	Both	12
Fishes	<i>Petromyzon marinus</i>	Sea Lamprey	1936	13	Both	1
Fishes	<i>Salmo trutta</i>	Brown Trout	1928	189	Both	11

## Table S1- Established Species Cont

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Hydroids	<i>Cordylophora caspia</i>	Freshwater Hydroid	1999	2	Both	1
Mollusks	<i>Bithynia tentaculata</i>	Mud Bithynia, Faucet Snail	1871	4	Both	1
Mollusks	<i>Cipangopaludina chinensis malleata</i>	Chinese Mystery Snail	1938	88	IL Only	18
Mollusks	<i>Corbicula fluminea</i>	Asian Clam	1962	1,544	Both	94
Mollusks	<i>Corbicula largillierti</i>	None	2008	5	IL Only	3
Mollusks	<i>Dreissena polymorpha</i>	Zebra Mussel	1989	683	Both	45
Mollusks	<i>Dreissena rostriformis bugensis</i>	Quagga Mussel	2002	22	Both	2
Mollusks	<i>Eupera cubensis</i>	Mottled Fingernailclam	2006	3	IL Only	3
Mollusks	<i>Potamopyrgus antipodarum</i>	New Zealand Mudsnail	2006	6	LM Only	0
Vascular Plants	<i>Acorus calamus</i>	Calamus, Sweet Flag	1904	110	IL Only	58
Vascular Plants	<i>Alopecurus geniculatus</i>	Water Foxtail	1927	9	IL Only	6
Vascular Plants	<i>Butomus umbellatus</i>	Flowering Rush	1957	23	IL Only	5
Vascular Plants	<i>Cyperus schoenoides</i>	Swamp Pricklegrass	1947	17	Both	7
Vascular Plants	<i>Egeria densa</i>	Brazilian Waterweed	1992	28	IL Only	16
Vascular Plants	<i>Eichhornia crassipes</i>	Common Water Hyacinth	1975	21	IL Only	8
Vascular Plants	<i>Iris pseudacorus</i>	Paleyellow Iris	1942	45	IL Only	20
Vascular Plants	<i>Juncus compressus</i>	Roundfruit Rush	1982	23	IL Only	3
Vascular Plants	<i>Lycopus europaeus</i>	Gypsywort	1976	9	IL Only	4
Vascular Plants	<i>Lysimachia punctata</i>	Large Yellow Loosestrife	1947	2	IL Only	2
Vascular Plants	<i>Lythrum hyssopifolium</i>	Hyssop Loosestrife	2011	2	IL Only	1
Vascular Plants	<i>Lythrum salicaria</i>	Purple Loosestrife	1903	185	IL Only	42
Vascular Plants	<i>Marsilea quadrifolia</i>	European Watercress	1941	20	IL Only	6
Vascular Plants	<i>Mentha aquatica</i>	Water Mint	1896	57	IL Only	35
Vascular Plants	<i>Mentha x gracilis</i>	Gingermint	1897	52	IL Only	28
Vascular Plants	<i>Mentha x piperita</i>	Peppermint	1943	13	IL Only	11

## Table S1- Established Species Cont

Vascular Plants	<i>Mentha x villosa</i>	Spearmint x Apple Mint	1951	3	IL Only	3
Vascular Plants	<i>Myosotis scorpioides</i>	True Forget-Me-Not	1897	49	IL Only	15
Vascular Plants	<i>Myriophyllum aquaticum</i>	Parrot Feather Watermilfoil	2008	2	IL Only	1
Vascular Plants	<i>Myriophyllum spicatum</i>	Eurasian Watermilfoil	1916	1,476	Both	38
Vascular Plants	<i>Najas minor</i>	Brittle Waternymph	1961	517	IL Only	54
Vascular Plants	<i>Nasturtium officinale</i>	Watercress	1877	167	IL Only	38
Vascular Plants	<i>Nelumbo nucifera</i>	Sacred Lotus	2012	2	IL Only	2
Vascular Plants	<i>Nymphoides peltata</i>	Yellow Floatingheart	1948	10	IL Only	5
Vascular Plants	<i>Phalaris arundinacea</i>	Reed Canarygrass	1900	225	IL Only	68
Vascular Plants	<i>Phragmites australis</i>	Common Reed	1921	270	Both	66
Vascular Plants	<i>Polygonum hydropiper</i>	Marshpepper Knotweed	1882	149	IL Only	71
Vascular Plants	<i>Potamogeton crispus</i>	Curly Pondweed	1911	1,138	Both	52
Vascular Plants	<i>Puccinellia distans</i>	Weeping Alkaligrass	1957	42	IL Only	16
Vascular Plants	<i>Rorippa sylvestris</i>	Creeping Yellowcress	1878	213	IL Only	65
Vascular Plants	<i>Salix caprea</i>	Goat Willow	1905	22	IL Only	5
Vascular Plants	<i>Schoenoplectus mucronatus</i>	Bog Bullrush	1975	14	IL Only	4
Vascular Plants	<i>Typha angustifolia</i>	Narrowleaf Cattail	1898	242	IL Only	65
Vascular Plants	<i>Typha x glauca</i>	Hybrid Cattail	1940	11	IL Only	9