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RESEARCH PAPER OPEN ACCESS

Mislabelling may explain why some prohibited invasive aquatic plants are still being sold in Belgium

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Abstract – In Belgium, a voluntary code of conduct intended to prevent introduction of invasive plants through the horticultural trade has been implemented since 2009. European Regulation 1143/2014 that imposes legal bans on a number of plant taxa entered into force in 2015. However, studies regarding the presence of invasive plants in the Belgian horticultural trade remained scarce. In 2016–2017 and in 2020, we surveyed a total of 11 garden centres specialized in water gardening and compiled a list of 285 aquatic plant taxa that were being traded. In 2020, four Belgian Consensus List species and one Communication List species were still offered for sale. Also, three species of Union Concern were still being sold in 2020. The plants of the Belgian Lists that were still being sold in 2020 and all except one of the European Union List plants were mislabelled, either because of misidentification or because a taxonomic synonym was used. Mislabelling may explain why some prohibited plants were still in trade. Therefore, retailers and plant producers should be encouraged to correctly identify the plants that are being traded. Our study illustrates that regular surveys are essential to assess the effectiveness of voluntary codes of conduct and legal trade bans.

Keywords: Mislabelling of aquatic plants / water gardening trade Belgium / Consensus List / Communication List / European Union List

1 Introduction

The worldwide aquarium and water gardening trade is a major mechanism of introduction and spread of non-native aquatic plants (Reichard and White, 2001; Keller and Lodge, 2007; Nunes *et al.*, 2015; Peres *et al.*, 2018). Numerous non-native aquatic plants have become invasive and several are known to have harmful effects on native ecosystems. Once established, aquatic invasive plants are often difficult to remove (Francis, 2012). This has urged scientists and legislators to work out measures to prevent introduction or further spread. Such preventive measures often include voluntary codes of conduct, adopted by horticulture professionals, gardeners and their sector federations or associations. The aim of such codes is the voluntary removal of target species from trade, to encourage awareness of risks associated with alien plants and to induce behavioural changes among stakeholders involved in sectors linked to the introduction of alien species (Dehnen-Schmutz and Touza, 2008). Lists of species with documented invasiveness (blacklists) are key to drafting such codes of conduct (Reichard and White, 2001; Reichard, 2004; Heywood and Brunel, 2008; Hulme *et al.*, 2008; Barbier *et al.*, 2013). The compilation of effective codes of conduct and legal trade bans requires accurate lists of taxa in the ornamental plant trade. Likewise, risk assessments and alien species prioritization processes require accurate information on the presence and frequency of non-native species in trade. Reliable lists of traded taxa enable scientists and legislators to derive information about the potential introduction routes of non-native species and are a crucial first step in estimating propagule pressure and developing risk assessment models (Dehnen-Schmutz and Touza, 2008; Brunel, 2009; Wilson *et al.*, 2009; Roy *et al.*, 2017). Furthermore, monitoring schemes intended to assess whether retailers comply with voluntary or legally-binding agreements regarding the sale of non-native and potentially invasive species also require accurate lists of traded taxa. Therefore, significant efforts are continuously being made to document plants valued as ornamentals by aquarium enthusiasts and water gardeners (Kay and Hoyle, 2001; Brunel, 2009; June-Wells *et al.*, 2012; Peres *et al.*, 2018), as well as stowaway plants unintentionally included with plants intended for sale (Maki and Galatowitsch, 2004).

The correct identification of plants provides a major challenge for scientists and government officials tasked with monitoring the aquarium and water gardening trade.

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Identification of plants based on morphological features alone can be difficult. Plants can lack the typical flower charateristics necessary for identification when they are sold outside the flowering season or when offered as seedlings. Also, different species can be very similar in appearance and sometimes non-native species strongly resemble native species. Therefore, the identity of morphologically similar species often needs to be verified with molecular techniques (Moody *et al.*, 2008; June-Wells *et al.*, 2012; Thum *et al.*, 2012; Ghahramanzadeh *et al.*, 2013). Identification becomes even more complex when hybrid taxa are being sold, because hybrids can strongly resemble one of their parent taxa (LaRue *et al.*, 2013). Moreover, identification keys for hybrids are scarce. Several studies report the misidentification or mislabelling of invasive species in the aquarium and water gardening trade, which could lead to the release or escape of blacklisted taxa (Maki and Galatowitsch, 2004; Moody *et al.*, 2008; Brunel, 2009; June-Wells *et al.*, 2012; Thum *et al.*, 2012; Yakandawala *et al.*, 2013).

In NW-Europe, the problem of aquatic invasive plants being sold as ornamentals has been widely acknowledged. Several NW-European countries have taken measures in order to reduce the introduction risk or further spread of aquatic invasive species through the horticultural trade. In the Netherlands, for instance, a code of conduct intended to prevent the introduction and spread of invasive plants became effective in 2011 (Verbrugge *et al.*, 2014). It included a blacklist of seven aquatic species and a watch list with seven more taxa. Awareness campaigns were launched in 2010 and 2011 by the Dutch government and their effectiveness has subsequently been assessed, as well as the compliance of retailers and plant producers with the code of conduct. The Dutch code of conduct drastically reduced the number of blacklisted aquatic plants being sold, despite a limited success of the public awareness campaigns (Verbrugge *et al.*, 2014). Several plants of the watch list, however, remained widely available and were often mislabelled (Ghahramanzadeh *et al.*, 2013; Verbrugge *et al.*, 2014).

