A REVIEW OF THE ECOLOGICAL EFFECTS OF EUROPEAN COMMON REED (*PHRAGMITES AUSTRALIS*) ON FISHES AND FISH HABITAT IN NORTH AMERICA

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Abstract

The invasive European Common Reed (*Phragmites australis*), first established in North America in the early 1900s, is now a dominant emergent aquatic plant in many coastal and inland wetlands. We conducted a review of the literature to evaluate the extent of ecological impacts on fishes and their habitat, including changes in the composition and abundance of native fishes and wetland plants, and alterations to water availability and substrate. Our review indicated that a reduction in the abundance of native fishes was found in 54.5% of the studies we evaluated. There were also impacts to fish habitat documented in 54.5% of the studies. Many studies were conducted in the eastern and northern United States, which showed that the abundance of juvenile and larval fishes was significantly lower in marshes dominated by *P. australis*, relative to those dominated by native plant species (*Spartina alterniflora*); however, changes to wetland plant abundance and composition, water availability, water temperature, nutrient cycling, substrate, reproduction and spawning, and general food web effects were also observed. These results indicate that *P. australis* poses numerous ecological impacts to the structure and function of wetland habitats, with implications for the ongoing productivity of aquatic ecosystems.

Le Roseau Commun Européen envahissant (*Phragmites australis*), établi en Amérique du Nord au début des années 1900, est maintenant une plante aquatique émergente dominante dans nombreuses des zones humides côtières et intérieures. Nous avons effectué une revue de la littérature pour évaluer l'étendue des impacts écologiques sur les poissons et leur habitat, y compris les changements dans la composition et l'abondance des poissons indigènes et des plantes de zones humides ainsi que les modifications de la disponibilité d'eau et du substrat hydriques. Notre examen a révélé qu'une réduction de l'abondance des poissons indigènes a été observée dans 54,54% des études évaluées. Il y avait aussi des impacts sur l'habitat des poissons documentés dans 54,54% des études. De nombreuses études ont été menées dans l'est et le nord des États-Unis, montrant que l'abondance des poissons juvéniles et larvaires était significativement plus bas dans les marais dominés par P. australis relativement à ceux dominés par les espèces végétales indigènes (*Spartina alterniflora*); cependant, des changements dans l'abondance et la composition des plantes de zones humides, la disponibilité de l'eau, la température de l'eau, le cycle des nutriments, le substrat, la reproduction et le frai, et les effets du réseau alimentaire généraux ont également été observés. Ces résultats indiquent que P. australis présente de nombreux impacts écologiques sur la structure et la fonction des habitats de zones humides, avec des implications pour la productivité continue des écosystèmes aquatiques.

Key Words

Phragmites; invasive; aquatic; fish; habitat

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Introduction

Ecosystems are increasingly connected as a result of economic growth and changing patterns of human movement. One consequence of increased connectivity is the human-mediated movement of species to regions where they are not native (Mooney and Cleland, 2001). Human-mediated movements can be intentional, such as the movement and sale of species in the pet trade (Smith et al., 2009), and unintentional, such as the inadvertent movement of species in ballast water (Ricciardi and MacIsaac, 2000). Many species movements are benign because the introduced species will be unable to survive in the recipient environment; however, a subset of species may become invasive by establishing reproducing populations and posing strong ecological, economic, and social consequences.

North American freshwater ecosystems have hosted many invasive species. The invasion of Sea Lamprey (*Petromyzon marinus*) into the upper Great Lakes through the Welland Canal in the 1950s decimated commercially and recreationally important sportfishes, and now requires a 12-million-dollar control program each year, as set into place by the Great Lakes Fisheries Commission (Christie and Goddard, 2003). The invasion of Zebra Mussel in the mid 1980s led to widespread foodweb changes, including decreases in phytoplankton (Lavrentyev et al., 1995), which were compounded by the arrival of Round Goby, a small benthic fish which competes with native fishes and preys upon molluscs and the eggs of native and introduced fishes (Chotkowski and Marsden, 1999). These are a sample of the ecological impacts posed by invasive species, which range from foodweb changes (Lavrentyev et al., 1995) to competition for suitable nesting habitats (Chotkowski and Marsden, 1999), as well as other structural and compositional changes to aquatic ecosystems.

Preventing the arrival, survival, and establishment of invasive species through research and management is critical to preserve ecosystems (Leung et al., 2002). However, for species that have already arrived and survived within a region, invasive populations need to be managed (Leung et al., 2002). In order to manage invasive species proactively and in ways that preserve biodiversity and ecosystem services, it is critical to understand their ecological impacts in the invaded range.

