A science agenda for managing non-native *Phragmites australis* through microbial intervention

Dr. Kurt P. Kowalski and Wesley Bickford
USGS – Great Lakes Science Center

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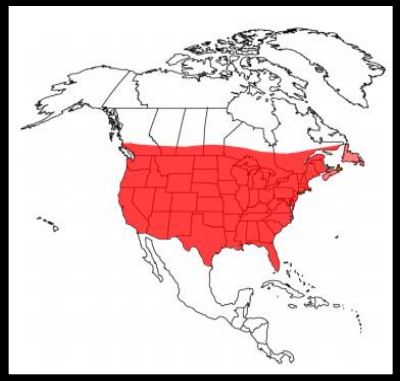
A Landscape-Scale Problem



- Direct impact on people and habitats
- Priority for resource managers
- Need comprehensive approach

Current Management Strategies

Chemical

Hydrologic

Mechanical

- Challenges
  - Resource intensive
  - Not species specific
  - Treat symptom rather than cause

Fire

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Developing Approaches

Biological Control

Mark Schwarzlander & Patrick Hafliger, CABI Biosciences, Bugwood.org

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Gene Silencing

WAYNE STATE UNIVERSITY

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Developing Approaches

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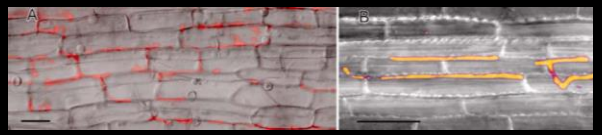
***Phragmites* Symbiosis Collaborative**



(Ernst et al. 2003)

Microbial Symbiosis

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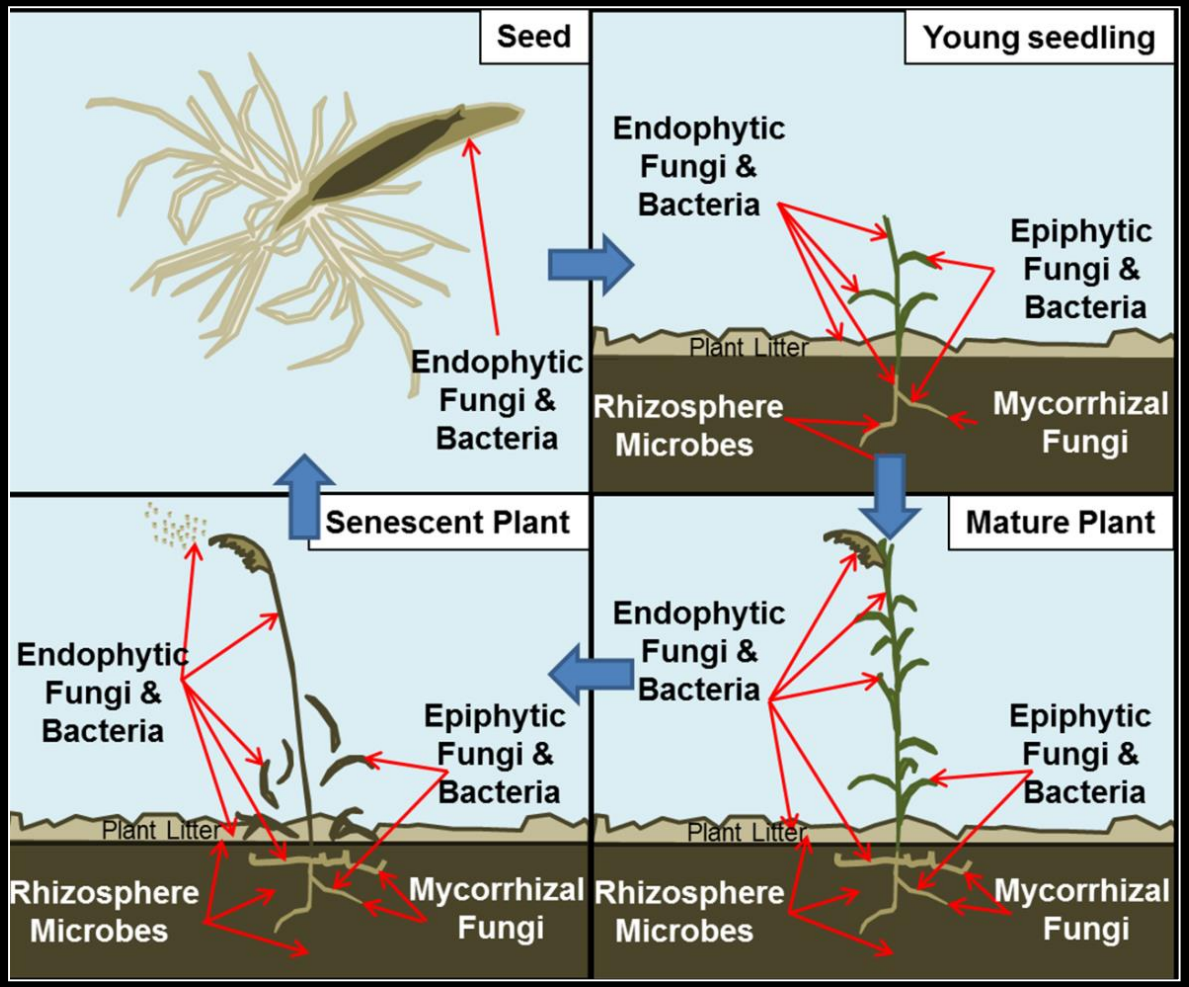
Plant Microbiota and Symbiosis



