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Does invasive species research use more militaristic language than other ecology and conservation biology literature?

Rachel M. Janovsky[1], Eric R. Larson[1]

1 *Department of Natural Resources and Environmental Sciences, University of Illinois, Urbana-Champaign, Illinois, 61801, USA*

Corresponding author: *Eric R. Larson* (erlarson@illinois.edu)

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Abstract

Invasive species research has been criticised for a reliance on hyperbolic or sensationalistic language, including the use of militaristic language that dates to the popularisation of this concept. We sought to evaluate whether the invasive species literature used more militaristic language than other literature across the fields of ecology and conservation biology, given that many research areas in these fields (e.g. competition) may routinely use militaristic language. We compared militaristic language use in journal articles on invasive species or other topics across both applied and basic science journals in the fields of ecology and conservation biology. We further restricted our study to papers where lead-authors were located at institutions in the United States, to evaluate whether militaristic language use varied over peace time and conflict periods for this country. We found no significant differences in the percentage of journal articles that used any militaristic language between either invasive species research or research on other topics, but we did find that invasive species research used a greater frequency (count) of militaristic language per article than research on other topics. We also found that basic rather than applied science journals were more likely to use militaristic language and we detected no significant effect of time period on the usage of militaristic language in the ecology and conservation biology literature. Researchers working on invasive species should continue to be conscientious about their language use on this occasionally controversial topic, particularly in basic science journals.

Keywords

Alien species, animal behaviour, competition, exotic species, introduced species, literature review, natural enemies, natural defences, non-native species

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Introduction

Invasive species are generally defined as organisms that have been introduced from their native range to new regions of the world by human actions and either: 1) spread rapidly or widely where non-native (Richardson et al. 2000, Blackburn et al. 2011) or 2) result in some harm or negative effect to native species, ecosystems or human society (Parker et al. 1999, Young and Larson 2011). Invasive species have emerged as a major area of research and management interest over recent decades in fields like ecology and conservation biology, as these biological invasions have accelerated concurrent with increasing human mobility and global trade (Seebens et al. 2017). For example, invasive species have been routinely attributed as a driver of biodiversity declines and the extinction crisis (Clavero and García-Berthou 2005) and have further been identified as causing impacts to human health and economies (Pimentel et al. 2005). Yet research on, and management of, biological invasions has occasionally been controversial both within scientific fields (Davis et al. 2011, Simberloff 2011), as well as between scientists or managers and members of the public who may favour some non-native species identified as invasive (Loss and Marra 2018) or object to particular management strategies for invasive species (Bremner and Park 2007).

One critique of invasion biology is that this research area lacks objectivity, reflected in part by language use by scientists or managers working on invasive species that may be militaristic, nativist, sensational or xenophobic (Simberloff 2003, Verbrugge et al. 2016). The identification of this research area as potentially militaristic is especially clear given the names "invasion" biology and "invasive" species, which may imply related terms like "attack" or "assault" to many readers. Further, although recognition of introduced species as a phenomenon dates back to at least the 16th century (Chew 2011, Kowarik and Pyšek 2012), the field of invasion biology was popularised by Elton (1958), largely in response to his own work managing animals and plants impacting the British economy and food supply during World War II. Some researchers, working on such species, have favoured other terminology like "alien", "non-indigenous" or "exotic", but these words lack either the implication of negative impact, or spread, that distinguishes an invasive species from the greater proportion of non-native or introduced species that do not cause some identified harm (Jeschke 2014) or remain localised after introduction (Richardson et al. 2000, Blackburn et al. 2011). As such, "invasive species" and related terms have persisted as common or even dominant phrases for this phenomenon, while continuing to attract critiques for their militaristic implications (Larson 2005).

Beyond the use of invasive or invasion with reference to non-native species that cause harm or spread rapidly and widely, other militaristic language has been observed to appear in the literature on these organisms, ranging from descriptors of ecological effects that might include "attack" to descriptors of management interventions that might include "combat" (Larson 2005). For example, Larson (2008) reviewed 166 articles that were published between 1999 and 2003 in the journal *Biological Invasions* and reported 36 instances of militaristic language use within these papers. Yet many

areas of general interest in ecology – such as competition, predation or succession – regularly include language or metaphor use with militaristic associations, irrespective of a focus on invasive species. As examples, animal behaviour literature on competitive interactions between individuals, populations or species frequently uses terms like "fight", independent of any focus on biological invasions (e.g. Arnott and Elwood 2009), whereas plant ecology literature often refers to natural "defences" against natural "enemies" (Palo and Robbins 1991, Landis et al. 2000). If invasion biology is to be specifically criticised for its reliance on militaristic language and related consequences (see discussion), this might ideally be based on evidence for greater use of such terminology than the broader fields of ecology or conservation biology as a whole.