European Common Reed (*Phragmites australis*) is an emergent wetland plant that spread throughout much of the Great Lakes region, reducing biodiversity since its introduction in the early 1900s (Wilcox et al., 2003). Its ability to reproduce sexually and asexually has made it a successful competitor and it has displaced many marshland and wetland plants since its establishment (Wilcox et al., 2003). As this species spreads throughout the Great Lakes region, it affects both aquatic plant and animal populations by re-shaping physical habitat availability and changing nutrient cycling (Wilcox et al., 2003). Although *P. australis* is believed to influence many wetland plants and fishes directly and indirectly, insufficient information exists on the impacts to freshwater fishes and their habitat, making it difficult to judge the past and future response of native fishes to the ongoing invasion. More importantly, a poor understanding of the impacts of *P. australis* also makes it difficult to develop control programs to address the key mechanisms of change. A review of existing literature is essential for describing the range and magnitude of impacts; therefore, the goal of this review is to understand the ecological impacts of European Common Reed on fishes and their habitat in North America.

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Materials and Methods

The goal of this review is to summarize the ecological impacts of *P. australis* on fishes and their habitat based on a synthesis of the primary literature. To conduct the literature review I used "Google Scholar" to search terms limited to "phragmites", "phragmites australis", "phragmites fish", and "phragmites fish habitat" to compile the initial set of papers to review. I focused on papers that discussed ecological aspects of *P. australis* in North America (Studies in the native range of Southern Ontario were excluded, as there is a native species of *Phragmites australis* found here) (Wilcox et al., 2003). Each article was assessed to determine the possible impacts to fish and fish habitat using the following impact classification scheme. Fish habitat impacts included changes to: native wetland plant abundance (i.e., the abundance of individual species), native wetland plant composition (i.e., the variety of species), water availability, water temperature, water chemistry (concentration of dissolved oxygen, etc.), nutrients and nutrient cycling (which nutrients are common in the aquatic habitat, and how they are used), and substrate (condition of the benthic depositional layer in wetlands). Changes to fishes included: changes in native species abundance, changes in native species composition, disruption to reproduction/spawning, competition, predation, genetic effects, changes in behaviour, and food web changes. Impact categories were chosen because they represent direct impacts to fish populations (e.g., reductions in richness or abundance) as well as indirect impacts to fish populations through habitat alterations (e.g., nutrient cycling), and therefore encompass ecological drivers that can change abundance and composition of fish populations within the Great Lakes.

When searching for papers concerning *P. australis*, I limited my research to those from the year 2000 and forward, so that the information would be relevant. I used a total of 34 papers to support my research, some of which concerned other species that *P. australis* has or may come into contact with.

During the review I recorded evidence of each impact category, based on studies done within the papers. I organized findings within an Excel spreadsheet that listed each of the possible impacts. This spreadsheet was organized with rows as the range of possible impacts on fish or fish habitat. Columns were labelled with the identity of each paper (authors and titles). This format allowed ecological impacts to be summarized across the set of papers (e.g., 10 papers discussed changes to the marsh food web since the establishment of *P. australis*). I then converted these numbers into percentages so that the extent of each ecological impact was known. Results were used to infer how *P. australis* has and may continue to affect fish populations and aquatic habitat in North America.

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Results

Overall Impacts:

European Common Reed has had many impacts on native fish and fish habitats, the most common being changes in the abundance of native fish species (***Figure 1***). Lesser, but still prevalent impacts include, but likely are not limited to, impacts to native wetland plant abundance and composition, water availability, water temperature, water chemistry, nutrient cycling, substrate, native species composition, reproduction and spawning, and the overall food web (***Figure 1***) (***Figure 2***). Of the papers reviewed, 50% showed impacts to native plant abundance, while 54.5% showed impacts to plant composition. Impacts to water availability were studied in 18.2% of papers, decreases in water temperature in 4.5%, changes in water chemistry in 13.6%, changes in nutrient cycling in 4.5%, and an altered substrate in 4.5% of papers. The most prevalent impact (changes in fish species abundance) was found in 54.5% of papers, fish species composition in 36.4%, affects to fish reproduction and spawning in 4.5%, genetic affects on fishes in 4.5%, and changes to the marsh food web were documented in 45.4% of papers.

Impacts to native fish species abundance:

Studies often displayed similar impacts to fish species abundance based on the structure and function of the wetland ecosystems surveyed. A study in Hog Islands, New Jersey involved sampling the number of eggs, larval fishes, and juvenile fishes present in sites dominated by Common Reed and *Spartina alterniflora* (Able and Hagan, 2003). It was found that there were more viable fish eggs within the *Spartina* marsh, as well as a much higher abundance of larval and juvenile fish, especially Mummichog (*Fundulus heteroclitus*) (Able and Hagan, 2003). Similar results were found in the Delaware Bay estuary in which a significantly lower amount of larval and juvenile Mummichog were found within the Common Reed dominated marsh, than within the *Spartina* dominated and restored *Spartina* marshes. This was also shown in studies done in the Hackensack Meadowlands in New Jersey, and the Connecticut River.