(Kowalski et al 2015)

BENEFITS

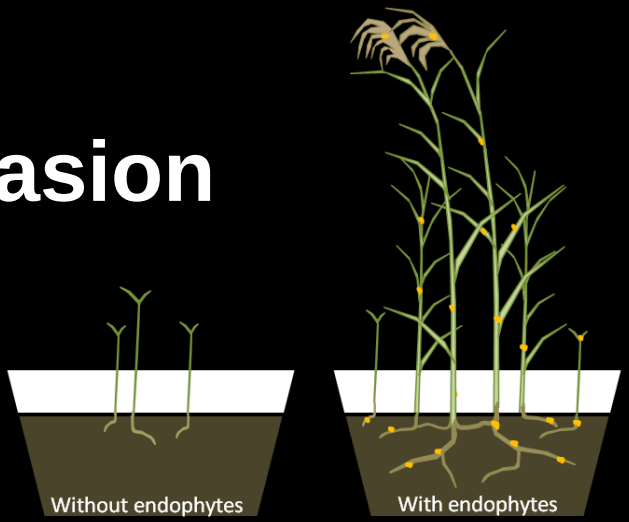
Tolerance
- Drought
- Temperature
- Salt
- Disease

Accelerated Development of Seedlings

Increased Growth and Yield

Symbiosis and Invasion

Does symbiosis influence invasion?



Native Pathogens

- *Enemy Release Hypothesis*

Novel Pathogens

- Biotic Resistance Hypothesis

Native Mutualists

- Seeds

Novel Mutualists

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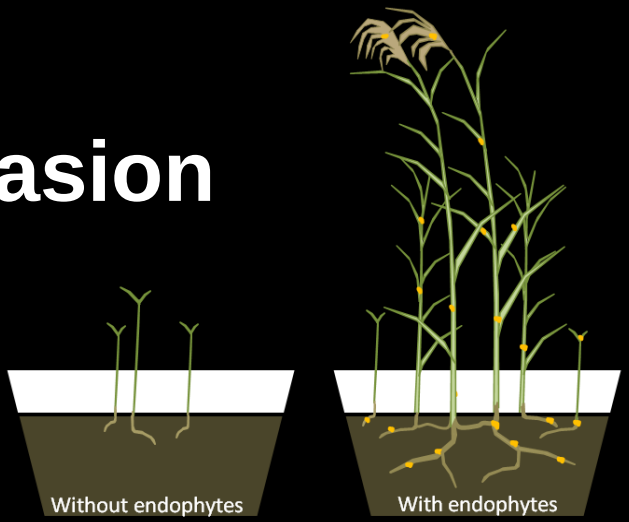
Symbiosis and Invasion

Does symbiosis influence invasion?



