How environmental managers perceive and approach the issue of invasive species: the case of Japanese knotweed s.l. (Rhône River, France)

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Marylise Cottet[1], Florence Piola[2], Yves-François Le Lay [1], Soraya Rouifed[2] and Anne Rivière-Honegger[1]*

*Corresponding author:

Email: marylise.cottet@ens-lyon.fr

Phone number: +33 437 376 348

Postal address: ENS de Lyon, bureau R 243, 15 parvis René Descartes, 69007 LYON

[1]UMR 5600 "Environnement, Ville, Société", CNRS, Université de Lyon, ENS de Lyon, 15 parvis René Descartes, BP 7000, 69342 Lyon Cedex 07, France

[2]UMR 5023 LEHNA, CNRS, Université Claude Bernard Lyon 1, ENTPE, 43 Boulevard du 11 novembre 1918, 69622 Villeurbanne Cedex, France

ABSTRACT

Studying the perceptions of stakeholders or interested parties is a good way to better understand behaviours and decisions. This is especially true for the management of invasive species such as Japanese knotweed *s.l.* This plant has spread widely in the Rhône basin, where significant financial resources have been devoted to its management. However, no control technique is recognized as being particularly effective. Many uncertainties remain and many documents have been produced by environmental managers to disseminate current knowledge about the plant and its management. This article aims at characterizing the perceptions that environmental managers have of Japanese knotweed *s.l.* A discourse analysis was conducted on the printed documentation produced about Japanese knotweed*s.l.* by environmental managers working along the Rhône River (France). The corpus was both qualitatively and quantitatively analysed. The results indicated a diversity of perceptions depending on the type of environmental managers involved, as well as the geographical areas and scales on which they acted. Whereas some focused on general knowledge relating to the origins and strategies of colonization, others emphasized the diversity and efficacy of the prospective eradication techniques.There is a real interest in implementing targeted actions to meet local issues. To do so, however, these issues must be better defined. This is a challenging task,as it must involve all types of stakeholders.

KEYWORDS

Discourse analyses; environmental managers; invasive species; Japanese knotweed *s.l.*; management; perceptions.

1. INTRODUCTION

1.1. When scientific uncertainties make management more difficult

Biological invasions, which are believed to be the result of global change, are of growing interest in the biological sciences (Vitousek*et al.* 1997) because of their potential effects on biodiversity. Invaded ecosystems are generally consideredasdisrupted areas,where native species are strongly threatened. Thus, the control of invasive species has become a priority for many countries, and several policy engagements have already been ratified and are being implemented (Genovesi and Shine 2004; Heywood and Brunel 2011). Therefore, managers need to find efficient and feasible control methods (Delbart*et al.* 2012). However, in the case of particularly efficient invaders, managing such species presents a considerable challenge, and while ecological studies are numerous and can help to define successful management techniques (Genovesi, 2011), the complexity of the ecological processes involved in invasion often makes it difficult to develop effective control methods.

Biological invasions pose not only a critical ecological issue but also an important social issue. The social dimensions of biological invasions were first considered in the early 2000s (McNeely 2001), following initiatives in environmental economics (Perrings*et al.* 2000; Pimentel *et al.* 2000). If managers want to efficiently manage invasive species when defining a management strategy, they must also consider the social dimension of the issue (Binimelis*et al.* 2007;Gobster 2011). On the one hand, the impacts of biological invasions are many and not limited solely to ecological consequences. They may also affect market or non-market goods and services produced (or no longer produced)by invaded systems (Colautti*et al.* 2006). On the other hand, what we define asa biological invasion (the degree to which the colonization of an area by a species becomes an invasion) as well as the management strategies we use to control them are widely influenced by human perceptions (Mack 2001).

1.2. Human perceptions, a key factor for managing biological invasions

When managing complex ecological processes, there are no standard rules defining what constitutes a good decision or action. Human perceptions that guide the definition of strategies rely sometimes on non-scientific criteria (Lévêque*et al.* 2012). For example, Starfinger*et al.* (2003) showedthat when there are insufficient data available to tackle a specific issue, there is a tendency to believe in stories about the beneficial or noxious impact of an alien species. Focusing on human perceptions as well as human values associated with biological invasions is a good way to better understand behaviours and decisions. Furthermore, this focus may help to define more efficient management strategies (Vanderhoeven*et al.* 2011). This research direction is also legitimatized given the fact that there is a wide diversity of stakeholders or interested parties involved in the management of biological invasions, each of them having a specific perception regarding the issue and a specific point of view regarding the action to take (Simberloff*et al.* 2005). Human perceptions are at their most heterogeneous when addressing questions that are confounded by many scientific uncertainties (Pahl-Wostl 2006), aseveryone tends to have his or her own perceptions depending on his or her personal experiences. With respect to invasive species, uncertainty is the norm (Williamson 1999; Horan *et al.* 2002). The definition of action relating to biological invasions must thereforetake into account this diversity of perceptions (Binimelis*et al.* 2007; Garcia Llorente*et al.* 2008). This article aims to serve this objective by choosing an original angle: the study of managers' perceptions.