Impacts to native plant abundance:

The presence of *P. australis* was shown to have an effect on wetland plant abundance and composition, as observed in the Hackensack Meadowlands of New Jersey and other nearby locations as well (Raichel et al., 2003). Studies conducted within Alloway Creek, in the Delaware Bay estuary and the Connecticut River documented a decrease in water availability in areas of marshes that were dominated by Common Reed (Warren et al., 2001; Able et al., 2003). This, in turn, also affected the abundance of larval and juvenile fishes due to loss of rearing habitat (Warren et al., 2001; Able et al., 2003). The temperature of the water was also found to be lower in marshes containing Common Reed, as the reed often is found to cover the surface of the water, preventing light and heat from entering (Able et al., 2003).

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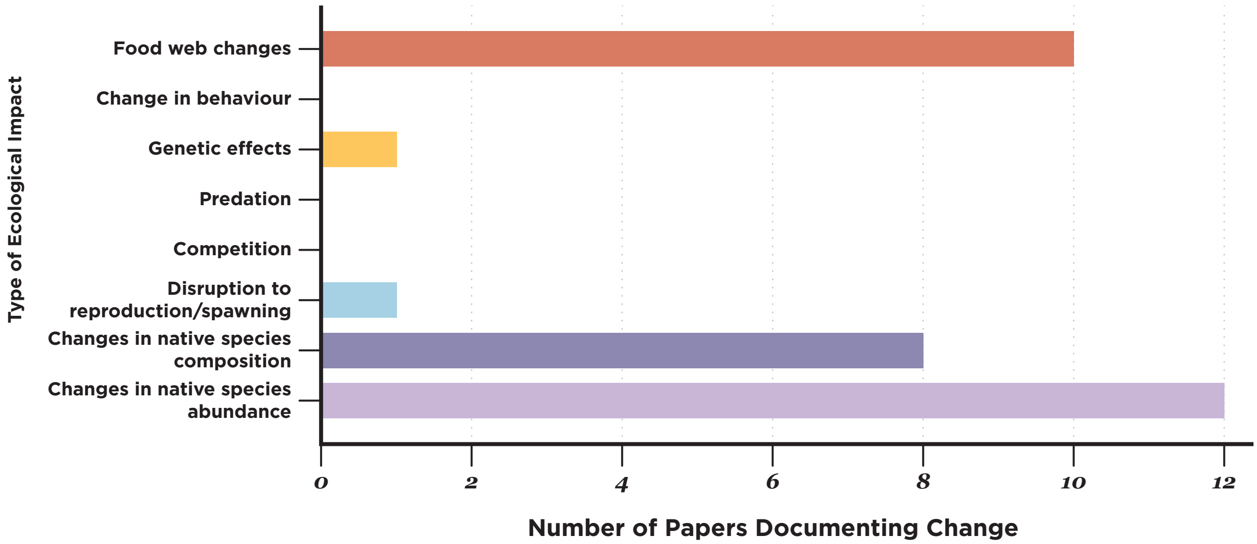

Figure 1: Summary of the ecological impacts of *P. australis* to native fishes in North America– *Count of the number of papers reviewed that document specific changes caused by P. australis, to native fishes in North America (total of 34 papers reviewed).*