Belgium adopted a similar preventive approach to reduce the number of invasive plant introductions, primarily based on an awareness campaign. A Belgian code of conduct targeting both terrestrial and aquatic invasive plants has been implemented in 2009 within the framework of the LIFE+ programme AlterIAS (Alternatives to Invasive Alien Species) (2010–2013), which aimed at raising awareness regarding plant invasions among horticulture professionals and gardeners. The Belgian code is a voluntary agreement intended to stop the sale of high impact species on a Consensus List drafted in consultation with the sector (Halford *et al.*, 2011a,b; 2014a,b). Twenty eight non-native plants were listed on the Consensus List (Halford *et al.*, 2011b), for which ecological impact assessments provided an evidence base (ias.biodiversity.be; Branquart, 2011; Vanderhoeven *et al.*, 2015). Eight plants of the Belgian Consensus List were categorized as aquatic, while at least three of the twenty terrestrial plants can be regarded as riparian or palustrine, suitable for marginal zones of garden ponds (Halford *et al.*, 2011b). The Belgian code also includes a Communication List, containing four strictly aquatic species and at least one plant that can be categorized as a palustrine species, for which caution is advised (Halford *et al.*, 2011b). However, information about the availability of aquatic plants in the Belgian horticultural trade is limited. In 2006, some information regarding the sale of invasive aquatic plants was obtained through a questionnaire (Vanderhoeven *et al.*, 2011; 2015). A baseline study, intended to quantify the presence and economic value of invasive non-native plants within the Belgian horticultural market, was carried out in 2010, but focussed primarily on terrestrial plants. Moreover, this study did not include visits to garden centres or plant nurseries. Instead, the surveys were limited to plant catalogues provided by retailers (Halford *et al.*, 2011a; 2014a,b). Similarly, a follow-up study carried out in 2013 evaluated changes in awareness and perception of the Belgian code of conduct, but did not include surveys to assess compliance with the code (Halford *et al.*, 2013; 2014a,b). Consequently, it is unknown to what extent invasive aquatic plants of the Consensus and Communication Lists are still for sale in Belgian water gardening centres and if plant names on labels provided by retailers or their plant producers are correct. Since January 1st 2015, the European Regulation (EU) 1143/2014 intended to prevent introduction and spread of invasive species became effective (European Parliament, Council of the European Union, 2014). At the heart of this European Regulation is a list of invasive alien species of Union Concern. An initial list entered into force on August 3rd 2016 and comprised 14 plants (European Commission, 2016). A first update of the Union List entered into force on August 2nd 2017 and included an additional nine plant taxa (European Commission, Directorate-General for Environment, 2017). A second update became effective on August 15th 2019 and added another 13 plant species to the Union List (European Commission, Directorate-General for Environment, 2019). The current list of 36 plants of Union Concern comprises at least 14 species that can be regarded as strictly aquatic, riparian or palustrine, suitable for garden ponds. The European Regulation imposes restrictions regarding trade in and possession of Union List species. However, Article 32 of the Regulation does allow the sale of Union List species to non-commercial users for up to one year after their inclusion on the Union List (European Parliament, Council of the European Union, 2014). Because of the lack of surveys, it is unknown to what extent Belgian retailers comply with the restrictions set out in the EU Regulation and if they made use of the transition period during which it was allowed to deplete commercial stocks of invasive plants of the Union List.

The aim of our study was to fill knowledge gaps regarding the presence of aquatic plants on the Belgian market and to investigate to what extent it was feasible to correctly identify these plants based on morphological features. We focussed our study on the Belgian water gardening trade, because plants intended for outdoor ponds are more likely to be cold-hardy than plants of subtropical or tropical origin sold in the aquarium trade. Non-native aquatic plants already adapted to a cool temperate climate have a higher probability of becoming established in Belgium and elsewhere in NW-Europe (Dullinger *et al.*, 2017), although climatic niche shifts can occur in plants introduced outside their native range (Wang *et al.*, 2017). The specific objectives of our study were (1) to compile a list of aquatic ornamental plants offered for sale in the Belgian water gardening trade, including cultivars and hybrids, and (2) to assess whether the plant names on the labels provided by retailers and plant producers were correct and up-to-date. We also investigated (3) whether water gardening

centres offered (potentially) invasive taxa included in the Consensus List and the Communication List of the Belgian code of conduct or in the European list of Union Concern. (4) Lastly, we checked for the presence of non-native stowaway plants in display trays.

2 Materials and methods

We surveyed a total of 11 Belgian garden centres specialized in selling water gardening items, five in 2016–2017 and ten in 2020. These were randomly selected from 21 specialized retailers retrieved from an internet search. The garden centres were visited between July 16th 2016 and July 5th 2017 and between July 11th and October 22nd 2020. In 2016–2017, retailer 1 was visited twice (July 16th 2016 and October 7th 2016), retailer 2 was visited three times (August 11th 2016, November 13th 2016 and July 5th 2017), retailer 3 was visited twice (August 11th 2016 and July 5th 2017) and retailers 4 and 5 were visited once (both on April 9th 2017). In 2020, retailers 2, 3, 4 and 5 were revisited and six extra garden centres were surveyed, indicated as retailers 6 to 11. All the garden centres were visited once in 2020: retailers 2, 3 and 6 on July 11th, retailers 4, 5 and 7 on October 3rd, retailer 8 on September 20th, retailer 9 on September 30th, retailer 10 on October 7th and retailer 11 on October 22nd. At each garden centre, we made lists of all aquatic, riparian and palustrine plants offered for sale. Whenever available on the labels, we also recorded information about the plant producers. We used retailer and plant producer codes to safeguard their privacy. All available plants and their labels were photographed. Occasionally, plants were purchased if identification at the retailer location or identification based on photographs proved to be difficult.