We expand on past studies like that of Larson (2008) by asking whether invasive species literature is more likely than research in ecology or conservation biology in general to use militaristic language (other than "invasive" or "invasion"). We documented militaristic language use in a random sample of research articles about either invasive species or other topics in both applied and basic ecology journals for two decades spanning periods of peace (1992–2001) and conflict (2002–2011) for our focal country (the United States). We expected to find more militaristic language use in invasive species papers than for other topics in ecology or conservation biology, given this research area's historic association with wartime impacts (e.g. Elton 1958) and previous criticisms on this language use in invasive species literature (Simberloff 2003, Larson 2005). We also anticipated that applied ecology journals might be more likely to use militaristic language than basic ecology journals, given that applied management actions or conservation goals might lend themselves to such militaristic language or metaphors (Larson 2008, Verbrugge et al. 2016). Finally, we were curious to determine if the cultural context of an active and prolonged period of military conflict might contribute to an increased use of militaristic language in invasive species literature in comparison to a relatively more peaceful preceding decade. Cumulatively, our study provides empirical evidence for the frequency of militaristic language use in invasive species literature in comparison to the fields of ecology and conservation in general across a variety of journals and over a recent two-decade time period.

Methods

We compared militaristic language use between research papers on invasive species to those on other topics in ecology and conservation biology for a series of applied and basic science journals over two time periods (peace and conflict). We used *American Naturalist*, *Ecology* and *Journal of Ecology* as basic science journals in our study; each of these journals does occasionally publish articles on applied topics, but were anticipated to be less likely to do so than journals dedicated to applied science in these fields, particularly when published by the same scientific societies (i.e. *Ecological Applications*). We used *Biological Conservation*, *Conservation Biology* and *Ecological Applications* as applied science journals in these fields; we did not include some relevant applied science

journals like *Biological Invasions* because they did not exist over the entire duration of our study period. We chose these six journals because they are leading journals in the fields of ecology and conservation biology that publish invasive species research and existed for the duration of our study interval.

We restricted our study to papers where the lead authors were located at institutions in the United States, in order to make a comparison of militaristic language use between a relatively peaceful time period for this country following the end of the Cold War (1992–2001) in contrast to an era of heightened military conflict (2002–2011), during which the United States engaged in major wars in Afghanistan and Iraq. We used the institutional address of the first author with the expectation that this was the person most responsible for writing the manuscript (Weltzin et al. 2006) and because the fields of ecology and conservation biology have had inconsistent interpretations of the meaning of corresponding or last author over time and relative to some other fields, where these designations imply seniority or primary responsibility for the work (Duffy 2017).

For each of the six journals included in our study, we sought to quantify militaristic language use in 10 invasive species articles published in the peace time period and 10 invasive species articles published during the conflict period, as well as in 10 articles on other (non-invasive species) topics published in the peace time period and 10 on other topics published during the conflict period. We selected articles for inclusion in this study using ISI Web of Science's (WoS) Core Collection, restricting searches to the relevant publication titles and time periods (above). We identified invasive species papers as those where the terms "invasive", "exotic", "alien" or "non-indigenous" appeared in a WoS topic search and identified all other papers as other topics. We confirmed these classifications during our quantification of militaristic language use in each scientific article (below). We omitted any articles where the address of the lead author was not at an institution in the United States per WoS. We further used WoS to omit any articles classified as opinion, editorials or reviews, restricting our analysis to primary research articles.

Upon compiling a list of candidate articles across our six focal journals for each time period (peace and conflict) and topic (invasive species or other), we used a random number generator to choose 10 from this list for each time, topic and journal combination, summing to 40 total articles considered for each journal. As exceptions, the *Journal of Ecology* published only two papers on invasive species, and the *American Naturalist* published only one, during the peace time period. As a consequence, our dataset consisted of 223 (rather than 240) articles analysed for frequency of use of militaristic language (Suppl. material 1). We downloaded the randomised articles (above) as PDFs and confirmed that they were either about invasive species or other topics, replacing any articles that were misclassified with the next available article on our randomised list for the appropriate time period and topic area.