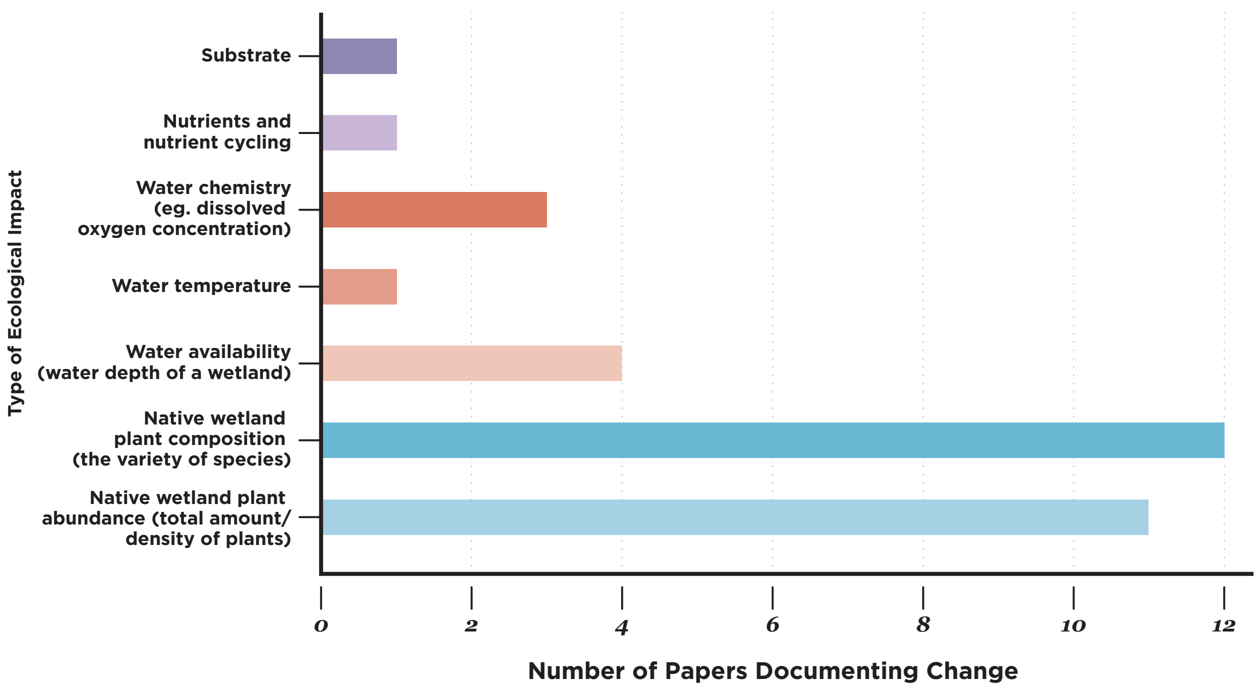

Figure 2: Summary of the ecological impacts of *P. australis* to fish habitat in North America– *Count of the number of papers reviewed that document specific changes caused by P. australis, to fish habitats in North America (total of 34 papers reviewed)*

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Other Impacts:

The water chemistry and nutrient cycling were found to change in marshes containing *P. australis* as opposed to those containing *S. alternifolia*, characterized by decreases in nitrogen and increases in sulfur (Weinstein, 2009). The sedimentation of marsh substrates also increased, while soil salinities were lower, compared to marshes that did not contain Common Reed (Warren et al., 2001; Weinstein et al., 2009). The richness of native species in Common Reed dominated marshes was reduced, as there were observed to be less fish species, avian species, and muskrats within 13 U.S. states studied (Kiviat, 2013). It was also found that there were less fiddler crabs in these marshes (Fell et al., 2003). However, in the Connecticut River, samples showed that there was an increase in shrimp species within the Common Reed marshes (Fell et al., 2003). There was found to be a disruption to spawning in these marshes, as nekton were not able to access areas of the marsh that had become overly dense, where they would usually be able to lay their eggs (Weinstein and Balletto, 1999). The overall food web in infected marshes was greatly impacted as compositions and abundances of species declined, as seen in the Hackensack Meadowlands where there was a large decline in the availability of prey for larval and juvenile fishes (Raichel et al., 2003). There was one study that suggested that Common Reed could have an affect on the genetics of native species, but not enough evidence was given to support this.

Discussion

A review of the existing literature on the impacts of the invasion of European Common Reed indicated that the most common impact was a reduction of the abundance of native fishes, especially Mummichog in eastern North America. Other documented impacts included a decrease in native wetland plant abundance and composition, lowered water availability, a decrease in water temperature, a change in water chemistry and nutrient cycling, altered substrate, a decrease in native species composition, effects to fish reproduction and spawning, and changes in the overall food web as species become more or less abundant in the invaded habitat. These ecological impacts suggest that *P. australis* has a measurable and diverse effect on its invaded ecosystems.

The invasion of *P. australis* had impacts on a range of species and functions, some being more affected than others. The Mummichog killifish had the most noted reaction to the establishment of Common Reed, as the abundance of larval and juvenile Mummichog decreased greatly. These observations occurred through the eastern and northern states of the U.S. Within the Great Lakes basin there are two species of fish in the same genus as the Mummichog that may be expected to have similar ecological responses. Banded Killifish (*Fundulus diaphanus*) can be found in habitats similar to Mummichog, (Fritz and Garside, 1975) and the Blackstripe Topminnow (*Fundulus notatus*), which is a species listed under the federal *Species at Risk Act*, is also found in streams in which Common Reed may or may have already invaded (Welsh et al., 2013). Both of these species could be expected to experience similar declines in larval and juvenile abundance as Mummichog, in a case of *P. australis* introduction, due to similar life history. The Banded Killifish and other small fishes often stay in shallow water year-round (Lane et al., 1996). If Common Reed invades the rivers and lakes that these fishes are established within, there is a chance that the Banded Killifish and Blackstripe Topminnow would be negatively affected (Lane et al., 1996).