We used standard keys (Mennema, 1994; Lambinon *et al.*, 1998; Stace, 2010) and online identification tools provided by the Botanic Garden of Meise (alienplantsbelgium.be) (Verloove, 2021), Q-bank (www.q-bank.eu) (van Valkenburg *et al.*, 2013) and eFloras (www.efloras.org) (eFloras, 2021), including the Flora of North America (floranorthamerica.org) (Flora of North America Editorial Committee, 1993+) and the Flora of China (Brach and Song, 2006), to check if the plants offered for sale were identified correctly by the retailers or the plant producers. For the identification of cultivars and hybrids, we relied on the horticultural database of the Royal Horticultural Society (RHS) (apps.rhs.org.uk/horticulturaldatabase) and descriptions provided by Brickell (2016). Additionally, we used several taxon-specific pictorial keys and descriptions available on the internet. For waterlilies (*Nymphaeaceae*) we consulted the waterlily database of the International Waterlily and Water Gardening Society (IWGS) (iwgs.org), the International Waterlily Collection (IWC) (www.internationalwaterlilycollection.com), the waterlily checklist of Water Gardeners International (WGI) (www.watergardenersinternational.org) and the website of the renowned hybridizer Latour-Marliac (latour-marliac.com). Online resources consulted to validate the names on the labels of pitcher plants (*Sarraceniaceae*) included the carnivorous plant names database of the International Carnivorous Plant Society (ICPS) (www.carnivorousplants.org) and the Carnivorous Plant Photo Finder (cpphotofiner.com). For irises (Iridaceae) we consulted the Iris Encyclopedia of The American Iris Society (wiki.irises.org) and for cannas (Cannaceae) we used the Wikipedia list of *Canna* cultivars (en.wikipedia.org/wiki/List_of_Canna_cultivars) and the Royal General Bulbgrowers' Association database (www.kavb.nl).

The International Plant Names Index (www.ipni.org) and World Flora Online (www.worldfloraonline.org) were consulted to check if the nomenclature of plant species was correct and up-to-date. The databases of the RHS, the IWGS, the ICPS and the Royal General Bulbgrowers' Association were used to assess the correctness of the horticultural names for cultivars and hybrids on the labels. Plant names in these databases are generally in accordance with the International Code of Nomenclature for Cultivated Plants (Brickell *et al.*, 2016). We checked whether genus, species epithet and/or cultivar/hybrid epithet used by retailers and plant producers were complete, up-to-date and correctly spelled, in accordance with the International Code of Nomenclature for Cultivated Plants (Brickell *et al.*, 2016) or the International Code of Nomenclature for algae, fungi, and plants (Turland *et al.*, 2018). The List of Union Concern (European Commission, Directorate-General for Environment, 2019) and the Belgian Consensus and Communication Lists (Halford *et al.*, 2011b) were consulted to check if the surveyed garden centres offered (potentially) invasive taxa included on these lists. Display trays were checked for the presence of submersed and floating non-native stowaway plants. Plant pots were checked for the presence of stowaway plants included in the Belgian Consensus and Communication Lists or in the European List of Union Concern.

3 Results

3.1 General observations

285 plant taxa were offered for sale by the retailers surveyed in 2016–2017 and 2020. These comprised 161 wild type species, 51 cultivated varieties, 70 hybrids and three plants that may have been either cultivars or hybrids (Appendix 1). Waterlilies (*Nymphaeaceae*) were the most numerous, followed by sedges (*Cyperaceae*) and irises (*Iridaceae*) (Fig. 1; Appendix 1). It is possible that some plant taxa were not in stock at the time of our surveys during summer and autumn, although several early-blooming plants, such as *Cardamine pratensis* and *Fritillaria meleagris*, were still available (Appendix 1). The confidence level of identification was categorized as high for 244 plant taxa (Appendix 1). For 23 plant taxa, the confidence level of identification was categorized as medium. Their identification was more challenging, in most cases because several morphologically similar taxa exist or because their flowers are small and inconspicuous. The confidence level of identification was categorized as low for 18 taxa, because important diagnostic features were missing at the time of our surveys or if their identity needs to be verified with molecular techniques. The validation of some cultivar and hybrid names was problematic, because identification tools were scarce and some hybrids were labelled with unregistered trade names (Appendix 1). All plants were labelled as aquatic plants. The term 'aquatic plant' had clearly been used in its broadest sense (Santamaría, 2002) and comprised true submersed and

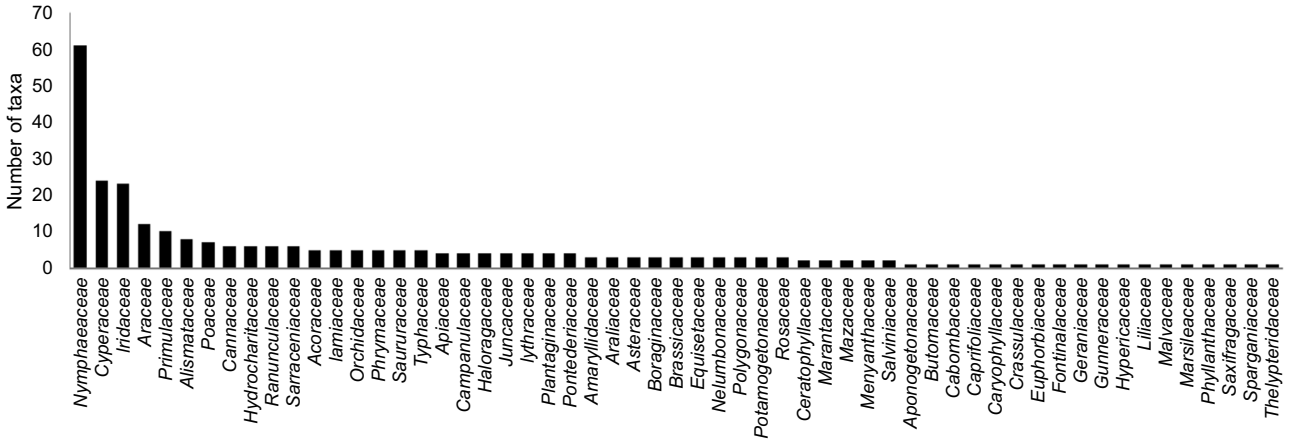

Fig. 1. Number of plant taxa per family offered for sale by the surveyed retailers.