We then quantified the frequency of militaristic language use in the PDF of each individual article by searching for and counting the following terms: army, attack, combat, defeat, defence, enemy, fight, war, weapon, win and victory. We also searched

for variations of the preceding words by tense, parts of speech or plural forms (e.g. fight, fighting etc.). We developed our word list based on militaristic language identified in past research on this topic (e.g. Simberloff 2003, Larson 2008, Verbrugge et al. 2016) and iteratively revised the list to include other words we encountered during our data extraction. We omitted proper nouns and words in the abstract, title or reference section from our count, instead including only militaristic language that occurred in the main text of articles. We did not count or include "invasive" or "invasion" in our analysis, assuming that these terms would certainly be more common in invasive species literature than other topic areas, focusing instead on the frequency of other militaristic language use within the fields of ecology and conservation biology (Larson 2005, Larson 2008).

We first tested whether the percentage of articles using any militaristic language (≥ 1 word) was different between papers on invasive species or other topics across all six journals together (n=6) or within the applied or basic science categories (n=3) using paired t-tests in SigmaPlot 14.0. We did not make this comparison between time periods owing to low replication of invasive species articles for some journals during the peace time period. We next sought to determine if the frequency (count) of militaristic words in articles varied by research topic, journal type and time period. We analysed this zero-inflated count data using generalised linear mixed models (glmm) with the glmmTMB package in R version 3.4.2. We used mixed models in order to include topic (invasive species or other), time period (peace or conflict) and journal type (applied or basic) as fixed effects, while including journal identity (i.e. *American Naturalist*, *Ecological Applications* etc.) as a random effect to account for variation between individual journals not included by the broader journal type category (applied or basic). We considered a number of models with different error distributions (e.g. Poisson, negative binomial etc.) and compared model performance with Akaike's Information Criterion (AIC). We found that negative binomial zero-inflated models best fit this dataset and used these models for our primary analysis.

Results

We found that a minority of research articles in the fields of ecology or conservation biology used militaristic language, as 67 of 223 (30.0%) scientific papers we searched used any of the terms or their variants included in our study. Invasive species articles in basic science journals were most likely to use any militaristic language (18 of 43 articles, 41.9%), articles on other topics in applied science journals were least likely to use any militaristic language (8 of 60 articles, 13.3%) and articles on other topics in basic science journals (21 of 60, 35.0%) or articles on invasive species in applied science journals (20 of 60, 33.3%) were intermediate. Invasive species articles in the basic science journals *Ecology* (55.0%) and *American Naturalist* (45.5%) and the applied science journal *Biological Conservation* (50.0%) had the highest incidence of militaristic language use, whereas articles on other topics in the applied science journals *Biological Conservation*