As Common Reed spreads through new wetlands, it replaces native plants along the way, lowering their abundance and reducing richness (Raichel et al., 2003). The lowered diversity of native plants can impact fishes and other native wetland species that use these plants as habitat or spawning grounds. It is harder for reproduction to take place as larger areas of water are reduced to shallow puddles (Able et al., 2003). Common Reed falls over onto the water surface, reducing light availability and lowering the temperature of the water in the infected areas (Able et al., 2003). This creates a problem as Common Reed often grows as a monoculture, and the stems are taller than those of native species, which causes them to block openings to water bodies (Able et al., 2003). The fallen plants also reduce the flow and availability of the water in creeks and rivers, making it difficult for nutrients to travel to different parts of the wetlands, and creating less habitat space for larval and juvenile species within these water bodies (Warren et al., 2001; Able et al., 2003). It was also found that the levels of nitrogen had decreased within marshes dominated by Common Reed, while levels of sulfur had increased (Weinstein et al., 2009). Thus the native wetland plants are also affected by the lowered soil salinity (Warren et al., 2001) and increased sedimentation (Able et al., 2003).

The composition of native wetland species has changed in wetlands where the Common Reed has become more dominant (Raichel et al., 2003). There has been a lower abundance of insects that are most often prey for larval and juvenile fish, making it more difficult for these fish to survive in a Common Reed dominated wetland, as surveyed in the Hackensack Meadowlands of New Jersey (Raichel et al., 2003). There was also a lower abundance of fiddler crabs (*Uca sp.*) which can result in less prey for some species, and an increase in the species previously preyed upon by the crabs (Fell et al., 2003). There was a higher abundance of shrimp species documented in these marshes as well, which could compete with native species for the limited prey available (Fell et al., 2003). Less avian species were found using these marshes which could be caused by the lack of available surface water and could cause the prey of these species to grow less in number (Raichel et al., 2003).

The invasive cattail hybrid (*Typha x glauca*) has been documented to replace the native broadleaf cattail (*Typha latifolia*) and the non-native, but also non-harmful narrow-leaved cattail (*Typha angustifolia*), in coastal marshes around the Great Lakes (Farrer and Goldberg, 2009). However, Common Reed has been documented to replace this cattail hybrid and could therefore be expected to change many areas used as fish habitat, as native cattail species grow in areas with little plant litter (Bellavance and Brisson, 2010), while the stems of Common Reed often fall over, creating large amounts of litter built up on the water surface (Able et al., 2003).

Conclusion

This review of literature pertaining to the impacts of the invasive European Common Reed (*Phragmites australis*) documented negative effects on native fish and fish habitat. The most common impacts were decreased abundance of native fishes. Common Reed also lowered the abundance and richness of native wetland plants, decreased water availability, lowered water temperatures, altered water chemistry and nutrient cycling, affected wetland substrate, decreased the composition of native wetland fishes and other species, altered fish reproduction and spawning, and affected the overall food web. These results provide critical information on how European Common Reed impacts the environments that it invades. Although the ecological impacts of invasive species are usually context dependent, the common impacts documented throughout the invaded range indicates that similar impacts may be expected throughout the Great Lakes basin as the species expands its range within coastal wetlands.

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Abbreviations

Abbreviation	Full Form
P. australis	*Phragmites australis*

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References

1. Mooney, H. Cleland, E. The evolutionary impact of invasive species. *PNAS* [online] **2001**, *98*, 5446-5451 http://www.life.illinois.edu/ib/451/Mooney%20(2001).pdf (Accessed April 20, 2018)

2. Smith, K. et al. Reducing the Risks of Wildlife Trade. *Science Magazine* [online] **2009**, *324*, 594-595 http://www.ogrod.uw.edu.pl/__data/assets/pdf_file/0013/2155/1b.pdf (Accessed June 20, 2017)

3. Ricciardi, A. MacIsaac, H. Recent mass invasion of the North American Great Lakes by Ponto–Caspian species. *Tree* [online] **2000**, 15, 62-65 https://www.researchgate.net/profile/Anthony_Ricciardi/publication/250923455_Recent_mass_invasion_of_the_North_American_Great_Lake_by_Ponto-Caspian_species/links/00b4951ee1552ed0fa000000/Recent-mass-invasion-of-the-North-American-Great-Lake-by-Ponto-Caspian-species.pdf (Accessed July 6, 2017)