1.3. The choice of studying managers' perceptions

Many scientific studies until now have been interested in characterizing public perceptions of the control and eradication of invasive species (Simberloff*et al.* 2005; Hulme 2006;Bardsley and Edwards-Jones 2007; Bremner and Park 2007; Andreu *et al.* 2009), and public opposition has repeatedly caused delays in or the abandonment of control efforts (Marshall *et al.* 2011; McNeely 2011). Better knowledge of public opinion towards these actions is a first step in fostering public involvement and gaining social acceptance (Selge*et al.* 2011). Nevertheless, the perceptions of environmental managers require specific attention.

- Environmental managers are charged with defining and implementing environmental plans. They are the ones who have to act (or not)and who have to meet the challenge of overcoming uncertainties (Liu *et al.* 2011). How do these uncertainties influence their perceptions, decisions and behaviours towards the plant and its management?
- They are also the ones in charge of producing and communicating information about invasive species to other stakeholders, tasks that require certain skills and principles (Jurin*et al.* 2010). Beyond the uncertaintiesthat they must address,when communicating on issues relating to a biological invasion, they face the challenge of correctly informing stakeholders about the invasive species. Indeed, the ambiguous and inconsistent use of terminology (Richardson *et al.* 2000;Collauti and Richardson 2009)and the use of emotive and manipulative language (Gobster 2005; Larson 2005; 2008; Stromberg *et al.* 2009;Selge*et al.* 2011) have already been widely criticized.

1.4. The case of Japanese knotweed *s.l*

1.4.1. The importance of conducting case studies

Research conducted on invasive species is instructive. In particular, these studies show that different criteria influence human perceptionsregarding a biological invasion. Several researchers have listed influencing criteria (Garcia Llorente*et al.* 2008;Selge*et al.* 2011), and some have even proposed a model to explain human perceptions of biological invasions (Gobster 2011). The following are among the influencing criteria identified:

- The impact caused by an invasive species appears to be one of the main structuring factors of human perceptions. These impacts can be negative or positive (Shapiro 2002;Bardsley and Edward-Jones 2006) and may affect ecosystems as well as social systems (Garcia Llorente*et al.* 2008). The negative impacts of invasive species on ecosystems are found to be a strong motivation for their eradication (Levine *et al.* 2003; Garcia Llorente*et al.* 2008;Selge*et al.* 2011). Nevertheless, ecological functions provided by species (Binimelis*et al.* 2007) or values associated with them (i.e., the aesthetic value of colourful plants such as purple loosestrife; the cultural value of feral pigs for particular ethnic groups, etc., Gobster 2011) may help to attenuate the observed negative impacts.
- Time can also influence human perceptions of a biological invasion such that the older the invasion, the less the species is identified as exotic, and the better it is valued (Bardsley and Edwards-Jones 2006; Garcia Llorente*et al.* 2008;Gobster 2011). Moreover, Starfinger*et al.* (2003) showed that perceptions of an invasive species can evolve over time, according to the scientific data available.
- Personal factors add many variationsto the perceptions of an invasive species. Such factors include education, economic status, rural or urban residence, cultural or regional characteristics, house size and distance: the closer the invasion, the more concerned people are likely to be (Garcia Llorente*et al.* 2008; Ehrenfeld 2010;Gobster 2011). Knowledge and expertise also play a critical role in the way we consider issues linked to biological invasions. Consequently, different stakeholders will often have different perceptions of the issue.

The previous studies show that reflections about biological invasions cannot be exclusively conducted in a global framework, as human perceptions of biological invasions depend on which species is under consideration, which area has been invaded and which stakeholder is affected. Data, therefore, should be focused onthe effect of a single species over a single area on a single-type stakeholder.

1.4.2. The Japanese knotweed s.l. invasion: a preoccupation of environmental managers

Taxa from the hybrid complex *Fallopia* (mainly *Fallopia japonica* (Houtt.)RonseDecraene,*Fallopiasachalinensis* (F. Schmidt ex Maxim.) RonseDecraene and the hybrid *Fallopia* x *bohemica* (ChrteketChrtkovaÏ)) are widespread invadersof North America (Shaw and Seiger 2002) and Europe (Child and Wade 2000). *F. japonica* and *F.sachalinensis* are rhizomatous perennial herbaceous plants that originated from Asia and were introduced in Europe in the XIX century because oftheir ornamental qualities (Bailey and Conolly 2000). Today,*F. japonica* is one of the most common invasive species in Europe, having been identified in 40 countries (Lambdon*et al.* 2008), including France. Hybridization between *Fallopia* taxa produces *F.* x *bohemica*,which exhibits higher genetic diversity (Tiébré*et al.* 2007), higher phenotypic variation (Herpigny*et al.* 2012), and higher performances (Parepa*et al.* 2014). *Fallopia* spp. colonize mainly in riparian habitats and disturbed areas (Bailey *et al.* 2009). In invaded sites, identified functional impacts include altered nutrient cycles (Dassonville*et al.* 2007; 2011) and reduced plant species diversity (Vanderhoeven*et al.* 2005; Gerber *et al.* 2008). Numerous mechanical, chemical or biological techniques have been tested, but none have demonstrated satisfying outcomes (for a review of these techniques and their effectiveness, see Delbart*et al.* 2012). In fact, some of them may even promote further invasion, as is the case for mowing interventions (Beerling*et al.* 1994; McHugh 2006), the most frequently used technique. Little is known about the response of the different taxa to the control methods. Moreover, as they invade similar habitats and as it is sometimes difficult to distinguish between them, they are often considered together. For these reasons and for convenience, in this paper, the term Japanese knotweed *s.l.* will be used to refer to the three taxa of interest: *F. japonica*, *F. sachalinensis*, and *F.* x *bohemica*(Bailey *et al.* 2009).