Target symbiotic relationships that confer benefits?

- Impact invasive properties of *Phragmites*?
- Benefit native plants?

BIOMASS PRODUCTION

TOLERANCE TO STRESS

STEM DENSITY

GROWTH RATE

RHIZOME GROWTH

SEED OUTPUT

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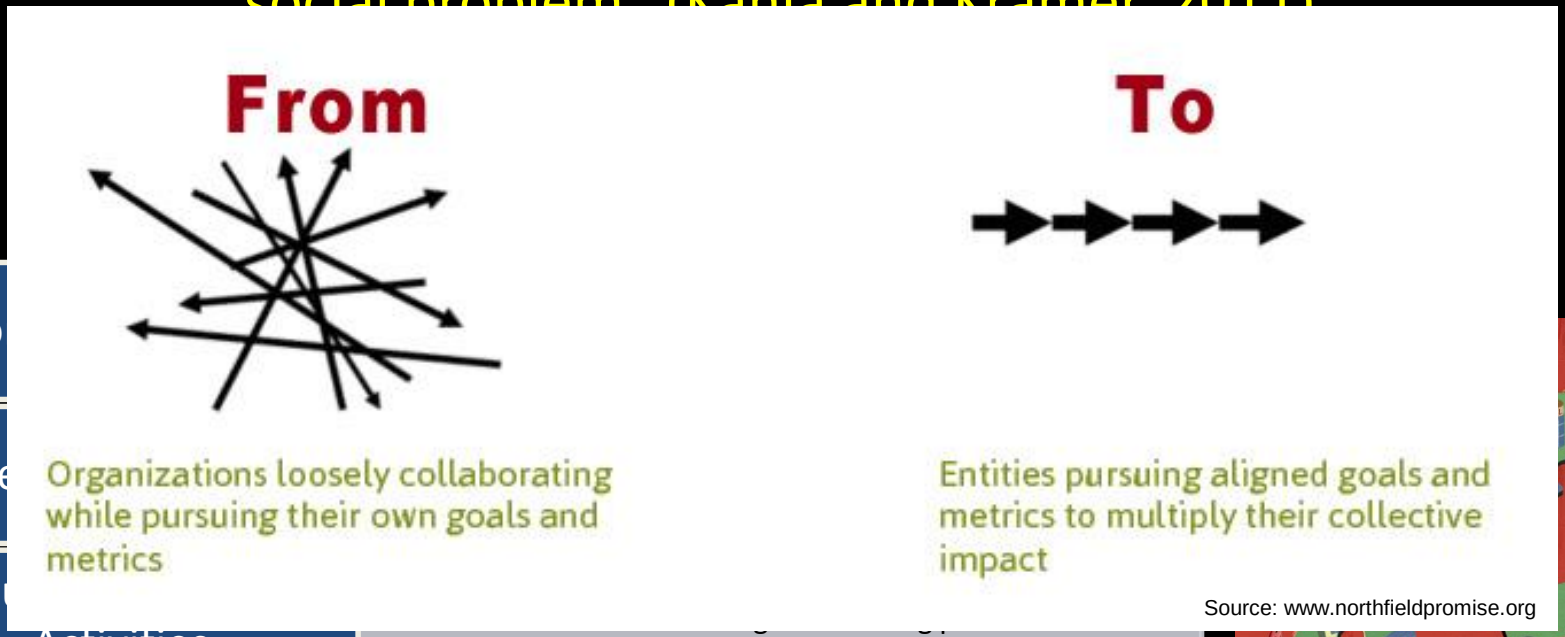
Collective Impact

"the commitment of a group of important actors from different sectors to a common agenda for solving a specific social problem" (Kania and Kramer, 2011)



Co

Share

Mut

Activities

Continuous Communication

- Consistent and open communication necessary
- Builds trust, assures objective, creates common motivation

Backbone Support

- Managing collective impact requires separate organization
- Serves as backbone for initiative and coordinates agencies

Kania and Kramer, 2011

Great Lakes PHRAGMITES COLLABORATIVE

LINKING PEOPLE, INFORMATION AND ACTION

Search!