4. Christie, G. Goddard, C. Sea Lamprey International Symposium (SLIS II): Advances in the Integrated Management of Sea Lamprey in the Great Lakes. *Journal of Great Lakes Research* [online] **2003**, *29*, 1-14. http://www.reabic.net/publ/Christie_et%20al_2003_Petromyzon%20marinus.pdf (Accessed April 8, 2017)

5. Lavrentyev, P. et al. Effects of the Zebra Mussel (*Dreissena polymorpha* Pallas) on Protozoa and Phytoplankton from Saginaw Bay, Lake Huron. *Journal of Great Lakes Research* [online] **1995**, *21*, 545-557. https://www.glerl.noaa.gov/pubs/fulltext/1995/19950015.pdf (Accessed April 7, 2017)

6. Chotkowski, M. Marsden, J. Round Goby and Mottled Sculpin Predation on Lake Trout Eggs and Fry: Field Predictions from Laboratory Experiments. *Journal of Great Lakes Research* [online] **1999**, *25*, 26-35. http://www.reabic.net/publ/Chotkowski_et%20al_1999_Neogobius%20melanostomus.pdf (Accessed April 8, 2017)

7. Leung, B. et al. An Ounce of Prevention or a Pound of Cure: Bioeconomic Risk Analysis of Invasive Species. *The Royal Society* [online] **2002**, *269*, 2407-2413. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1691180/pdf/12495482.pdf (Accessed April 8, 2017)

8. Wilcox, K. et al. Historical Distribution and Abundance of *Phragmites australis* at Long Point, Lake Erie, Ontario. *Journal of Great Lakes Research* [online] **2003**, *29*, 664-680. https://www.researchgate.net/profile/Scott_Petrie/publication/228435384_Historical_Distribution_and_Abundance_of_Phragmites_australis_at_Long_Point_Lake_Erie_Ontario/links/00b7d5273d5236e9a3000000/Historical-Distribution-and-Abundance-of-Phragmites-australis-at-Long-Point-Lake-Erie-Ontario.pdf (Accessed April 8, 2017)

9. Able, K. Hagan, S. Impact of Common Reed *Phragmites australis*, on Essential Fish Habitat: Influence on Reproduction, Embryological Development, and Larval Abundance of Mummichog (*Fundulus heteroclitus*). *Estuaries* [online] **2003**, *26*, 40-50. https://marine.rutgers.edu/pubs/private/141.pdf (Accessed April 4, 2017)

10. Raichel, D. Able, K. Hartman, J. The Influence of *Phragmites* (Common Reed) on the Distribution, Abundance, and Potential Prey of a Resident Marsh Fish in the Hackensack Meadowlands, New Jersey. *Estuaries* [online] **2003**, *26*, 511-521. https://marine.rutgers.edu/pubs/private/151.pdf (Accessed April 5, 2017)

11. Warren, R. et al. Rates, Patterns, and Impacts of *Phragmites australis* Expansion and Effects of Experimental *Phragmites* Control on Vegetation, Macroinvertebrates, and Fish Within Tidelands of the Lower Connecticut River. *Estuaries* [online] **2001**, *24*, 90-107. https://www.researchgate.net/profile/R_Warren/publication/251355678_Rates_Patterns_and_Impacts_of_Phragmites_australis_Expansion_and_Effects_of_Experimental_Phragmites_Control_on_Vegetation_Macroinvertebrates_and_Fish_within_Tidelands_of_the_Lower_Connecticut_River/links/53ebd0c90cf250c8947c7619.pdf (Accessed April 5, 2017)

12. Able, K. Hagan, S. Brown, S. Mechanisms of Marsh Habitat Alteration Due to *Phragmites*: Response of Young-of-the-year Mummichog (*Fundulus herteroclitus*) to Treatment for *Phragmites* Removal. *Estuaries* [online] **2003**, *26*, 484-494. https://marine.rutgers.edu/pubs/private/149.pdf (Accessed April 5, 2017)

13. Weinstein, M. Litvin, S. Guida, V. Essential Fish Habitat and Wetland Restoration Success: A Tier III Approach to the Biochemical Condition of Common Mummichog *Fundulus herteroclitus* in Common Reed *Phragmites australis*- and Smooth Cordgrass *Spartina alterniflora*- Dominated Salt Marshes. *Estuaries* [online] **2009**. http://www.montclair.edu/profilepages/media/1992/user/FundulusTierIII.pdf (Accessed April 5, 2017)

14. Kiviat, E. Ecosystem services of *Phragmites* in North America with emphasis on habitat functions. *AoB Plant* [online] **2013**, *5*. https://academic.oup.com/aobpla/article/doi/10.1093/aobpla/plt008/160281/Ecosystem-services-of-Phragmites-in-North-America (Accessed April 5, 2017)