Because of the uncertaintiesregarding management, there is no consensus with respect to the most effective way to control Japanese knotweed *s.l.* (Delbart*et al.* 2012) or evenwhetherit should be controlled. Ongoing ecological field research may produce knowledge likely to help define the best management plan for this plant (Rouifed 2011). Nevertheless, thisresearch must be completed with data relating to the field of human perceptions, especially to better understand the main issues associated with the management of Japanese knotweed *s.l.*and the best action to take from the perspective of the managers.

1.4.3. A need for research relating to human perceptions of Japanese knotweed s.l.

Only a few studies have considered the social dimension of Japanese knotweed *s.l.* invasion. Child *et al.* (1998) conducted a contingent valuation study to assess the socially acceptable cost of controlling the plant. Apart from this study, only factual and incomplete data relating to the human perceptions of Japanese knotweed *s.l.* are available. For instance, Vanderhoeven*et al.* (2011) determined that, in Belgium, Japanese knotweed *s.l.*is one of the species mentioned by horticulture professionals and nature reserve managers during surveys when asked which species would become a problem in the next few years. Further research on human perceptions of Japanese knotweed *s.l.* is therefore required.

Herein, we aim to extend these initial data by characterizing the perceptions of environmental managers working along the Rhône River with Japanese knotweed *s.l.* By analysing what they have written about this plant, we aim to determine:

(1) What typesof environmental managers are actually concerned about Japanese knotweed *s.l.* and produce information about it?

(2) What are the perceived issues linked with the management of the plant?

(3) What strategies do the environmental managers recommend tomanagethis plant, and what arguments do they use to justify their choices?

2. MATERIALS AND METHODS

2.1. Study area

The Rhône River, one of the main Mediterranean rivers, originates at the Furka glacier in the Swiss Alps. The river is 812 km long, with more than 500 km located in France. The Rhône flows into the Mediterranean Sea, where it terminates in a very largedelta. Upstream of this delta, at Beaucaire, the mean river flow reaches 1700 m^3/s (Olivier *et al.* 2009). The Rhône River is a powerful unifying element of southern and eastern France because it crosses or delimits many administrative areas, including regional, infra-regional and local authorities. Many environmental managers attached to these various geographical areas are facing the challenge of how to control Japanese knotweed *s.l.* as part of their mission.

While few data are available concerning the intensity of the Japanese knotweed *s.l.* invasion along this watercourse, according to the inventory conducted in 2001 for the regional water authority (Boyer and Laval 2001), the invasion is variable, with the upper regionexhibiting a far greater invasion than the lower region. However, two sectors appear to be more specifically colonized. One, in the Upper Rhône, is the 40 km section downstream from the confluence with Les Usses River, and the second, in the Middle Rhône, is a 90 km section downstream from the city of Lyon. The Japanese knotweed *s.l.* invasion is of major concern to environmental managers and has led to numerous management plans, following the measures (2010 to 2015) defined by the regional water authority to "fight against invasive exotic species" (article OF6-C).

2.2. Constitution of the corpus

We aim to gather all documents relating to Japanese knotweed *s.l.* produced by managers involved in the management of this plant along the Rhône River in France. The preliminary analysis suggests that printed documents on this plant are relevant sources for studying stakeholders' perceptions, as each document published by a management structure is often collectively written and validated. The discourse it produces about a given issue is therefore assumed to correspond to management structure's perceptions regarding the issue.

To be as exhaustive as possible when collecting this documentation, a multi-step, rigorous collection strategy was established. As a first step, we conducted a general search of the Internet, using the scientific and common names of the plant, place names, and words such as 'management', 'control', and 'management practices', in French. As a second step, we contacted by telephone different types of management bodies whose responsibilities included issues related to the Rhône River. They were asked to send us by post or e-mail a copy of any documents relating to Japanese knotweed *s.l.* that they had produced or had in their possession. For some of these institutions, we went on-site to gather the available documents. This contact procedure was pursued at three geographical levels:

- at the local level: all "communautés de communes" (a regrouping of local authorities with jurisdiction on certain matters) or individual municipalities (when not collectively organized), as well as all local water associations;
- at the regional or infra-regionallevel: everyregional or infra-regionalauthority ("conseils régionaux et départementaux") as well as all decentralized state services ("direction régionale de l'environnement, de l'aménagement et du logement", "direction départementale des territoires");
- at the Rhone-Mediterranean basin level: the Rhône-Mediterranean Corsica water agency ("Agence de l'eau Rhône Méditerranée Corse").