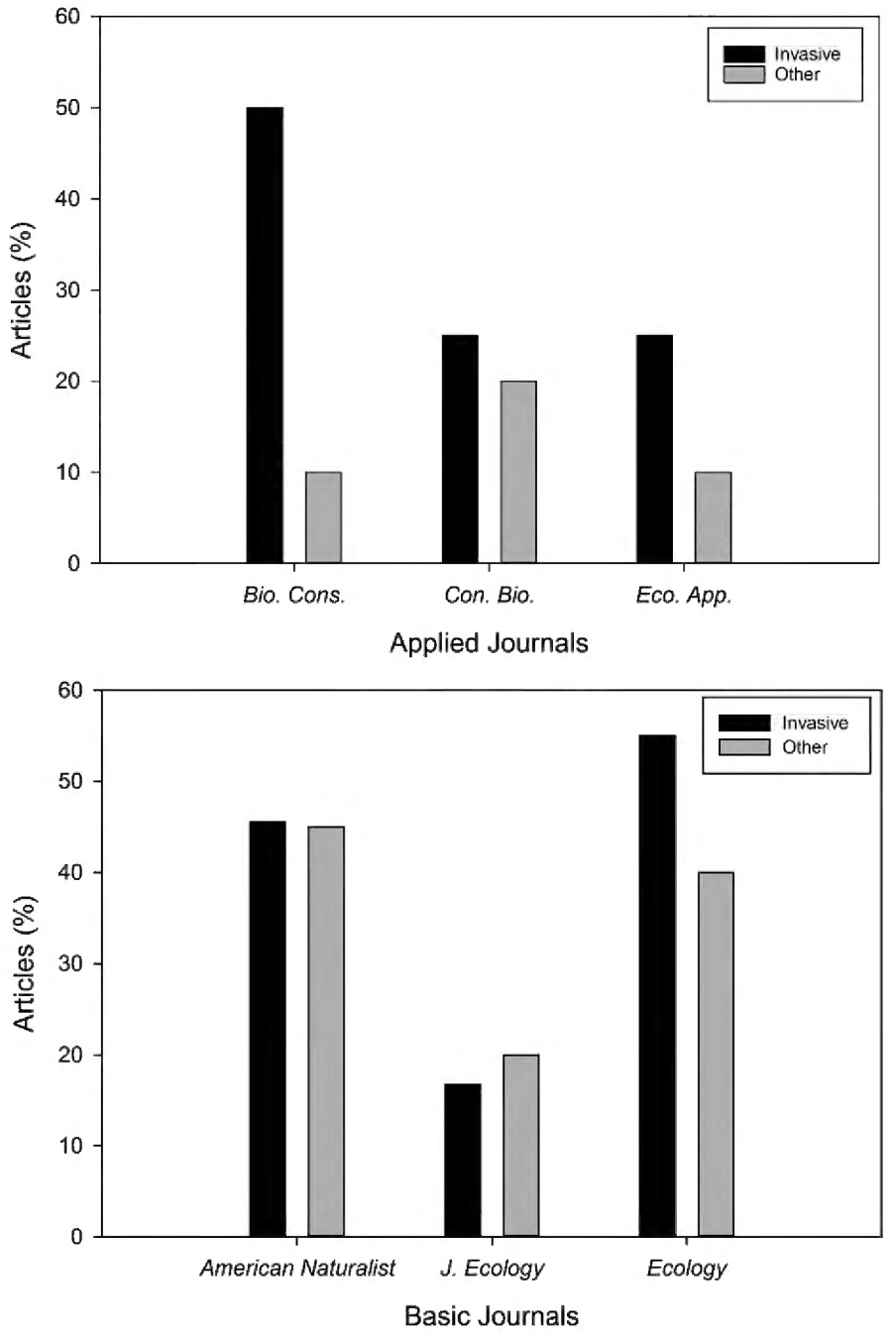

Figure 1. The percentage of articles published in three applied and three basic journals in the fields of ecology and conservation biology using any (≥ 1) militaristic language over our study period in papers either on invasive species or other topics. Each journal by topic (invasive or other) combination had 20 articles evaluated with the exception of invasive species articles for both *American Naturalist* (11) and *Journal of Ecology* (12), which had few eligible articles on invasive species prior to 2001 (see main text).

and *Ecological Applications* had the lowest incidence of militaristic language use (10% each; Figure 1). However, there was no significant difference in the percentage of articles using any militaristic language by paired t-tests, with all three P-values ≥ 0.12.

When testing frequency (counts) of militaristic word use in articles, we found that scientific papers in basic science journals and on the topic of invasive species were significantly more likely to use militaristic language than those articles in applied science journals or on other topics (Table 1). However, the time period (peace or conflict) had no effect on word counts of militaristic language within articles. Similar to the percentage of articles using any militaristic language (above), counts or frequencies of militaristic language words within articles were highly skewed or zero-inflated, with many articles having no use of this language, but some articles have very frequent use (Figure 2).

Table 1. Results of a negative binomial zero-inflated mixed model (glmmTMB package, R Version 3.4.2) on frequency (counts) of militaristic language use in scientific articles in the fields of ecology and conservation biology. These mixed models included time period (peace time or conflict), journal type (applied or basic science) and topic (invasive species or other topics) and also included journal identity (e.g. *American Naturalist*, *Ecological Applications* etc.) as a random effect.

Predictor	Estimate (SE)	P-value
Intercept	1.188 (0.403)	0.003**
Peace Time	-0.018 (0.284)	0.949
Basic Science	1.132 (0.499)	0.023*
Other Topics	-1.050 (0.330)	0.002**

Significant at ≤ 0.05 (*), ≤ 0.01 (**), ≤ 0.001(***)