Home About Biology Management Research Resources

Phragmites australis (common reed) is a highly invasive plant species now common in North American wetlands. Its continued progression across the Great Lakes Basin will increasingly challenge resources

Management Monday! May is National Wetlands Month! Learn, explore, go out and appreciate these amazing systems.

www.greatlakesphragmites.net

Collaborative for Microbial Symbiosis and *Phragmites* Management

Purpose

Support and facilitate research focused on furthering the science of *Phragmites* and symbiosis

Strategy

Engage microbial scientists to develop a research agenda toward a common goal

- Collective Impact

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Collaborative for Microbial Symbiosis and *Phragmites* Management

What do we know about *Phragmites* and symbiosis?

↓

What gaps exist in our understanding?

↓

Create Science Agenda

↓

Craft individual research projects addressing gaps

↓

All members contribute to goal of microbe-based *Phragmites* control

The Collaborative

- International Membership
- ~10 Researchers
  - Microbial ecologists
- Active since April 2013

Smithsonian Environmental Research Center

USDA United States Department of Agriculture Agricultural Research Service

Indiana University

The College at Brockport State University of New York

Cornell University College of Agriculture and Life Sciences

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Collaborative for Microbial Symbiosis and *Phragmites* Management

What do we know about *Phragmites* and symbiosis?

What gaps exist in our understanding?

Create Science Agenda

Craft individual research projects addressing gaps

All members contribute to goal of microbe-based *Phragmites* control

frontiers in MICROBIOLOGY

REVIEW ARTICLE

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Advancing the science of microbial symbiosis to support invasive species management: a case study on *Phragmites* in the Great Lakes

Kurt P. Kowalski[1]*, Charles Bacon[2], Wesley Bickford[1], Heather Braun[3], Keith Clay[4], Michèle Leduc-Lapierre[3], Elizabeth Lillard[3], Melissa K. McCormick[5], Eric Nelson[6], Monica Torres[7], James White[7] and Douglas A. Wilcox[8]

[1] U.S. Geological Survey, Great Lakes Science Center, Ann Arbor, MI, USA
[2] U.S. Department of Agriculture, Agricultural Research Service, Athens, GA, USA
[3] Great Lakes Commission, Ann Arbor, MI, USA
[4] Department of Biology, Indiana University, Bloomington, IN, USA
[5] Smithsonian Environmental Research Center, Edgewater, MD, USA
[6] Department of Plant Pathology and Plant-Microbe Biology, Cornell University, Ithaca, NY, USA
[7] Department of Plant Biology and Pathology, Rutgers University, New Brunswick, NJ, USA
[8] Department of Environmental Science and Biology, The College at Brockport, State University of New York, Brockport, NY, USA

Edited by:
Giulia De Lorenzo, Sapienza, Università di Roma, Italy

Reviewed by:
Laila Pamela Partida-Martínez, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Mexico
Matteo Lotto, University of Naples, Italy

***Correspondence:**
Kurt P. Kowalski, U.S. Geological Survey, Great Lakes Science Center, 1451 Green Road, Ann Arbor, MI 48105, USA
e-mail: kkowalski@usgs.gov

A growing body of literature supports microbial symbiosis as a foundational principle for the competitive success of invasive plant species. Further exploration of the relationships between invasive species and their associated microbiomes, as well as the interactions with the microbiomes of native species, can lead to key new insights into invasive success and potentially new and effective control approaches. In this manuscript, we review microbial relationships with plants, outline steps necessary to develop invasive species control strategies that are based on those relationships, and use the invasive plant species *Phragmites australis* (common reed) as an example of how development of microbial-based control strategies can be enhanced using a collective impact approach. The proposed science agenda, developed by the Collaborative for Microbial Symbiosis and *Phragmites* Management, contains a foundation of sequential steps and mutually-reinforcing tasks to guide the development of microbial-based control strategies for *Phragmites* and other invasive species. Just as the science of plant-microbial symbiosis can be transferred for use in other invasive species, so too can the model of collective impact be applied to other avenues of research and management.

