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Assessment of online search terms associated with aquatic invasive species and plant management: Implications for education and outreach

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ABSTRACT

People use search engines (e.g., Google) to find online information related to specific questions about aquatic plant management (APM). How people search about APM (e.g., what key words they use and what web sites they click on) is critical information to guide professionals from science-based institutions about best practices for educational programming to reach audiences searching the internet for solutions to control aquatic invasive species. This study examined 113 of the most searched key words relating to APM, and from these key words, 1,130 web sites were categorized into either institutional/governmental, commercial, or mixed purpose/other. Web-site quantity and web-site rank were recorded for each key word from Google, which controls the vast majority of the search-engine market in the United States. Our results showed there were significantly more commercial web sites present in the first 10 search results and that commercial web sites had the highest rankings overall compared to other categories. Key words that are scientific, specific, or about invasive species were more likely to result in institutional/governmental web sites. However, key words that are vernacular terms, are negatively framed, or are related to control/management were more likely to result in commercial web sites. Considering many APM web sites from institutional entities such as universities and government agencies are educationally motivated with an emphasis on science, the use of vernacular, negatively framed, or control/management terms in key-word searches for APM information would likely not result in finding these web sites. Overall, our results highlight likely communication gaps for scientific institutions that can provide useful insight for the creation of web sites, outreach materials, and promotional strategies to target an APM audience.

Key words: science communication, aquatic plants, search-engine optimization, web-site language, Google, macrophyte.

INTRODUCTION

Aquatic plant management (APM) is an increasingly important field, and effective communication about management strategies is crucial to considering factors such as the significant ecological and economic impacts of aquatic invasive species. Between 1970 and 2017, biological invasions have cost the global economy 1.288 trillion U.S. dollars (Diagne et al. 2021), and aquatic invasive species alone have cost the global economy an estimated 345 billion U.S. dollars over time (Cuthbert et al. 2021). Additionally, aquatic invasive species can cause significant harm to aquatic ecosystems biotically and abiotically (Vander Zanden et al. 1999, Gallardo et al. 2015, Jackson et al. 2017). Aquatic invasive plants can impact biodiversity, impede boating activity, reduce aesthetics, decrease native fish population, and alter the entire ecosystem (Santos et al. 2011, Schultz and and Dibble 2012). To manage these issues, a variety of tools are available (e.g., chemical control, biological control, mechanical control, etc.) (Hussner et al. 2017). Despite the importance of utilizing these tools in strategies for best practices of APM, the language, strategy, and social implications of APM are understudied.

The strategies for plant control vary widely depending on the stage of establishment, plant species, waterbody, and available resources (Netherland et al. 2005). Combining strategies with an "integrated pest management" approach and monitoring/assessing the biological community (Madsen and Wersal 2012) can be key to implementing ecologically optimized control actions. Integrated pest management is globally accepted as a more comprehensive method for pest control; however, a gap exists between this awareness and how often these principles are practiced (Hokkanen 2015, Stenberg 2017, Deguine et al. 2021). For example, lakeshore property owners in Wisconsin may seek chemical control methods as an initial response to new invasive plant populations when other approaches may be a better initial option (Shaw et al. 2024). This initial response of chemical control methods could complicate sustainable integrated pest management approaches (Owen et al. 2015) in future efforts to control macrophytes as well as aquatic photosynthetic organisms (APOs), which include cyanobacteria, algae, and aquatic embryophytes.

Other relevant communication gaps may exist. For example, a previous survey in Wisconsin found that lakeshore property owners are much less aware of aquatic invasive species management techniques than they are of ways to prevent their spread

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(Shaw et al. 2024). Additionally, some lakeshore property owners are willing to implement control actions that are harmful to native plants so long as these methods control invasive species (Shaw et al. 2024). This could be counterproductive, because some large-scale control efforts using herbicides can have a larger negative impact than the aquatic invasive plant itself (Mikulyuk et al. 2020, Vander Zanden et al. 2024) and only a small percentage of nonnative species introductions become highly abundant (Hansen et al. 2013, Vander Zanden et al. 2024). Moreover, lakeshore property owners indicate they are curious and hopeful when it comes to invasive species control actions (Shaw et al. 2024). Therefore, there is an opportunity to provide them with the best scientific information available for decision making about how to manage aquatic invasive species once present, because there are notable ecological benefits from aquatic invasive species removal (Vander Zanden et al. 2024).