15. Fell, P. et al. Comparison of Fish and Macroinvertebrate Use of *Typha angustifolia*, *Phragmites australis*, and Treated *Phragmites* Marshes along the Lower Connecticut River. *Estuaries* [online] **2003**, *26*, 534-551. https://www.researchgate.net/profile/R_Warren/publication/248117313_Comparison_of_fish_and_macroinvertebrate_use_of_Typha_angustifolia_Phragmites_australis_and_treated_Phragmites_marshes_along_the_lower_Connecticut_River/links/53ebd08f0cf24f241f1534c6.pdf (Accessed April 5, 2017)

16. Weinstein, M. Balletto, J. Does the Common Reed, *Phragmites australis*, Affect Essential Fish Habitat?. *Estuaries* [online] **1999**, *22*, 793-802. https://www.researchgate.net/profile/Michael_Weinstein7/publication/225637146_Does_the_Common_Reed_Phragmites_australis_Affect_Essential_Fish_Habitat/links/545b6db70cf28779a4dd3ec3.pdf (Accessed April 5, 2017)

17. Hagan, S. Brown, S. Able, K. Production of Mummichog (*Fundulus hereroclitus*): Response in Marshes Treated for Common Reed (*Phragmites australis*) Removal. *Wetlands* [online] **2007**, *27*, 54-67. https://marine.rutgers.edu/pubs/private/182.pdf (Accessed April 5, 2017)

18. Fritz, E. Garside, E. Comparison of age composition, growth, and fecundity between two populations each of *Fundulus heteroclitus* and *F. diaphanus* (Pisces: Cyprinodontidae). *Canadian Journal of Zoology* [online] **1975**, *53(4)*, 361-369. http://www.nrcresearchpress.com/doi/pdf/10.1139/z75-047 (Accessed June 20, 2017)

19. Welsh, D. et al. The effects of age, sex, and habitat on body size and shape of the blackstripe topminnow, *Fundulus notatus*, (Cyprinodontiformes: Fundulidae)(Rafinesque 1820). *Biological Journal of the Linnean Society* [online] **2013**, *108(4)*, 784-789. https://academic.oup.com/biolinnean/article/108/4/784/2415769 (Accessed June 20, 2017)

20. Lane, J. Portt, C. Minns, C. Nursery Habitat Characteristics of Great Lakes Fishes. *Canadian Manuscript Report of Fisheries and Aquatic Sciences* [online] **1996**, *2338*. https://www.researchgate.net/profile/Charles_Minns/publication/253563110_Nursery_Habitat_Characteristics_of_Great_Lakes_Fishes/links/00b4952a9d8d441392000000.pdf (Accessed June 20, 2017)

21. Aday, D. The Presence of and Invasive Macrophyte (*Phragmites australis*) Does not Influence Juvenile Fish Habitat Use in a Freshwater Estuary. *Journal of Freshwater Ecology* [online] **2007**, *22*, 535-537. http://www.tandfonline.com/doi/pdf/10.1080/02705060.2007.9664185 (Accessed April 5, 2017)

22. Amsberry, L. et al. Clonal Integration and the Expansion of *Phragmites australis*. *Ecological Applications* [online] **2000**, *10(4)*, 1110-1118. https://www.researchgate.net/profile/Mark_Bertness/publication/240777645_Clonal_Integration_and_the_Expansion_of_Phragmites_australis/links/5534dde30cf2df9ea6a3ebfc.pdf (Accessed May 3, 2017)

23. Angradi, T. Hagan, S. Able, K. Vegetation Type and the Intertidal Macroinvertebrate Fauna of a Brackish Marsh: *Phragmites* vs. *Spartina*. *Wetlands* [online] **2001**, *21*, 75-92. https://marine.rutgers.edu/pubs/private/117.pdf (Accessed April 5, 2017)

24. Bonanno, G. Giudice, R. Heavy metal bioaccumulation by the organs of *Phragmites australis* (common reed) and their potential use as contamination indicators. *Ecological Indicators* [online] **2009**, *10*, 639-645. https://www.researchgate.net/profile/Giuseppe_Bonanno/publication/248412865_Heavy_Metal_Bioaccumulation_by_the_Organs_of_Phragmites_Australis_Common_Reed_and_Their_Potential_Use_as_Contamination_Indicators/links/550a68cd0cf26198a63ab17d.pdf (Accessed May 3, 2017)

25. Chambers, R. et al. *Phragmites australis* Invasion and Expansion in Tidal Wetlands: Interactions among Salinity, Sulfide, and Hydrology. *Estuaries* [online] **2003**, *26*, 398-406. https://www.researchgate.net/profile/David_Osgood2/publication/225528969_Phragmites_australis_invasion_and_expansion_in_tidal_wetlands_Interactions_among_salinity_sulfide_and_hydrology/links/56e9a0cb08ae3a5b48cc82db.pdf (Accesed May 3, 2017)