Two criteria were used to justify the inclusion of a document in the corpus.First, it had to specifically focus on Japanese knotweed *s.l.*(not simply on invasive species); second, it must have been produced by an environmental manager who was responsible for the management of an area crossed or bordered by the Rhône River or one of its tributaries. We digitally scanned each document using OCR software (Omnipageprofessional©, Nuance

Communications Inc., Burlington, Massachusetts, US) and built a database to associate metadata with each of these documents. These metadata included the following:

- the publication date. In the case that the publication was in draft (i.e., not final) form, the date planned for publication was entered into the database. As a result, the corpus includes some sources listed as published in 2013;
- the type of stakeholder producing the document;
- the nature of the document.

The collection of the documentation for the corpus ended in April 2012 and allowed usto gather 81 documents. In spite of the systematic sampling, we may have missed certain documents. Nevertheless, since we have collected every document that the managers have archived or have heard about, we can consider that our collection is a large sample of the universe of relevant documents. One limit must however be underlined: we chose to gather only the printed documentation, which excludes online publications dealing with the question of Japanese knotweed *s.l.*, such as websites, blogs… As the environmental managers are more and more inclined to use these media as a way for communicating, this exclusion may have biased our sample.

2.3. Corpus analysis: a statistical analysis of textual data

The corpus was both qualitatively and quantitatively analysed. A statistical analysis of textual data (Lebart*et al.* 1998) was performed using the open source software Iramuteq© (Ratinaud and Dejean 2009), which was recently developed (2008) and which isregularly updated. It relies on R software (R Core team, 2013) as well as the python language.

Iramuteq© reproduces the classification algorithm, described by Reinert (1983; 1990) and implemented in the Alceste© software, which has led to numerous publications (Brochet and Dubourdieu 2001;Dransfield*et al.* 2004; Parr *et al.* 2011). It corresponds to a top-down hierarchical classification based on five stages.

(1) Segmentation. The corpus is segmented into two textual units: (a) the texts composing the corpus – in our case, each document produced by environmental managers and qualified by the metadata defined above (publication date, type of stakeholder and nature of the document); (b) the text segments (through an iterative process, each text is cut into a number of segments, defined according to a number of words – 40 by default).

(2) Lemmatization. Using a grammatical dictionary, each verb, noun, adjective, *etc.*, is reduced to its basic dictionary entry, named a lemma.

(3) Production of a contingency table. The matrix crosses the reduced forms (in columns) and the text segments (in rows). Among the reduced forms, only the analysable forms (nouns, verbs, adjectives, adverbs, *etc*.) are retained; supplementary forms (prepositions, pronouns, conjunctions and auxiliary verbs, *etc*.) are excluded from the table. The presence or absence of each analysable reduced form within each text segment is specified at intersections of the matrix (respectively noted as 1 vs. 0).

(4) Processing of a top-down hierarchical classification from the contingency table. Relying on an iterative algorithm, the software aims at defining classes thatmaximize the distance between two subsets (using χ^2 metrics). The iterative process stops when sub-classes are not significantly different. Specific forms of a class are then removed from the other class. This analysis is then repeated on the larger of the two classes, and so on, until the requested number of classes is reached (10 by default). Two independent analyses with different lengths of text segment are processed, and their results are statistically compared to test the stability of the classes.

(5) Description of the classes. The number of text segments classified in each class is specified. For each class, a list of the reduced forms associated with it is created (the degree of association with the class is indicated by the χ^2 value). The modality of the metadata variables most associated with each class is also specified. These classes are then finally interpreted as “lexical worlds” (Rouré and Reinert 1993).

We also performedstatistical treatments relying on the co-occurrence analyses of specific lexical forms (Lebart*et al.* 1998). In particular, using Iramuteq©, we conducted similarity analyses. Based on graph theory, theseanalyses aim to study proximity and relationships between components (in our case, the lexical forms) of a set (in our case, the corpus) using a maximum tree (Marchand and Ratinaud 2012). The plot resulting from this analysis had specific properties: (a) the greater the occurrence of a lexical form, the greater the size of the characters; (b) the greater the co-occurrence between two lexical forms, the thicker the line that linked them. Such a graph was used to analyse the relationships between all lexical forms associated with a class, which resulted from the top-down hierarchical analysis.

3. RESULTS

3.1. Who produces information about Japanese knotweed *s.l.*, and in what form?

The corpus was composed of 81 documents (195,006 words total) published between 1998 and 2013. However, the production of information about Japanese knotweed *s.l.*was marginal until 2006 (Fig1A). That year marked a strong increase in the number of documents produced, and the number continued to increase in the following years.