emersed aquatic plants, floating plants, riparian plants, as well as palustrine plants adapted to grow in waterlogged substrate, although *A. italicum* could be categorized as a woodland species (Verloove, 2021) and *A. karataviense* grows on limestone scree in its natural environment (www.pacificbulbsociety.org). Plant producer 2 was the most popular plant producer and provided plants and plant labels for four out of five retailers surveyed in 2016–2017 and for nine out of ten retailers surveyed in 2020 (Appendix 1).

3.2 Mislabelling

118 plant taxa (41%) had been mislabelled, because of the use of a taxonomic synonym, an unregistered trade name or a misidentification. The labels of 16 taxa contained two or more types of mistakes, such as a combination of misidentification, misspelling and/or the use of a synonym (Appendix 2).

Misspelling was the most common cause of mislabelling (Appendix 2). 63 plant names were misspelled on the label, including the names with multiple taxonomic errors. In most cases, spelling mistakes were minor typographical errors, limited to one or two letters in the genus, the specific epithet or in the cultivar or hybrid epithet. However, sometimes misspellings were more substantial. For instance, in four cases, cultivar names were represented as hybrids (*i.e.*, the specific epithet was missing). In two other plant names the cultivar epithet was used as a specific epithet (*i.e.*, the specific epithet was missing and the cultivar epithet was not enclosed between single inverted commas). In one unresolved case, listed as *Nymphaea tetragona* 'Rubra' in Appendices 1 and 2, it is likely that the infraspecific name and the specific epithet were erroneously represented as a hybrid epithet on the labels provided by plant producer 2, both enclosed between single inverted commas. The plants were labelled *N.* 'Pygmaea Rubra', which occurs as an unchecked name in the IWGS database. However, *N.* 'Pygmaea Rubra' could be a misspelling of *N. pygmaea* 'Rubra', which according to the IWGS is a synonym of the cultivar *N. tetragona* 'Rubra'.

The use of synonyms was another common cause of mislabelling. 38 plant taxa (19 species, 17 cultivars and two hybrids) were labelled with a taxonomic synonym (Appendix 2). The synonymy of most plants was easy to trace with the help of extensive databases such as The Plant List and the IWGS database. Nonetheless, two *Sarracenia* hybrids were particularly problematic because their names appear to be unresolved. For instance, according to the ICPS, *S.* 'Stevensii' is a synonym of *S.* x *catesbaei*, which is a cross between *S. flava* and *S. purpurea*. However, a comment posted on the Carnivorous Plant Photo Finder states that the name *S.* 'Stevensii' is also used for a Dutch hybrid of uncertain parentage, possibly a cross between *S. rubra* subsp. *gulfensis* and *S. leucophylla*. Since the plants were provided by plant producer 2, based in the Netherlands, it cannot be ruled out that plants labelled as *S.* 'Stevensii' are in fact the Dutch hybrid with uncertain parentage and not the true *S.* x *catesbaei*. *S.* 'Farnhamii' is a problematic name for a cross between *S. leucophylla* and *S. rubra*, because in the RHS database this hybrid is being referred to as *S.* x *readei*. According to the ICPS database, however, *S.* x *readei* is an illegitimate name, because it is a later synonym of *S.* x *farnhamii*. We therefore retained the name *S.* 'Farnhamii' in our list. If *S.* 'Farnhamii' is valid, then the labelling by plant producer 2 is correct, apart from a minor spelling error (Appendix 2).

Twenty taxa were labelled with unregistered trade names (Appendix 2), which can be considered mislabelling if a registered cultivar or hybrid name exists or if a trade name is used instead of an accepted species name. The trade names *Canna* Pink, *C.* Red and *C.* Yellow were used for plants that most closely resembled *C.* Toucan® 'Rose', *C.* Toucan® 'Dark Orange' and *C.* Toucan® 'Yellow' respectively. These were indicated as varieties of *C. generalis* (www.provenwinners.com). However, the name *C. generalis* is rather problematic in itself, because it could refer to a synonym of *C. indica* or to *C.* x *generalis*, which is an invalidly published horticultural hybrid (Maas-van de Kamer and Maas, 2008). Hence, in the former case the cannas sold as *C.* Pink, *C.* Red and *C.* Yellow would be cultivars of *C. indica* and in the latter case they would be varieties of a complex hybrid, which consists of *C. glauca*, *C. indica*, *C. iridiflora* and *C. warscewiczii* (Patra *et al.*, 2008; WCSP, 2020). Two cultivars labelled *Nelumbo nucifera* 'white' and *N. nucifera* 'pink' were morphologically identical to *N. nucifera* 'Alba plena' and *N. nucifera* 'Rosea plena'

Table 1. Number of retailers surveyed in 2016–2017 ($N = 5$) and in 2020 ($N = 10$) selling species included in the Belgian Consensus and Communication Lists and in the European List of Union Concern. The number of retailers where these species were present as stowaways are added between brackets.