Effective communication about APM necessitates understanding and addressing stakeholders' questions and concerns about aquatic plants they want to manage. These efforts can go awry or cause conflict due to poor communication and ineffective public engagement (Warner and Kinslow 2013, Crowley et al. 2017). Public engagement is necessary because people are vectors for the spread of invasive species and aquatic plants (Anderson et al. 2014, Lobato-de Magalhães 2023). The public can also provide valuable support for management and monitoring if ideal strategies are employed (Reaser et al. 2020). If scientific entities such as government agencies, universities, and conservation organizations aim to control or slow the spread of these organisms, then care should be taken to communicate effectively throughout any stage of the control effort. Education regarding aquatic invasive species has historically employed various methods to reach the intended audiences, using social media, signage and brochures, in-person outreach, and cinema advertisements (Shaw et al. 2014, 2021; Witzling et al. 2016). Additionally, existing research on aquatic invasive species communication suggests the analysis of search terms for optimizing outreach (Witzling et al. 2016).

Yet disparities may exist between connecting the searcher and noncommercially motivated results, because many businesses pay for online advertisements or may use key words less likely to be used by scientific entities offering online resources related to APM. When someone searches various terms related to APM online, a wide array of information sources with varying levels of credibility and authority, as well as different motivations, may appear in the search results. Considering this, if educationally motivated organizations want to expose the search-engine user to a wider variety of information and strategies for APM, understanding language used by the target audience could improve their outcomes. This could increase public engagement in these topics, help scientifically authoritative sources increase their audience, and develop strategic management options for invasive species driven by institutions and APM practitioners (Warner and Kinslow 2013).

However, effective communication can be difficult, because there are contrasting issues, cultures, and traits that surround different water bodies (Gabriel and Lancaster 2004) and how people talk about APOs. This leads to a diversity of terms when using search engines regarding APM/APOs. Specifically, across this diversity, colloquial terms used in online searches may not line up with scientific terms, which can cause a gap in information discoverability. Therefore, analyzing search language and general search data could be beneficial for natural resource professionals tasked with educating the public about APM. A person searching the internet to learn about APM options may believe they are receiving neutral results about their options, and yet may end up receiving biased or skewed information (White 2013) and product promotions from companies as options.

Google key-word analysis is commonplace among businesses to increase their page ranking (i.e., search-engine results page). Key words in this context are the terms or phrases one types in to the search engine to retrieve information, and the search-engine results page (SERP) is where they end up after clicking the search button. Existing research has examined how search-engine optimization techniques can enhance visibility for extension fact sheets (Moore et al. 2015), compared search volume of aquatic invasive species with other ecological problems (Kovalenko et al. 2021), and analyzed the sale of invasive aquatic plants online and which types of web sites are involved (Kay and Hoyle 2001). We used similar methods to determine what APM-related key words people are using in Google SERPs, and what type of web sites show up as a result of using those words. We further analyzed how certain types of web sites rank with different types of key words.

Because key words help determine the ranking of material on a particular subject (Iqbal et al. 2022), understanding key words relevant to APM could help the understanding of what information search-engine users are seeking and what web sites they are accessing using these key words and phrases. The objective of this research was to help scientific entities better understand search dynamics related to APM to increase traffic to their web sites and reach more online information seekers with science-based integrated pest management (IPM) strategies. We hypothesized that regardless of semantics (e.g., synonymity), how searches are worded will have a relationship with the type of the web sites people are exposed to (e.g., a commercial site vs. institutional site) and the ranking positions and quantity of these web sites in the SERPs. Results of this study can inform science communicators about content development and search-engine optimization to cater to the way people seek out information about APM.

MATERIALS AND METHODS

Key-word selection

More than 1,000 key words pertaining to aquatic photosynthetic organisms (APOs) and their management were examined before their selection for the study. The online software Semrush, which offers key-word analysis and search-engine optimization capabilities, was used to help identify key words and search terms. In instances where there were similar terms, the version of the key word with the highest traffic was used. Key words were targeted under the relationship of the concepts of "water," "plant," and APO "management," wherein relevant synonyms and related words were examined by APM experts based on traffic count on Semrush and referencing thesauruses. Related key words and variations of key words are suggested on Semrush, which informed the overall key-word selection for the

study. Specific key words, such as "Eurasian watermilfoil," were analyzed based on existing literature and selected if sufficient search data were generated. AnswerThePublic and Google Trends were also used to inform key-word analysis and selection, because trending data of searches and search suggestions regarding key words can help broaden understanding of relevant key words and reduce personal bias in selection. Key words related to aquatic plant management were only included in the final analysis if they received more than 20 searches per month in the United States. This list was reviewed by the project team comprised of aquatic invasive species outreach professionals, researchers, and practitioners, and in total, 113 key words were selected for further analysis using Semrush (examples in Table 1, full list in Supplemental Table 1).