Keywords: symbiosis, *Phragmites*, invasive species management, fungi, bacteria, collaborative, endophyte, Great Lakes Region

INTRODUCTION

Invasion of native ecosystems by non-native (i.e., exotic) plant species is a widespread problem. For example, Morse et al. (1995) estimated that more than 5000 exotic plant species have become established and displaced native plant species in the U.S. The problem continues to grow as over 700,000 hectares per year of wildlife habitat are invaded by invasive species (Babbitt, 1998). Invasive plants negatively impact both the ecosystems and the economy of the United States (Pimentel et al., 2000), where about 400 of the 958 species listed as endangered or threatened are considered to be at risk due to pressure from invasive species (Wilcove et al., 1998). Management and control of invasive plants is a priority for many agencies and organizations across the United States and entails a significant investment of resources. For example, the National Invasive Plants Council, composed of members of many federal agencies with a goal to provide high-level interdepartmental coordination of federal invasive species actions, estimated that $2.2 billion (U.S.) was spent during FY2012 on invasive species activities (National Invasive Species Council, 2014). The total control cost for exotic and invasive aquatic weeds in the United States is estimated at $100 million annually (Pimentel, 2005). In the State of Florida alone, $14.5 million is spent annually on aquatic hydrilla (*Hydrilla verticillata*) control, and *H. verticillata* infestations in only two Florida lakes have amounted to $10 million annually in recreational losses, including swimming and boating (Center et al., 1997). Similarly, state departments of natural resources, various collaboratives, and local watershed councils are also concerned with invasive species. In the Great Lakes region, the Great Lakes Restoration Initiative (GLRI), the largest U. S. investment in the Great Lakes in two decades, includes combating invasive species as one of its five urgent issues (Great Lakes Restoration Initiative, 2010, 2014).

Although extensive resources from state and federal agencies have been devoted to both management and control of invasive plant species across the U.S., there is evidence that this intensive investment may not be producing the intended management results (Reid et al., 2009; Martin and Blossey, 2013). There is a need for new, innovative tools to control invasive

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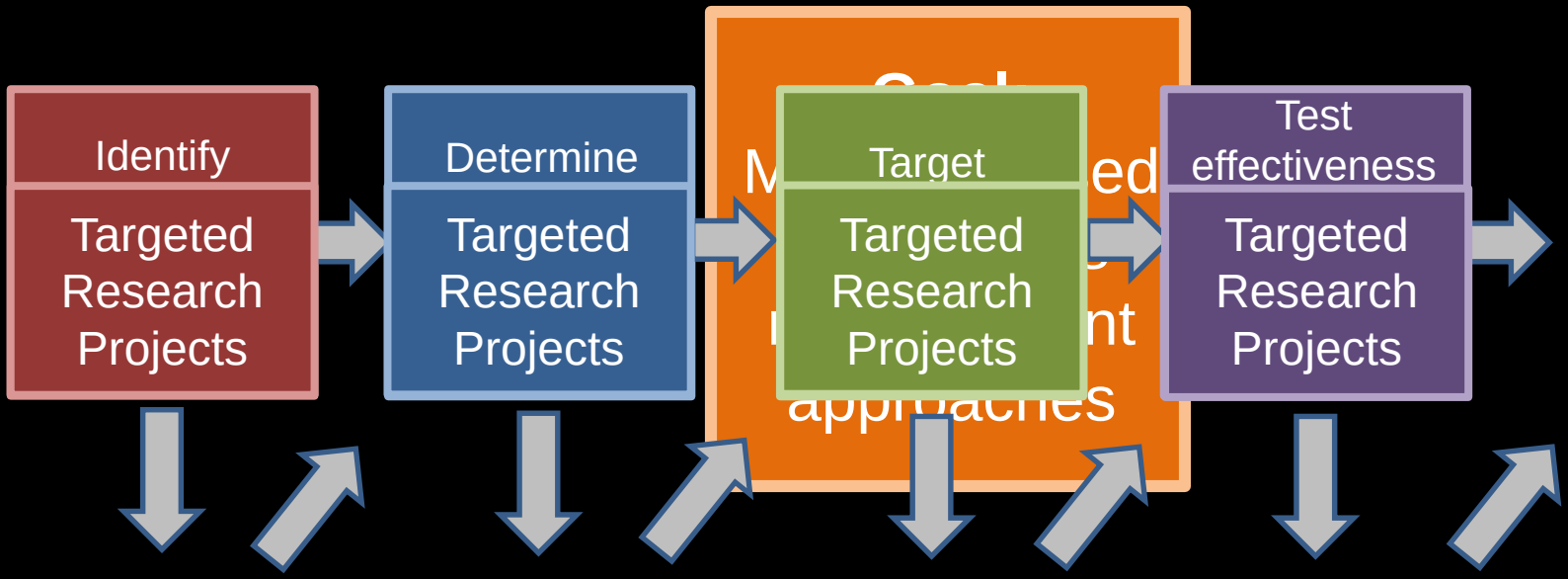
Conceptual Strategy