Plant species	Retailers 2016–2017	Retailers 2020	Belgian Code	European Regulation
Azolla filiculoides	3 (3)	2 (6)	Communication List	–
Cabomba caroliniana	1 (0)	1 (0)	–	3 August 2016
Crassula helmsii	1 (0)	2 (1)	Consensus List	–
Cyperus eragrostis	4 (0)	9 (2)	Consensus List	–
Egeria densa	5 (0)	5 (1)	Consensus List	–
Eichhornia crassipes	5 (0)	0 (0)	–	3 August 2016
Erythranthe guttata	3 (0)	3 (1)	Consensus List	–
Gunnera tinctoria	5 (0)	5 (0)	–	2 August 2017
Lagarosiphon major	1 (0)	0 (2)	Consensus List	3 August 2016
Lemna minuta	0 (1)	0 (9)	Communication List	–
Lysichiton americanus	3 (0)	0 (0)	Communication List	3 August 2016
Salvinia molesta	4 (0)	2 (0)	–	15 August 2019

respectively. A third *Nelumbo* cultivar labelled *N. nucifera* 'red' remains unidentified, because several similar red semi-double flowered cultivars exist. For *Mimulus* 'Bonfire', the extended hybrid epithet 'Bonfire Red' had been used on labels provided by plant producer 2. 'Bonfire Red' refers to the red flower colour of this selected clone of *M.* x *hybridus*, which is a fertile hybrid of *M. cupreus* and *M.* x *smithii* (Vallejo-Marín, 2012). Several *Nymphaea* were labelled with the unregistered names: *N.* 'Odorata Alba', *N.* 'Perry's Magnificent', *N.* 'Peter Slocum', *N.* 'Rubra punctata', *N.* 'Tropical Pink', *N.* 'Venusta' and *N.* 'Yellow Supan'. These were probably hybrids, because a species epithet was missing and the trade name was represented as a hybrid epithet, enclosed between single inverted commas, but it was not possible to find a definite match with registered hybrids. A part of the names of two other *Nymphaea* hybrids, *N.* 'Odorata Sulphurea' and *N.* 'Perry's Fire Opal', was missing. A variegated cultivar of *Lysimachia punctata* was labelled *L. variegata* and was a definite match with the registered cultivar *L. punctata* 'Alexander'. *Myriophyllum simulans* was mislabelled *M. propium* by plant producer 1. The trade name *M. brasiliensis* was used for an unidentified *Myriophyllum* species. In accordance with information provided by Q-bank, plants sold as *M. brasiliensis* should not be confused with *M. brasiliense*, since the latter is a synonym of *M. aquaticum*.

Misidentifications were rare. Only thirteen taxa had been misidentified by the retailers or the plant producers (Appendix 2). In 2016, plastic cups containing *Ceratophyllum submersum* were mislabelled *C. demersum* by plant producer 2, whereas in 2017 the plastic cups were simply labelled *Ceratophyllum*, without specific epithet. The inflorescence and leaf characteristics of available *Gunnera* showed that *G. tinctoria* was consistently misidentified as *G. manicata*, while a picture on the labels provided by plant producer 2 showed leaves, leaf stems and an inflorescence of the true *G. manicata*, as described by Sykes (1969). Orchids sold as *Dactylorhiza praetermissa* were most likely *D.* x *grandis*, a cross between *D. fuchsii* and *D. praetermissa*, based on the clustering of leaves along the lower half of the stem, up to six bract-like leaves along the stem and a compact cylindrical inflorescence with pale flowers (Stace, 2010). Plants offered as *Spiranthes cernua* 'Chadds Ford' were likely *S. cernua* 'Chadd's Ford' x *S. odorata*, based on the timing of flowering and the rounded lip of the flowers (Gravendeel, 2016). Plants sold as *Mimulus luteus* – now *Erythranthe lutea* – matched the description of *E. guttata*. Their flowers never showed red blotches on the corolla lobes and the corolla throat was always closed by two boss-like swellings on the lower lip, while *E. lutea* has one or more red blotches on the corolla and an open throat (Stace, 2010; Verloove, 2021). All surveyed retailers consistently misidentified and mislabelled *Salvinia molesta* as *S. natans*, even though the distinction between the *S. auriculata* complex – which includes *S. molesta* – and *S. natans* is fairly easy based on leaf characteristics (Verloove, 2021). Plants sold as *Vallisneria gigantea* were tentatively referred to as *Vallisneria* sp. in Appendices 1 and 2, since morphological features alone do not allow to reliably separate *Vallisneria* species (Les *et al.*, 2008). Finally, pitcher morphology and a vertical position of the operculum suggests that plants labelled *Sarracenia leucophylla* were in fact hybrids, with *S. purpurea* as one of the parent taxa. These plants most closely resembled *S.* 'Barba'. Interestingly, a genuine *S. leucophylla* was depicted on the labels provided by plant producer 2.

3.3 Taxa of the Belgian consensus and communication lists

Five species of the Belgian Consensus List – *Crassula helmsii*, *Cyperus eragrostis, Egeria densa, Erythranthe guttata* and *Lagarosiphon major* – were sold by one or more retailers during the 2016–2017 survey. However, *L. major* was no longer sold during the 2020 survey (Tab. 1; Appendix 1). *C. eragrostis* was sold as *C. alternifolius*, while the distinctive inflorescence of the former species (Verloove, 2021) was clearly depicted on the labels provided by plant producer 2. *Crassula helmsii* and *Egeria densa* were always labelled with the synonyms *C. recurva* and *Elodea densa* respectively. As mentioned earlier, *Erythranthe guttata* was mislabelled as *Mimulus luteus*. Two species of the Belgian Communication List – *Azolla filiculoides* and *Lysichiton americanus* – were available, although the latter was only found during the 2016–

2017 survey. *Azolla filiculoides* had been consistently mislabelled *A. caroliniana*, which is a taxonomic synonym (Evrard and Van Hove, 2004). Only *A. filiculoides* has thus far been reported from Belgium, but it should be noted that *Azolla* species are difficult to identify based on morphological features (Verloove, 2021). Therefore, the presence of similar species such as *A. cristata* cannot be excluded. *Azolla cristata* has been collected in Italy and the name *A. caroliniana* has also been used for *A. cristata* in the past (Lastrucci *et al.*, 2019). None of the hybrids offered for sale were derived from Consensus or Communication List species.