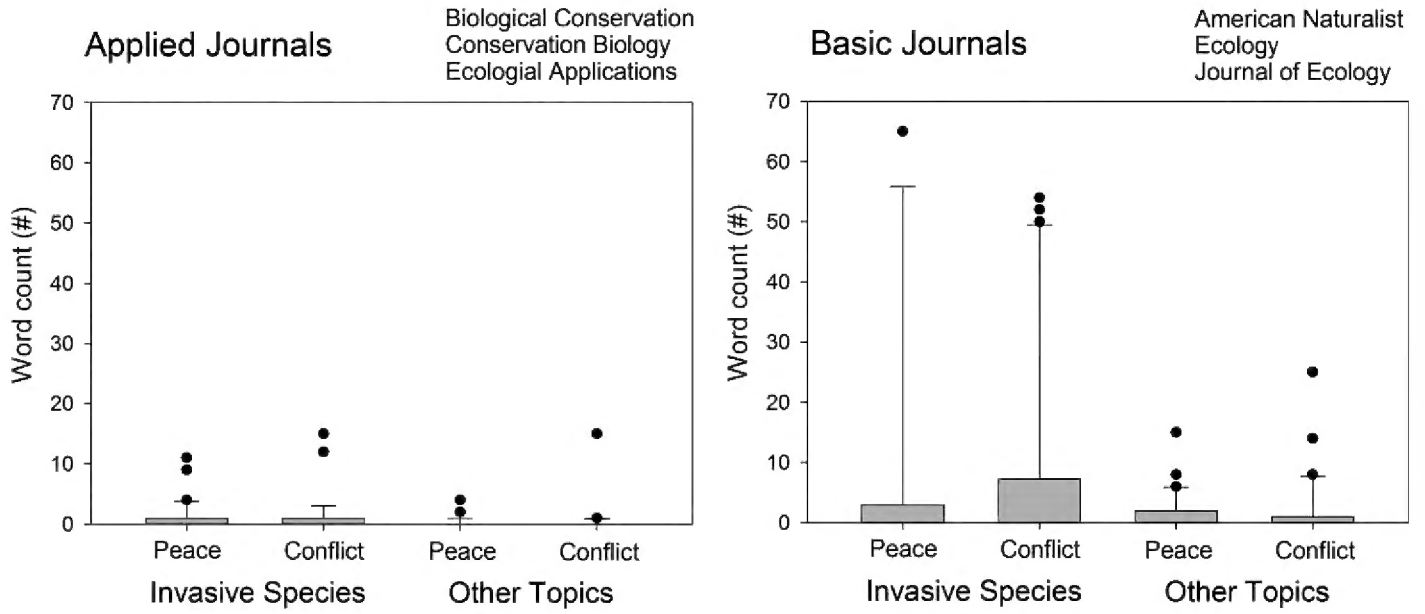

Figure 2. Frequency (counts) of militaristic language use (Table 1) in scientific journal articles in applied and basic science journals in the fields of ecology and conservation biology, given for papers on invasive species or other topics and for two time periods in the United States (peace time as 1992–2001, conflict as 2002–2011).

The most common militaristic language across these 223 articles were variants of attack/attacking (found in 14.3% of articles), defence/defends (found in 13.5% of articles) and enemy/enemies (found in 9.9% of articles). Terms like combat/combatting (2.2%), fight/fighting/fought (1.8%) and battle/battling (0.9%) were relatively rare and some terms like victory/victorious or war were never used in the 223 articles considered.

Discussion

The study and management of invasive species have been partially linked with militaristic context and language use since their popularisation by Elton (1958), yet this relationship exposes researchers or managers concerned with invasive species to accusations of bias or subjectivity (Larson 2005, Larson 2008). Such language could even

reduce support for invasive species research or management because of the "boomerang effect", in which some extreme persuasive language can have the opposite effect on its audience (Byrne and Hart 2009). Suggestions to use alternative terms for "invasive" or "invasion" have not been universally adopted, as many scientists and resource managers working on this topic prefer the implication of either impact or spread that differentiates invasive species from the majority of introduced or non-native species. However, if some use of "invasive" or "invasion" is inevitable in this literature, must other militaristic language be similarly inevitable? Larson (2005) gives vivid examples of scientists writing with militaristic metaphors about impacts of, or management responses to, invasive species and this same author later documented the frequency of such militaristic language use in the journal *Biological Invasions* (Larson 2008). However, because some militaristic language is widely used by certain concepts in the field of ecology (e.g. fights between individuals, natural defences, natural enemies), we sought to determine whether use of militaristic language was greater specifically in the invasive species literature relative to research on other topics in ecology and the related field of conservation biology.