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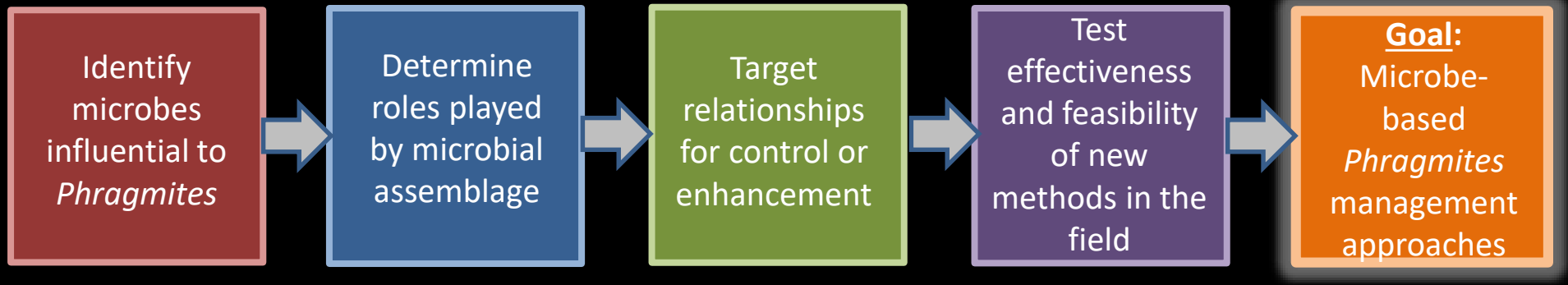
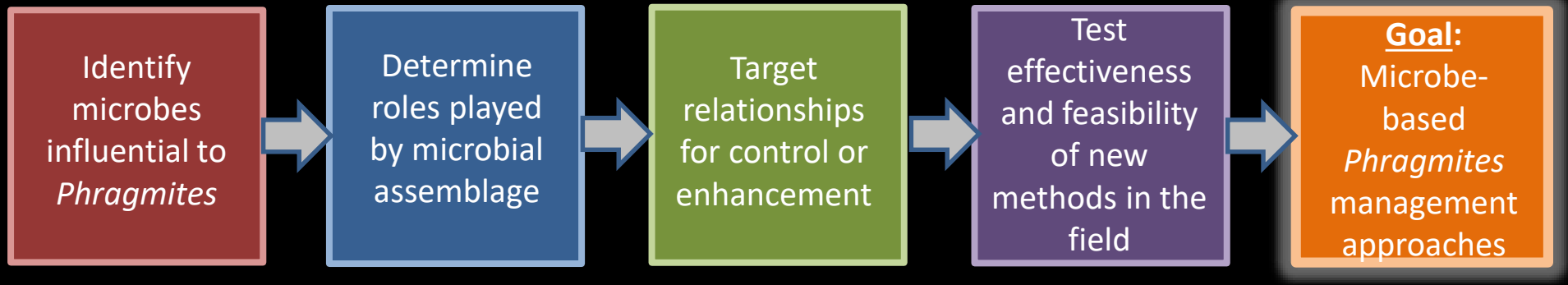
Conceptual Strategy



