Aquatic Botany 136 (2017) 112–137

Contents lists available at ScienceDirect

Aquatic Botany

journal homepage: www.elsevier.com/locate/aquabot

Review

Management and control methods of invasive alien freshwater aquatic plants: A review

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ARTICLE INFO

Article history:
Received 27 April 2016
Received in revised form 2 August 2016
Accepted 2 August 2016
Available online 23 September 2016

Keywords:
Biological control
Chemical control
Eradication
Early detection
EU regulation 1143/2014
Macrophyte
Management costs
Mechanical control
Rapid control

ABSTRACT

Introduced invasive alien aquatic plants (IAAPs) threaten ecosystems due to their excessive growth and have both ecological and economic impacts. To minimize these impacts, effective management of IAAPs is required according to national or international laws and regulations (e.g. the new EU regulation 1143/2014). Prevention of the introduction of IAAPs is considered the most cost effective management option. If/when prevention fails, early detection and rapid response increases the likelihood of eradication of the IAAPs and can minimize on-going management costs. For effective weed control (eradication and/or reduction), a variety of management techniques may be used. The goal or outcome of management interventions may vary depending on the site (i.e. a single waterbody, or a region with multiple waterbodies) and the feasibility of achieving the goal with the tools or methods available. Broadly defined management goals fall into three different categories of, containment, reduction or nuisance control and eradication. Management of IAAP utilises a range of control methods, either alone or in combination, to achieve a successful outcome. Here we review the biological, chemical and mechanical control methods for IAAPs, with a focus on the temperate and subtropical regions of the world and provide a management diagram illustrating the relationships between the state of the ecosystem, the management goals, outcomes and tools.

Contents

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http://dx.doi.org/10.1016/j.aquabot.2016.08.002
0304-3770/

1. Introduction

Aquatic plants play an important role in the functioning of aquatic ecosystems (Jeppesen and Sondergaard, 1998). However, introduced invasive alien aquatic plants (IAAPs) may threaten ecosystems due to their excessive growth and have both ecological and economic impacts (Getsinger et al., 2014; Brundu, 2015). Ecologically, they change the macrophyte community composition (Santos et al., 2011; Hussner, 2014), modify macroinvertebrate species richness and abundance (Stiers et al., 2011), deplete oxygen (Shillinglaw, 1981) and alter the food web structure (Villamagna and Murphy, 2010). Moreover, dense macrophyte stands can increase the flood risk by impeding river flow (Holm et al., 1969; Wilcock et al., 1999; Thouvenot et al., 2013), hinder shipping and navigation (Holm et al., 1969) and impair recreational water sports activities, which decreases the value of lakefront property (Halstead et al., 2003). Furthermore, IAAPs clog hydropower dams, which reduces hydropower generation (Clayton and Champion, 2006), and they reduce the water flow and availability in irrigation and drainage systems (Holm et al., 1969).

Due to their potential for large scale negative impacts, IAAP risk assessments have been carried out in numerous countries and several species are now subject to management and control (Table 1). The European parliament adopted a regulation on invasive species (Reg. EU no. 1143/2014), which came into effect on the 1st of January 2015 and regulates the introduction and management of IAAPs in Europe, with the aim of rapid eradication of populations already present and prevention of future invasions (Genovesi et al., 2015). In addition to this EU regulation, the management of IAAPs in general is receiving increased attention, but as yet a comprehensive review of management methods for IAAPs is lacking. Recent guides for the management of IAAPs are focused in specific countries (e.g. for New Zealand: De Winton et al., 2013; for the US: Gettys et al., 2014). In this paper, we examine and review the spectra of control methods for IAAPs to guide management decision making, reviewing management experiences from different parts of the world, with a focus on freshwater bodies in the temperate and subtropical regions.

1.1. The crucial role of aquatic vegetation for ecosystem functioning

Whereas IAAPs can be perceived as a threat, generally freshwater macrophytes are appreciated for their major structuring role in shallow aquatic ecosystems (Scheffer et al., 2001; Burks et al., 2006). Native, multispecies macrophyte beds provide habitats that support biodiversity within aquatic systems and macrophytes perform important ecosystem functions, including nutrient retention, enhancing water clarity by trapping sediment (Cotton et al., 2006; Horppila and Nurminen, 2003; Wang et al., 2015), inhibiting algal blooms (Gross, 2003),providing food for herbivores (Carpenter and Lodge, 1986; Van Donk and Van de Bund, 2002; Bakker et al., 2010; Declerck et al., 2011; Massicotte et al., 2015) and habitat for fish (Jeppesen and Sondergaard, 1998). In principle some of these benefits of macrophytes could also be provided by invasive macrophytes (Grutters et al., 2015a,b). Therefore, depending on the ecosystem