DOI: 10.13034/jsst.v11i1.294

26. Chambers, R. Meyerson, L. Saltonstall, K. Expansion of *Phragmites australis* into tidal wetlands of North America. *Aquatic Botany* [online] **1999**, *64*, 261-273. https://www.researchgate.net/profile/Laura_Meyerson/publication/222445868_Expansion_of_Phragmites_australis_into_tidal_wetlands_of_North_America/links/0912f50bfad0e7063e000000/Expansion-of-Phragmites-australis-into-tidal-wetlands-of-North-America.pdf (Accessed April 5, 2017)

27. Gratton, C. Denno, R. Restoration of Arthropod Assemblages in a *Spartina* Salt Marsh following Removal of the Invasive Plant *Phragmites australis*. *Restoration Ecology* [online] **2005**, *13(2)*, 358-372. http://144.92.199.81/wp-content/uploads/2012/01/16.-Gratton-and-Denno-2005-Restoration-Ecology-Arthropod-FW-in-invaded-wetlands.pdf (Accessed May 3, 2017)

28. Hanson, S. Osgood, D. Yozzo D. Nekton Use of a *Phragmites australis* Marsh on the Hudson River, New York, USA. *Wetlands* [online] **2002**, *22*, 326-337. https://www.researchgate.net/profile/David_Yozzo/publication/225586716_Nekton_use_of_a_Phragmites_australis_marsh_on_the_Hudson_River_New_York_USA/links/57bc7fb908ae3fbb8643ff56.pdf (Accessed May 3, 2017)

29. Posey, M. et al. Benthic communities of common reed *Phragmites australis* and marsh cordgrass *Spartina alterniflora* marshes in Chesapeake Bay. *Marine Ecology Progress Series* [online] **2003**, *261*, 51-61. http://www.int-res.com/articles/meps2003/261/m261p051.pdf (Accessed May 3, 2017)

30. Vasquez, E. et al. Salt tolerance underlies the cryptic invasion of North American salt marshes by an introduced haplotype of the common reed *Phragmites australis* (Poaceae). *Marine Ecology Progress Series* [online] **2005**, *298*, 1-8. http://www.int-res.com/articles/feature/m298p001.pdf (Accessed May 3, 2017)

31. Wainwright, S. et al. Relative importance of benthic microalgae, phytoplankton and the detritus of smooth cordgrass *Spartina alterniflora* and the common reed *Phragmites australis* to brackish-marsh food webs. *Marine Ecology Progress Series* [online] **2000**, *200*, 77-91. https://www.researchgate.net/profile/Michael_Weinstein7/publication/240809113_Relative_importance_of_benthic_microalgae_phytoplankton_and_the_detritus_of_smooth_cordgrass_Spartina_alterniflora_and_the_common_reed_Phragmites_australis_to_brackish-marsh_food_webs/links/54e4f5a40cf22703d5bfe8f1/Relative-importance-of-benthic-microalgae-phytoplankton-and-the-detritus-of-smooth-cordgrass-Spartina-alterniflora-and-the-common-reed-Phragmites--australis-to-brackish-marsh-food-webs.pdf (Accessed May 2, 2017)

32. Weis, J. Weis, P. Is the invasion of the common reed, *Phragmites australis*, into tidal marshes of the eastern US an ecological disaster?. *Marine Pollution Bulletin* [online] **2003**, *46*, 816-820. https://www.researchgate.net/profile/Judith_Weis/publication/10682051_Is_the_invasion_of_the_common_reed_Phragmites_australis_into_tidal_marshes_of_the_eastern_US_an_ecological_disaster/links/5535acc40cf268fd0015e35a.pdf (Accessed April 5, 2017)

33. Farrer, E. Goldberg, D. Litter drives ecosystem and plant community changes in cattail invasion. *Ecological Applications* [online] **2009**, *19(2)*, 398-412 https://deepblue.lib.umich.edu/bitstream/handle/2027.42/116913/eap2009192398.pdf?sequence=1&isAllowed=y (Accessed April 30, 2018)

34. Bellavance, M. Brisson, J. Spatial dynamics and morphological plasticity of common reed (*Phragmites australis*) and cattails (*Typha sp.*) in freshwater marshes and roadside ditches. *Aquatic Botany* [online] **2010**, *93*, 129-134 https://www.phragmites.crad.ulaval.ca/files/phragmites/Bellavance_Brisson.pdf (Accessed April 30, 2018)

DOI: 10.13034/jsst.v11i1.294