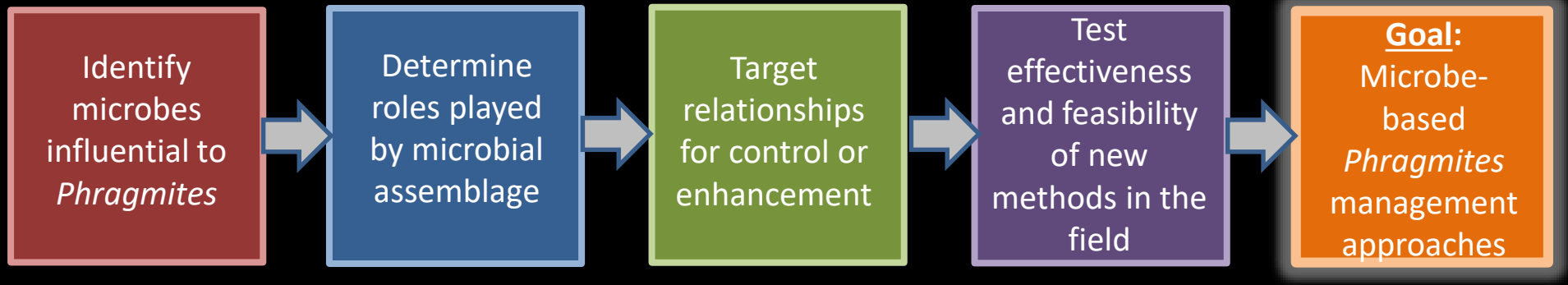
MICROBIAL INVENTORY
Composition and transmission method
Variation of microbiome in time and space
Relevant pathogenic microbes and interactions with mutualistic microbes
Compare microbiomes of native and invasive *Phragmites*
Target native plant species for probiotic exploration
Variation in native species in space, species, and growth stage

Conceptual Strategy



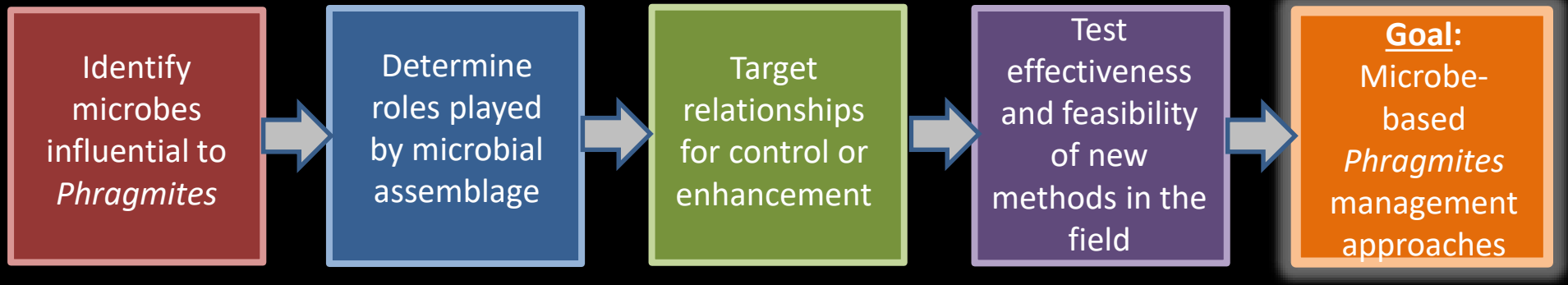
BENEFITS OF MICROBES
Test plant response to inoculation by microbes
Determine microbes with key impacts (e.g., growth)
Competitive impacts of inoculants on *Phragmites*
Impacts of *Phragmites* pathogens on native species
Increase competitiveness of native species
Impact on plant-development pathways