Diverse types of environmental managers were involved in this production (Fig1A). Some were attached to the regional water authority, to local or regional authorities or state services, to environmental protection associations, to environment consultancy firms, to building companies operating on the river, to regional conservation bodies (conservatoires botaniquesrégionaux), or to local water associations. Thus, both public and private stakeholders contributed to the production of information about Japanese knotweed *s.l.* Managers working within local water associations were the main stakeholders diffusing information about Japanese knotweed *s.l.*as they alone produced almost half of the documentation. However, their contribution to the production was relatively late and occurred mainly from 2010 onward. In other words, the strong increase in production observed over these last few years was mainly due to this one group of stakeholders. Nonetheless, local and regional authorities, state services, and environmental consultancy firms also had a significant input.

The documentation produced was quite diverse, consisting of management plans, syntheses of technical meetings, management guides, identification guides, information leaflets and specialized journal articles (see Table 1 for a description of the documents). The various documents addressed diverse target groups in that some - management guides and synthesis studies - were intended for environmental managers who already confronted ecological invasions and thus focused on management methods. Others - specialized journal and information leaflet - addressedthe general public with potentially no knowledge of the issueand thus provided informationabout the plant, its colonization and its impacts.These two uses were roughly equally shared if we consider the number of produced documents per category (Fig1B).

Following a spatial analysis, we observed that the production of documents relating to Japanese knotweed *s.l.* also turned out to be diverse (Fig2), with the number of documents produced upstream being far higher than the number produced downstream. This longitudinal division of the river seemed to correspond to the intensity of the invasion (Boyer and Laval, 2001). That is, the more invaded the area was, the more documentation on the plant being produced by environmental managers.

3.2. What is said about Japanese knotweed *s.l.*

3.2.1. Main components of the discourses

The top-down hierarchical clustering classified97.7 % of the text segments within 5 lexical classes (Fig3a). The clustering tree marked a first segmentation dividing textual segments into two parts, each having a semantic unity.The first regrouped classes 1 and 2(including 13.2 % and 24.2 % of the textual segments, respectively), and focused on the fight against Japanese knotweed *s.l.* The second regrouped classes 3, 4 and 5 (including 19.6 %, 18.7 % and 24.3 % of the textual segments, respectively), and involved information on the invasion (mechanisms of dispersion) as well as strategies for managing the plant. The most significant textual segments for each class are presented inTable 2.

Class 3 (Fig3b) brought together all available strategies and resources for managing Japanese knotweed *s.l.* On the one hand, it listed all possible actions aimed at controlling the plant: it mentioned both preventive measures aimed at limiting its expansion, such as awareness actions ("prevention", "awareness", "communication") or follow-up actions ("cartography", diagnostic", "monitoring", "inventory"), and restorative measures when the plant is already established ("eradication", fight", "techniques", "method", "means"). The need to acquire knowledge also held a significant position within this class ("information", "knowledge", "to know"). On the other hand, this class took stock of all stakeholders concerned with the invasion of Japanese knotweed*s.l.* in that it referred both to management experts ("manager", "Rhône-Méditerranée-Corse" [water agency], "local" or "field" "stakeholder", "authority"), to economic actors ("company"), and to the general public ("public"). Many geographical areas and many spatial scales involved in the management of the plant were also listed, including "basin", "Saône", "Rhône", "regional", "*région*" (or regional authority), and "*département*" (or local authority). This inventory responds to the concerns of developing specialized stakeholdernetworks to better control Japanese knotweed*s.l.* ("network", "work[ing]" "group").

Classes 5 (Fig3d) and 4 (Fig3c) comprised knowledge relating to the dispersal mechanisms of Japanese knotweed *s.l.*Class 5 described the origins of the introduction of the species ("to introduce", "exotic", "Europe", "Asia", "origin", "ornamental", "century", "human" "activity"), its strategies of colonization and adaptation ("hybrid", "competition", "reproduction", "pioneer"), including its preferred environments for developing ("wetland", "railway" "track", "road", "side") and finally, problems it could cause ("ecological""impact", "nuisance", "biodiversity", "monospecific", "ecosystem" "functioning", "bank" "erosion"). This class appeared to more generally describe certain dispersal mechanisms common to invasive species ("giant hogweed", "ragweed", "animal"). Class 4 was more specifically focused on watercourses, described as one of the main affected environments but also one of the main means of dispersal.

Eradication was at the core of classes 1 (Fig3e) and 2 (Fig3f). Class 2 listed a considerable number of the techniques used – either today or in the past – to fight Japanese knotweed *s.l.* ("to mow", "to cut", "chemical" "treatment", "uprooting", "tarpaulin"). Actions specifically focused on the main reproductive organs of the plant: its aerial ("stalk"), or its underground parts ("rhizome") – as both are strongly involved in its reproductive capabilities in vegetative propagation. Therefore, a significant place in this class was given to the physiology of the plant. The experimental component of these actions was strongly present, as the effectiveness of the eradication techniques used wasassessed experimentally ("protocol", "experimentation", "plot", "counting", "m²"). Finally, the lexicon relating to seasons and seasonality was very much present ("end", "beginning" "May", "June", "season", "period", "month"), as was the lexicon linked to repetition ("to repeat", "times", "repetitive"). This finding indicated, on the one hand, that environmental managers were used to relying on a seasonal calendar to implement actions against Japanese knotweed *s.l.*, and on the other hand, that their interventions must necessarily be repeated. Class 1 focused on a specific technique that was experimentally used to eradicate the plant. This technique involved mechanical action aimed at crushing the rhizomes into small enough particles (using construction machinery) to impede their vegetative reproduction. This class insisted on the effectiveness of this method ("complete" "mortality", "to achieve" "result", "efficiency") and mentioned the necessary preventive measures to implement in such experimental trials so as not to further disperse the plant ("cleaning", "to clean", "caterpillar" "machine").