3.4 Taxa of the European Union List

Six species of the European Union List (European Commission, Directorate-General for Environment, 2019) – *Cabomba caroliniana*, *Eichhornia crassipes*, *Gunnera tinctoria*, *Lagarosiphon major*, *Lysichiton americanus* and *Salvinia molesta* – were offered for sale at one or more retailers during the 2016–2017 survey, although within a transition period that allowed retailers to sell their old stock. During the 2020 surveys, however, only *C. caroliniana, G. tinctoria* and *S. molesta* were still being sold by the surveyed retailers (Tab. 1; Appendix 1). *Eichhornia crassipes* and the aforementioned *L. americanus* were labelled correctly, whereas *C. caroliniana* was labelled correctly in 2016, but in 2017 the specific epithet was missing. *Lagarosiphon major* was always labelled with the synonym *Elodea crispa*. As mentioned earlier, *Gunnera tinctoria* was consistently misidentified as *G. manicata* and *Salvinia molesta* was always misidentified as *S. natans*. None of the hybrids offered for sale were derived from European Union List species.

3.5 Stowaway plants

During the survey in 2016–2017, six stowaway species were recorded in display trays at the surveyed retailers, including the native *Lemna minor*, *L. trisulca* and *Spirodela polyrhiza* and the non-native *Azolla filiculoides*, *Egeria najas* and *L. minuta*. *A. filiculoides* and *L. minuta* are on the Belgian Communication List (Tab. 1). *Lemna minor* was found at all retailers, while *L. minuta* and *L. trisulca* were only recorded at retailers 1 and 2 respectively. *S. polyrhiza* was observed in display trays at retailers 2, 3 and 4. *E. najas* was found only at retailer 4. *A. filiculoides* was present as a stowaway in display trays and in plastic cups with *C. demersum* at retailers 1, 4 and 5. In 2020, eight floating and submerged species were found as stowaways in display trays, including the native *Lemna minor*, *Myriophyllum spicatum* and *Spirodela polyrhiza* and the non-native *Azolla filiculoides*, *Egeria densa, Lagarosiphon major, Landoltia punctata* and *Lemna minuta*. *Lemna minor* was found at all surveyed retailers, while *M. spicatum* was only recorded at retailers 5 and 6 and *S. polyrhiza* at retailers 5, 8 and 11. The non-native species *L. punctata* was not recorded in 2016–2017, but was found at retailers 4, 5 and 10 in 2020. European Union List species *L. major* was recorded as a stowaway at retailers 3 and 7. The Belgian Communication List species *A. filiculoides* and *L. minuta* were widely present as stowaways in 2020. *A. filiculoides* was found in display trays at six retailers and *L. minuta* was found at nine out of ten surveyed retailers. Belgian Consensus List species *E. densa* was found as a stowaway at retailer 6. Three more species of the Belgian Consensus List – *Crassula helmsii*, *Cyperus eragrostis and Erythranthe guttata* – were observed as stowaways in pots with plants intended for sale. *C. helmsii* and *E. guttata* were found as stowaways at retailer 6 and *C. eragrostis* was recorded as a stowaway at retailers 6 and 8 (Tab. 1).

4 Discussion

Our study provides an overview of aquatic, riparian and palustrine plants offered for sale on the Belgian horticultural market and could serve as a baseline for future monitoring. The majority of plants offered for sale at the surveyed water gardening centres were wild type species, but a large proportion were cultivars or hybrids. The availability of a large selection of cultivars and hybrids indicates that special colour and shape variations are characteristics sought after by water gardeners. Consequently, propagule pressure of popular cultivars and hybrids may be relatively high. Moreover, aberrant traits may negatively or positively affect the survivability and the establishment potential of cultivars and hybrids outside the protective environment of gardens. Variegation or partial albinism, for instance, may result in reduced vigour and survivability, because the loss of chlorophyll pigments interferes with photosynthesis (Kumari *et al.*, 2009). However, (partial) albinism in plants is often unstable and usually reverts back out (Delool and Tilney-Bassett, 1986; Kumari *et al.*, 2009). In some cases, white leaf variegation may even be a beneficial trait, because it may mimic insect tunnelling damage to discourage additional insect attacks (Lev-Yadun, 2014). Moreover, several studies have shown that under certain environmental conditions cultivars may outperform wild type plants in terms of biomass or seed production (Wilson and Mecca, 2003; Schröder and Prasse, 2013). The invasive potential of hybrids may vary as well. Numerous examples of invasive hybrid plants have been documented. The invasion success of hybrids has been attributed to increased genetic variation, which may allow rapid adaptations to their environment and increase their fitness (Ellstrand and Schierenbeck, 2000; Reed and Frankham, 2003; Blair and Hufbauer, 2010; LaRue *et al.*, 2013; Wasekura *et al.*, 2016). Hybrid waterlilies (Nymphaeaceae) formed the largest group of taxa offered for sale in the Belgian water gardening trade, but popular clones are typically sterile (Holmes, 2011). Sterile hybrids may have less invasive potential, because of their inability to produce seeds or to hybridize with native species, although some may still be able to maintain viable populations or even expand their range through vegetative reproduction (Santamaría, 2002; Eckert *et al.*, 2016). The voluntary Belgian code of conduct does apply to cultivated varieties and hybrids derived from Consensus List species (Halford *et al.*, 2014a). However, none of the cultivars and hybrids offered for sale by the surveyed retailers were derived from species represented on the Belgian Consensus and Communication Lists.