Conceptual Strategy



TARGETING RELATIONSHIPS FOR CONTROL
Microbial sensitivity to inhibitors
Selectivity of inhibitors for target groups
Endophyte sensitivity to low-impact treatments
Competitive response to treatment of mutualistic/pathogenic microbes
Competitive response of native plants after microbial treatments
Mechanisms that underly reductions in competitiveness

Conceptual Strategy



TEST CONTROL METHODS
Considerations to scale up to landscape-level applications
Discussions with regulatory bodies
Impact on non-target species
Direct environmental impact of treatments
Costs for microbiome manipulation strategy
Optimal management efficacy at varying time scales

Implementing the Science Agenda

Target
lationships
control or

Test
effectiveness
and feasibility
of new
ods in the
field

Goal:
Microbe-based *Phragmites* management approaches

Biol Invasions
DOI 10.1007/s10530-016-1137-y
PHRAGMITES INVASION

Diversity of fungal endophytes in non-native *Phragmites australis* in the Great Lakes

Keith Clay · Zackery R. C. Shearin · Kimberly A. Bourke · Wesley A. Bickford · Kurt P. Kowalski

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Abstract Plant–microbial interactions may pl
key role in plant invasions. One common micr
interaction takes place between plants and fu
endophytes when fungi asymptomatically colc
host plant tissues. The objectives of this study we

Biol Invasions
DOI 10.1007/s10530-016-1160-z
PHRAGMITES INVASION

Evaluation of the functional roles of fungal endophytes of *Phragmites australis* from high saline and low saline habitats

Marcos Antônio Soares · Hai-Yan Li · Kurt P. Kow
Marshall Bergen · Mónica S. Torres · James Francis

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Abstract Non-native *Phragmites australis* decreases biodiversity and produces dense stands in North America. We surveyed the endophyte communities in the stems, leaves and roots of collections of *P. australis* obtained from two sites with a low and high salt

Microb Ecol (2016) 72:407–417
DOI 10.1007/s00248-016-0793-x
PLANT MICROBE INTERACTIONS

Functional Role of Bacteria from Invasive *Phragmites australis* in Promotion of Host Growth

M. A. Soares[1] · H-Y. Li[2] · K. P. Kowalski[3] · M. Bergen[4] · M. S. Torres[4] · J. F. White[4]

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Abstract We hypothesize that bacterial endophytes may enhance the competitiveness and invasiveness of *Phragmites australis*. To evaluate this hypothesis, endophytic bacteria were isolated from *P. australis*. The majority of the shoot meristem isolates represent species from phyla *Firmicutes*, *Proteobacteria*, and *Actinobacteria*. We chose one species from each phylum to characterize further and to conduct growth promotion experiments in *Phragmites*. Bacteria tested include *Bacillus amyloliquefaciens* A9a, *Achromobacter spanius* B1, and *Microbacterium oxydans* B2. Isolates were characterized for known growth promotional traits, including greenhouse experiments. All three isolates were found to increase the growth of *P. australis* under low soil nitrogen conditions and showed increased absorption of isotopic nitrogen into plants. This suggests that the *Phragmites* microbes we evaluated most likely promote growth of *Phragmites* by enhanced scavenging of nitrogenous compounds from the rhizosphere and transfer to host roots. Collectively, our results support the hypothesis that endophytic bacteria play a role in enhancing growth of *P. australis* in natural populations. Gaining a better understanding of the precise contributions and mechanisms of endophytes in enabling *P. australis* to

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Alterna

Promote beneficial microbes in desirable species

Additional Information

Kowalski et al. 2015. Advancing the science of microbial symbiosis to support invasive species management: A case study on *Phragmites* in the Great Lakes. *Frontiers in Microbiology* 6:95. doi: 10.3389/fmicb.2015.00095

http://journal.frontiersin.org/article/10.3389/fmicb.2015.00095/abstract

http://greatlakesphragmites.net/webinars-presentations/

USGS **Email: kkowalski@usgs.gov**