3.2.2. A technical discourse responding to a wish for effective action

This classification shows that more than one-half of the discourses were dedicated to actions aimed at controlling Japanese knotweed *s.l.*, and more than one-third specifically focused on restorative methods. The discourses of environmental managers appeared to strongly promote the implementation of actions to eradicate the plant. This willingness to take action against Japanese knotweed *s.l.* was specifically obvious when we considered the "efficiency" lemma, cited as many as 121 times in the corpus. Table 3, presenting its co-occurring lemmas, highlights the fact that the "efficiency" lemma relates, above all, to the actions implemented for controlling this plant, as this wish to be "more efficient" (36 co-occurrences) led environmental managers to be creative about the methods used to destroy the plant. Figure 4 summarizes the new techniques proposed (and when) and how their uses have evolved over time. We observed that while many techniques were tested, some were only very marginally cited in the documentation produced by environmental managers (thermal actions, grazing, *etc.*), and others had sometimes been abandoned (chemical treatments). On the other hand, other techniques were often mentioned.Mowing, for example, was the most cited method for controlling the plant. Uprooting was also well represented. It can be concluded that the information produced about Japanese knotweed *s.l.*was highly technical.

3.2.3. Issues mentioned for controlling this plant

In the documentation produced by environmental managers, actions against Japanese knotweed *s.l.*were strongly motivated by its impacts:there were 228 occurrences of the "impact" lemma present in the corpus. However, when we considered its co-occurring lemmas (Table 4), discourses on their possible impacts appeared to be rather weakly explained. While "environments" (n=30), "ecosystems" (n=16) and "landscapes" (n=11) were said to be affected by Japanese knotweed *s.l.*, the ways in which they were affected were unclear. The only impacts concretely qualified, albeit with very poor frequency, were related to the loss of biological diversity ("biodiversity", n=11; "diversity", n=7, "monospecific, n=4) or landscape diversity ("homogenization", n=2; "standardization", n=2). Few references were made to the role of foliage in reducing biodiversity ("foliage", n=4; "shade", n=3). Reduced access ("accessibility", n=4), and bank erosion ("undercutting", n=2), both induced by the plant, were only marginally mentioned.

3.3. Does every type of environmental manager have similar views about Japanese knotweed *s.l.*?

3.3.1. A diversity of arguments focusing on certain themes

The distribution of textual segments within the different classes of the top-down hierarchical classification, according to the type of environmental manager who produced them, provided information about the diversity of proposals relating to Japanese knotweed *s.l.* Each type of stakeholder was inclined to use certain classes of discourse. The probability of occurrence of classes, for each type of stakeholder, is particularly high a low in respect to a hypothesis of independence (Pearson's residuals; tables5a and 5b).

- Class 3, which describes all strategies and stakeholders involved in the management of Japanese knotweed *s.l.*, was significantly more represented in the discourse of regional conservation bodies compared to other stakeholders.

- Class 5, which describes origins, colonization strategies and the potential impact of Japanese knotweed *s.l.* invasion, was greatly more represented in the discourse of the regional water authority, whereas less represented in the discourse of consultancy firms.
- Class 4, which describes the role of watercourses in dispersing the plant, was more represented in the discourse of consultancy firms but also, to a far lesser extent, of environmental protection associations. It was on the contrary less represented in the discourse of other stakeholders.Class 2, which describes all the techniques used to eradicate Japanese knotweed *s.l.*, was generally more represented in the discourse of local or regional authorities or state services, oflocal water associations, and, to a lesser extent, ofenvironmental protection associations. Conversely, it was greatly less represented in the discourse of the regional water agency.
- Class 1, which is related to mechanical meansof crushing rhizomes, was more represented in the discourse of consultancy firms and, to a lesser extent,of building companies operating on the river. This class is less represented in the discourses of other stakeholders, particularly the regional water agency.