We found that a minority of papers in ecology or conservation biology used any militaristic language (≥ 1 word use per paper), but this use was heterogeneously distributed, with papers in some journals using this terminology frequently and other publications using this terminology rarely. However, we found no significant difference between the percentage of journal articles using any militaristic language in invasive species research relative to other topic areas. We did, however, find that the frequency (count) of militaristic language use was significantly higher in both invasive species papers and in papers published in basic, rather than applied, science journals. We also evaluated whether the time period (peace or conflict) affected militaristic language use, restricting our study to papers lead-authored at institutions in the United States and defining a recent peace time and conflict period. We found no effect of time period on frequency of militaristic language use across these papers, suggesting that researchers in ecology and conservation biology were not necessarily influenced by cultural or historical context with respect to use of militaristic language.

It is perhaps not surprising that invasive species literature uses more frequent militaristic language than other research areas in ecology or conservation biology, given past work and criticism on this topic (Simberloff 2003, Larson 2005, Larson 2008, Verbrugge et al. 2016). We do caution, however, that our contrast of invasive species literature to the broader ecology or conservation biology literature did not match journal articles by specific topic or theme. Invasive species papers may be more likely to be on topics like competition where militaristic language is common, whereas broader ecology or conservation biology literature may include many topics – like ecosystem ecology – where militaristic language might be less common. For example, our papers with the most frequent use of militaristic language were often about competitive behavioural interactions between animals (McGlynn 1999) or about plant defences to enemies as contrasted with interactions with mutualists (Swope and Parker 2010). A future study could more closely match papers on invasive species to papers on other

topics in similar research areas using tools like propensity-score matching (i.e. Caliendo and Kopeining 2008) or restrict the overall analysis to narrower themes or areas in ecology (e.g. competition).

We were surprised to find militaristic language use more common in basic than applied science journals, which ran counter to our prediction that management or conservation-focused articles in applied science journals might be most likely to use militaristic language. Instead, the type of theory-driven research appearing in basic science journals in ecology (i.e. McGlynn 1999, Swope and Parker 2010) is apparently more likely to rely on militaristic language, defying our initial prediction. We propose that researchers working primarily in basic science in ecology might be less aware of controversies around language use in this field than applied researchers and, accordingly, more likely to use militaristic language. However, this hypothesis would require additional study, perhaps by conducting qualitative social science interviews with basic and applied ecologists (e.g. Selge et al. 2011).

We recognise that different methods or approaches could be applied to our research question in future work. For example, we developed a word list of militaristic language that we then manually searched for in a random sample of scientific articles. First, our word list is not necessarily exhaustive and could arguably be expanded to include some other terms, or be criticised for our interpretation of included terms as militaristic. Despite the somewhat *ad hoc* nature of our militaristic word list, we still found some significant differences in language between invasive species and other journal articles, as well as between applied and basic science journals, when analysing word frequency or count. Second, we restricted ourselves to manually searching a random 223 journal articles (of an intended 240), but machine-learning textual analyses could facilitate a much broader search of ecology and conservation biology literature for our question (e.g. Boiy and Moens 2009, Cheng et al. 2018). Finally, our study analysed primary research articles only, but militaristic language use by invasive species researchers or managers could be more common in opinion or editorial writing within scientific journals, or in communications to policy-makers or to the public (Verbrugge et al. 2016). We found militaristic language use to be relatively rare in invasive species research in particular and ecology or conservation biology research in general, but these scientific articles may not reflect the most common or most problematic uses of militaristic language in communicating about invasive species and other topics in ecology.

Conclusions

Whether communicating to other scientists, policy-makers or the general public, researchers working in the fields of ecology and conservation biology often seek to use metaphors and other literary devices to make their writing more accessible and engaging (e.g. Wood-Charlson et al. 2015). Yet some such language use in scientific writing can reflect biases or assumptions of the authors or cause negative reactions or criticisms from the audience (Simberloff 2003, Larson 2005, Larson 2008). For example, we find

the term "invasive" useful for distinguishing between introduced species that do or do not cause harm where non-native, or spread rapidly or widely after introduction, while simultaneously finding some sensationalistic language like "war" on invasive species to be hyperbolic or distasteful. As a result, we were curious to know how dependent invasive species literature was on militaristic language relative to the broader fields of ecology and conservation biology. We found that invasive species research does use significantly more militaristic language when present in an article than other research in ecology or conservation biology and that basic science in ecology makes more frequent use of militaristic language than applied science or conservation biology. Researchers in ecology and conservation biology should be conscientious about their choice of language in reporting their research, and this recommendation may be particularly urgent for basic science on the topic of invasive species.

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Supplementary material 1

Papers used in statistical analyses with counts of militaristic language use per paper

Authors: Rachel M. Janovsky, Eric R. Larson

Data type: statistical data

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