The validation of plant names on the labels of Belgian retailers was usually fairly straightforward with the aid of standard identification keys and internet resources. Validation of cultivar and hybrid names was more challenging than

validation of species names, because identification keys for cultivars and hybrids are scarce. However, a photo of the flower on the label or the flower itself, in combination with a registered horticultural name, allowed for comparison with flower photos retrieved from internet sources. This double control allowed to filter out any obvious mistakes in cultivar or hybrid names. Flower photos on the labels could often serve as a double control for wild type plants as well and were useful for the identification of plants that were not in bloom at the time of the survey, although in such cases a thorough examination of vegetative characteristics was carried out, because occasionally the photo and the name on the label did not correspond with the actual plant offered for sale. When a plant was labelled with an unregistered trade name, a double control was not possible and the identification was merely based on comparing photos. Consequently, several cultivars and hybrids labelled with trade names could not be identified with absolute certainty. Occasionally, validation was further complicated because of discrepancies between the consulted databases and the occurrence of taxonomically unresolved names. Nonetheless, the identity of only a small number of plants in our list remained uncertain. The identity of morphologically similar species and plants that were not in bloom at the time of our survey could be further investigated with molecular techniques in a follow-up study (Moody *et al.*, 2008; June-Wells *et al.*, 2012; Thum *et al.*, 2012; Ghahramanzadeh *et al.*, 2013). Molecular techniques could also be useful to investigate whether the number of hybrids offered for sale was underestimated, since hybrid plants may strongly resemble one of their parent taxa (LaRue *et al.*, 2013; Kabátová *et al.*, 2014; Ciotir *et al.*, 2017).

Several studies have reported mislabelling of aquatic plants (Maki and Galatowitsch, 2004; Moody *et al.*, 2008; Brunel, 2009; June-Wells *et al.*, 2012; Thum *et al.*, 2012; Yakandawala *et al.*, 2013) and our results indicate that this problem persists in the Belgian water gardening trade. More than one third of the plant taxa available for sale were mislabelled, which was a consequence of misspelling, the use of a taxonomic synonym, misidentification, the use of an unregistered trade name, or a combination of these types of mistakes. The most common mistakes were minor typographical errors that still allowed an unambiguous identification. The use of taxonomic synonyms was another common mistake, but the valid names were usually easy to trace with the aid of internet resources. Typographical errors and the use of synonyms were therefore generally less problematic compared to misidentifications. Misidentifications and the use of unregistered trade names were relatively rare. Although there is no legal obligation to register a name for cultivars or hybrids, the use of an unregistered trade name can be considered mislabelling if a registered name exists or if a trade name is used instead of an accepted species name. It is not clear why retailers and plant producers sometimes used unregistered trade names if a registered name was available. The original name tag provided by the plant producers or hybridizers may have been lost in transport or the use of the registered name may have been considered commercially unimportant. Some hybridizers may not register their hybrids in order to keep the parentage secret. Nonetheless, hybridizers should be encouraged to register their hybrids, because registration would facilitate the traceability of the hybrid formulas. The hybrid formulas are required in order to check whether hybrids are derived from species included in the Belgian Consensus and Communication Lists. It is unknown to what extent retailers and plant producers were aware of mistakes on the plant labels, although according to Verbrugge *et al.* (2014), retailers occasionally prefer to use erroneous names over valid names if their customers are more familiar with the former. Retailers and plant producers may perceive validation of plant names and keeping track of taxonomic progress as time consuming and commercially unimportant. Therefore, retailers and plant producers may not feel inclined to check the spelling or the validity of names on the original name tags provided by plant producers or hybridizers. Nonetheless, guidelines compiled by the European and Mediterranean Plant Protection Organization (EPPO) encourage retailers and plant producers to correctly identify the plants that are being traded. The EPPO also advises to accurately label plants with the correct name in order to avoid confusion (EPPO, 2009).

Maki and Galatowitsch (2004) and Thum *et al.* (2012) have expressed concerns that mislabelling may lead to the continued sale of prohibited aquarium and pond plants. These concerns may be valid for the Belgian water gardening trade as well. During our first survey in 2016–2017, we encountered six plant species that are currently regulated in Europe (European Commission, Directorate-General for Environment, 2019). Four of these – *Cabomba caroliniana*, *Eichhornia crassipes*, *Lagarosiphon major* and *Lysichiton americanus* – were included in the initial European Union List that became effective on August 3rd 2016 (European Commission, 2016). However, the trade in these species was not illegal at the time of the first survey. The first survey in 2016–2017 was carried out within a transition period during which Article 32 of Regulation (EU) 1143/2014 allowed retailers to deplete their old stock (European Parliament, Council of the European Union, 2014). *Lagarosiphon major* was always mislabelled and *C. caroliniana* was mislabelled in 2017. Two other Union List species, *Gunnera tinctoria* and *Salvinia molesta*, were also consistently mislabelled, but were not subjected to selling restrictions at the time of the 2016–2017 surveys. Both species were added to the European List afterwards (European Commission, Directorate-General for Environment, 2017; 2019). However, in 2020, *C. caroliniana*, *G. tinctoria* and *S. molesta* were still being sold, even though the transition period provided in EU Regulation 1143/2014 had expired and the trade in these plants was prohibited (European Commission, Directorate-General for Environment, 2019). In 2016–2017, five species of the Belgian Consensus List – *Crassula helmsii*, *Cyperus eragrostis, Egeria densa*, *Erythranthe guttata* and *L. major* – and two species of the Communication List – *Azolla filiculoides* and *L. americanus* – were offered for sale by one or more of the surveyed retailers. These were still being sold in 2020, except *L. americanus.* All five available species of the Belgian Consensus List and *A. filiculoides* were consistently mislabelled.