These results show that each group had a specific position when approaching the issue of Japanese knotweed *s.l.* Some types of stakeholders, such as the regional water agency, tended to emphasize all knowledge relating to the Japanese knotweed *s.l.* invasion processes. On the other hand, other types of stakeholders, such as local or regional authorities, state services, local water associations and environmental protection associations, were more likely to diffuse information relating to the techniques used for eradicating the plant. This was also the case for consultancy firms, who more specifically mentioned mechanical crushing techniques. Regional conservation bodies appeared to take a particular stand,as they gave a more general view of the issue, mentioning both strategies and the stakeholders involved in the management of Japanese knotweed *s.l.*

3.3.2. Degrees of emotionalism linked to the Japanese knotweed s.l. invasion

Four terms that were frequently usedto qualify the Japanese knotweed *s.l.* invasion were “impact”, “nuisance”, “risk” and “menace”, all of which have a negative connotation. Nevertheless, they were associated in the French language (the original language of the corpus), with different significations, thus revealing information about the way the environmental managers perceived the invasion.The “nuisance” and “impact” terms (in this corpus, systematically considered as negative) characterize the invasion in a tangible, measurable way.Other terms, such as “risk” or “menace”, on the other hand, refer to the invasionin a more intangible way: both evoke a potential danger. The former supposes that ecosystems and/or societies (often not specified further) were vulnerable to this invasion. The latter clearly evoked the danger associated with the invasion, as the termswere related to the vocabulary of fear and had a strong emotive connotation.

The different types of environmental managers seemed to have different uses for some of these terms (Fig5). In particular, the terms “impact” and “nuisance” were more represented in the discourse of the regional water agency compared to the whole population of managers. Conversely, the term “menace”was more represented in the discourse of local water associations. Thus, the Japanese knotweed *s.l.* invasion appeared to generate strong emotions, specifically among this group of environmental managers.

4. DISCUSSION

4.1. Discourses promote an integrated action andfocus on the eradication stage

This study indicates that environmental managers of the Rhone River strongly want to take action against Japanese knotweed *s.l.* This attitude may be encouraged by the many policy engagements aimed at controlling and even eradicating priority invasive species (Delbart*et al.* 2012). As there is heavy pressure being placed on the environmental managers who are held responsible for maintaining environmental quality for the future,the uncertainties linked with the management of Japanese knotweed *s.l.* may have contributed, in several ways, to the willingness to take action. Most invasions are spreading too fast and too unpredictably to do anything other than respond immediately (Sims and Finnoff 2013). Thus, the “wait and see” approach appears to be, in many cases, inappropriate, thereby justifying the motivation for environmental managers to act. Moreover, behavioural studies havedemonstrated that the threat of fearsome risks (those that induce strong emotional response, such as fear and anxiety) activate certain cognitive mechanisms that push people towards action (Loewenstein and Lerner 2003;Sunstein and Zeckauser 2011). Such reactions are thought to be more frequent in uncertain situations (Patt and Zeckhauser 2000). The emotional response of environmental managers to a Japanese knotweed *s.l.*invasion – tangible in their discourses– may explain their willingness to take action against the plant. This tendency may also be reinforced by uncertainties relating to the effectiveness of the proposed experimentalmethods of control. The absence of visible results and the need for repeated interventions encourage managers to experiment with other methods. This series of successive failures and the lack of control over the plant may have resulted in frustration among the network of environmental managers (Allison 2011), thus encouraging them to pursue other strategies.

Which actions are considered by environmental managers? Their discourses tackle a wide diversity of modalities of intervention and promote an integrated approach towards environmental management:

- Theytake into account every stakeholder (managers, economic actors, thepublic) and every territorial scale (local, regional, catchment) concerned with Japanese knotweed *s.l.*
- They consider different actions depending on the invasion stage.During introduction stage, knowledge acquisition and information campaigns are recommended; during colonisation stage, follow-up actions are proposed; andduring establishment stage, eradication measures are advanced.

Nevertheless, the discourses of environmental managers focus, above all, on possible actions when the plant is already established. They have tested over time a large variety of techniques aimed at stopping or at least slowing down colonization. The information produced about Japanese knotweed *s.l.* is very technical, and environmental managers mention all of their successes and failures, sometimes describing in detail the way they implemented actions and sometimes recommending certain procedures for increased efficiency. We believe that the development of discourses – and consequently of actions – relating tothe invasion prevention and monitoring stages are beneficial, and we argue that it is best to act at the earliest possible stage of the invasion, that is, before it is too advanced to be reversed (Boyer, 2005). In the Rhône River case, for instance, we have found that uninvaded areas, such asthe downstream section of the river, produce little information about the Japanese knotweed s.l. invasion. Conversely, the more heavily invaded an area is, the more documentation the environmental managers produce about these plants, and therefore, the more they worry about the presence of the plants. An efficient management system should consider implementing action before this stage.