It is not clear whether retailers purposely made use of the permission to sell old stock under Article 32 of EU Regulation 1143/2014 and if they were aware that some of the Union List species were mislabelled. However, there were no indications that plants were deliberately mislabelled to mislead customers or government officials and scientists tasked with monitoring the trade, since the vast majority of mislabelled taxa

encountered during both surveys do not occur on the European Union List. The sale of the plants included in the Belgian Consensus and Communication Lists was not illegal, because the Belgian code of conduct is a voluntary agreement (Halford *et al.*, 2011a,b; 2014a,b) and – as mentioned earlier – at the time of the first survey in 2016–2017 retailers were allowed to clear old stock of *L. major* and *L. americanus*, which also occur on the European Union List. Nonetheless, our study indicates that the Belgian voluntary code was ineffective to prevent the sale of some (potentially) invasive species included in the Consensus and Communication Lists, possibly because an insufficient number of retailers and plant producers endorsed the code or because they were unaware of mistakes on the labels. It is unknown whether any of the surveyed retailers or the plant producers had endorsed the Belgian voluntary agreement. It should be noted that several aquatic, riparian and palustrine plants of the Belgian Consensus List and the European Union List that were available during the survey conducted by Halford *et al.* (2011a), including *Hydrocotyle ranunculoides*, *Ludwigia grandiflora*, *L. peploides*, *Myriophyllum aquaticum*, *M. heterophyllum* and *Impatiens glandulifera* were never observed during our surveys, which may be attributed to the implementation of the Belgian code of conduct and the European Regulation. Also, in 2020, the European Union List species *Eichhornia crassipes*, *Lagarosiphon major* and *Lysichiton americanus* were no longer sold by the surveyed retailers.

Besides plants intended for sale, display trays often harboured stowaway plants. European Union List species *Lagarosiphon major* was still present as a stowaway in 2020, although the species was no longer for sale at the surveyed retailers. Stowaway floating plants, including the Belgian Communication List species *Azolla filiculoides* and *Lemna minuta*, sometimes adhered to the plastic pots of plants intended for sale when they were lifted out of the display trays. Plastic cups with submerged plants were sometimes contaminated with the Belgian Communication List species *A. filiculoides*. Occasionally, the Belgian Consensus List species *Crassula helmsii*, *Cyperus eragrostis* and *Erythranthe guttata* were found as stowaways in pots with plants intended for sale. Consequently, contamination of plastic pots and cups may lead to the inadvertent release of potentially invasive aquatic plants into garden ponds (Maki and Galatowitsch, 2004).

Halford *et al.* (2014a) indicated that limited resources prevented them from carrying out country-wide surveys after the implementation of the Belgian code of conduct. Surveys to assess whether plants of the Belgian Consensus List and the European Union List are withdrawn from sale and the possibility of applying molecular techniques will depend on the availability of funding and specialized personnel. Nonetheless, our study shows that monitoring the water gardening trade is feasible with limited resources, since specialized water gardening centres represent only a small minority compared to the large number of non-specialized garden centres (Halford *et al.*, 2014a; Verbrugge *et al.*, 2014). Moreover, the number of aquatic plant producers is limited. A single plant producer based in the Netherlands provided plants for four out of five retailers surveyed in 2016–2017 and nine out of ten retailers surveyed in 2020 and was observed to be the only plant producer of a large number of non-specialized Belgian garden centres as well (pers. obs.). Therefore, monitoring a small number of specialized water gardening centres could provide a representative overview of aquatic, riparian and palustrine plants available on the Belgian horticultural market, since non-specialized garden centres are likely to sell only a small selection of pond plants. Also, it would require little effort to inform the small number of plant producers about mislabelled plants, which may simplify the prevention of the trade in invasive taxa in Belgium. Furthermore, focussing surveys solely on aquatic plants featuring on the Belgian Consensus and Communication Lists and on the European Union List may provide an efficient monitoring strategy, since most of them are identifiable with standard keys and internet resources. Since several species of the Belgian Consensus and Communication Lists and of the European Union List were mislabelled, our study implies that mere scanning of catalogues – a method applied by Halford *et al.* (2011a) – is insufficient to monitor the trade.

Our study shows that surveys are essential to assess the effectiveness of the regulations and voluntary codes of conduct that apply in Belgium. Besides imposing selling restrictions and ensuring the correct labelling of plants, biosecurity and phytosanitary measures should be put in place in order to prevent the introduction or spread of potentially invasive non-native species through the water gardening trade.

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Supplementary Material

Appendix 1. List of plants offered for sale by the surveyed retailers in 2016–2017 and in 2020. Plant families, taxon categories and confidence levels of identification are also given. Taxa of the Belgian Consensus and Communication Lists and the European Union List are indicated separately. *In 2020, surveys of retailers 2 and 3 were limited to submersed and floating plants and taxa of the Belgian Consensus and Communication Lists and the European List of Union Concern.

Appendix 2. List of mislabelled plants encountered during the surveys of 2016–2017 and 2020. The erroneous names used on the labels are listed separately for each plant producer. The taxon categories, types of taxonomic errors and confidence levels of identification are also given.

The Supplementary Material is available at https://www.kmae.org/10.1051/kmae/2022005/olm.

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