4.2. Varying positions of environmental managers

Japanese knotweed *s.l.* has led to widely differing proposals, according to the type of environmental manager making the proposal. In particular, there appears to be a strong difference of approach between those managers who define policy at a regional level (regional water agency) and focus on the knowledge available and those who implement policy at a regional or local level (local or regional authorities, state services, local water associations) and focus on action. Managers implementing environmental policies arehighly interested in control and eradication techniques and the effectiveness of these techniques. They are also the ones more frequently using emotional language to characterize the Japanese knotweed *s.l.* invasion. This use of language may reflect their strong and increasing need for success in managing this issue given that since 2006, the majority of information produced about Japanese knotweed *s.l.* has come from these stakeholders. The pressure resulting from management policies that expect quick results in managing invasive species may be a more sensitive issue for managers in the field, as they directly experience the success or failure of their intervention and feel more directly responsible for it. From another perspective, the emotional component of their discourses may not be a sign of a greater preoccupation but may only translate their willingness to bring the Japanese knotweed *s.l.* issue to the attention of funding bodies (including the regional water agency) to obtain funds to act against the spread of this plant. The use of controversial language in the field of invasion biology has already been widely observed, sometimes because its terminology connotes nativism, racism or xenophobia (Subramaniam, 2001; O'Brien, 2006), sometimes because it is militaristic (Davis et al., 2001; Larson, 2005). These criticisms have led some authors to advocate that scientists use more neutral terms for introduced species (Larson, 2005; Davis, 2009). The results of our study may suggest that environmental managers do the same and be more attentive to the terminology used. We doubt that this evolution of language, if indeed possible (Larson, 2010; Simberloff, 2006), will lead to a consensus in the way that Japanese knotweed *s.l.* is perceived and has to be managed: those attitudes appear to be more firmly embedded and to be influenced by heterogeneity of worldviews about relation (and definition) of human society and biota (Simberloff, 2012). Nevertheless, such an effort would enable sharing of views and discussion about actions to implement on a more neutral basis.

The information provided by the regional water agency (the managers defining policy at a regional level) uses less emotive terms. Moreover, this agencysays little about the available methods for controlling the plant but rather focuses on the diffusion of knowledge related to the origins of the Japanese knotweed *s.l.* invasion, its colonization strategies and the nuisance it creates. The position of the regional water agency appears to be more reflective, or at least more dedicated, to the diffusion of information related to the Japanese knotweed *s.l.* invasion. Nevertheless, the attitude of the agency is far from disassociated with action,as the control of invasive species is part of the programmed measures (2010-2015) that it defined and funded[1]. However, as the information it produced did not focus on a way to achieve this objective, a gap exists between the two types of managers: environmental managers who implement management policies need effective methods to efficiently control the plant, as required by the regional water agency, but the agency only diffuses general knowledge related to colonization processes. Misunderstandings and frustrations may result from these heterogeneous positions. The communication strategy of the regional water agency may be more successful if their general information was complemented with more technical detailsregarding methods of eradication. However, even if the information produced by the regional water agency does not meet the expectations of environmental managers who have to implement these management projects, the efforts aimed at diffusing general knowledge regarding the origins, mechanisms and impacts of Japanese knotweed *s.l.* colonization should be maintained.

[1] Article OF6-C requiring to "fight against invasive exotic species".

4.3. Towards a more targeted management

In theenvironmental managers' discourses, the management of Japanese knotweed *s.l.*isapproachedfrom a global perspective. Recommendations for action define general rules regardless of the socio-economic and environmental context of the area under consideration. These rules flow from the premise that ecosystems are bounded by frontiers within which are found, either exclusively or primarily, native species. This premise, however,is far from the reality, and defining such a reference state is delicate if not impossible (Dufour and Piégay 2009). This perception of a stable and balanced nature has long been called into question by academic ecologists (Simberloff, 2014). According to this author, the idea of a balance of nature lives on especially among conservationists and environmentalists. This may explain why this point of view is salient in the discourse of environmental managers.

The efficiency of management may be improved ifa targeted strategy for each identifiable plant area was defined. Such a definition should then be the result of a wide collective reflection relating to local issueslinked withactionagainst invasive species. In view of thisidea, environmental managers may have interest in clarifying the local issues linked with action (or inaction) against the plant in each given context andin defining the priorities related to its control. There are questions that must be addressed. For example, are there ecologicalissues (detrimental to other species)?aestheticissues (size of plant and visual place in the landscape)?securityissues (decrease in visibility)?economic issues (bank erosion)?Are ecological or geomorphological characteristics of the invaded area favourable to a rapid dispersion of the plant? The efficiency of themanagement may benefit from a more specific, spatially heterogeneous action that considers local issues (Epanchin-Niell and Hastings 2010). Certain studies have already considered this approach and merit a specific attention (Filippi and Aronson 2010).

5. CONCLUSION

This article studied the documentation relating to Japanese knotweed *s.l.* produced by environmental managers working along the Rhône River and characterized their views on this invasive plant. The results indicatedthat there isa gap between the proposals of stakeholders defining management plans at a regional level and those of stakeholders who are implementing actions locally. Whereas the former werefocused on providing general knowledge about invasion processes, the latter werefocused on listing technical methods for controlling and eradicating the plants and providing information regarding the effectiveness of these methods. These different approaches result, each in their own way, from uncertainties related to biological invasions and may lead to misunderstandings among stakeholders. Nevertheless, they all agreed on one point: the need to take action against Japanese knotweed *s.l.* While there wasan interest in conducting targeted actions to meet local issues, to do so, the issues must be better defined. This is a challenging task that must involve all types of stakeholders including environmental managers, scientists, association members, users and the public. Uncertainties relating to environmental management can only be overcome if management projects result from political projects that have been collectively discussed and validated.

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