Data collection

We searched each key word individually on the Semrush software (2023 Guru version), which pulls the data from Google. Manual confirmation of each Semrush result was checked using Google Incognito, in which site data and cookies are deleted when one exits the mode. For each key word, we recorded the amount of traffic for each key word, related key words, and key-word variations (Supplemental Figure 1). In analyzing each key word, we recorded the traffic volume per month in the United States and related key-word traffic volume per month. The top 10 organic (not paid for or advertised) results of the SERP were categorized as institutional/governmental, commercial, or mixed purpose/other (as described in the following).

For the top 10 web-site results in each SERP, we recorded the amount of traffic to web sites and the web-site ranking averaged in 1 yr from February 2022 to February 2023. All 1,130 web sites in our study were categorized and analyzed for highest rank in each SERP and most placements in all the SERPs. For categorizing web sites, each web site was individually examined and categorized, and this process was repeated by four different individuals. Overall, 5,276 web sites were categorized by all users with a reliability score of 97.6% (Mao 2017).

For each key word, the first listed web site/web page was recorded as the highest-ranking result. The most common category listed in the top 10 results for each key word was recorded. If a web site on the SERP was irrelevant to the field of aquatic plants or APM, then it was categorized as not relevant (i.e., the word "plant" within the key word "water plant," occasionally generating results for words related to water treatment plants or those that were industrially related but not related to APM). Key words were categorized into seven groups: specific APO terms (e.g., Eurasian watermilfoil), general APO terms (e.g., submerged aquatic vegetation), invasive species (e.g., invasive aquatic plants), negatively framed (e.g., aquatic weeds), control or management terms (e.g., Eurasian watermilfoil control), scientific terms (e.g., *Myriophyllum spicatum*), and vernacular terms (e.g., milfoil) (examples in Table 1, full list Supplemental Table 1).

Web-site categorization

Institutional/governmental web sites were defined as web sites intended for user education, instruction, or information from sources generally thought of as informationally authoritative, and that do not sell products or services. They were categorized

Table 1. Examples of key words that were analyzed associated with each category.

Scientific	Vernacular	Specific Aquatic Photosynthetic Organisms /Plant Terms	General Aquatic Photosynthetic Organisms /Plant Terms	Invasive Species	Negative	Control Terms
Myriophyllum spicatum	Milfoil	Eurasian watermilfoil	Aquatic plant	Invasive aquatic plants	Aquatic weeds	Eurasian watermilfoil control
Hydrophyte	Plants that grow underwater	Starry stonewort	Submerged aquatic vegetation	Invasive water plants	Fishing weeds	Aquacide pellets
Macrophyte	Lake grass	Duckweed	Lake plants	Invasive pond plants	Lake weeds	Lake weeds removal
Submerged aquatic vegetation	Cabbage weeds in lakes	Potamogeton	Pond weeds	Invasive pond weeds	Water weeds	Lake weed killer
Diquat dibromide	Lake seaweed	Water lilies	Floating plants	Invasive lake weeds	Weed that grows underwater	How to kill pond weeds

as institutional information pages if they are either a governmental organization (e.g., natural resource department), educational institution including university extension programs, or an entity created and supported by one of these (e.g., Fish and Wildlife Agency YouTube channel). Academic journals and peer-reviewed articles were also placed in this category. The authoritative extensions ".gov" and ".edu" typically belong in this category, while others like ".info," ".org," and ".com" can be considered depending on what organization is hosting them. The goal of these web sites is to increase awareness about aquatic plant management or potentially influence behavior with science-based information, but not financially benefit from sharing information about aquatic plant management.

Commercial web sites were defined as web sites intended primarily for promoting or selling products and services, although educational material might also be present (Martindale et al. 2001). Domains ending with ".com" were primarily expected to meet this definition, considering it was originally meant to indicate for-profit businesses; however, this ending is not exclusive to commercial entities. Other expected extensions were ".net" and ".co." If the web site sells a product or provides a service for money related to APOs or their management, it was categorized as commercial. However, if a web site generates income based on driving traffic to other web sites but not by products sold on their web site, this was not considered commercial. If the site offered a product not sold on their web site but sold through dealers, such as herbicide companies, then they were also considered commercial.

Mixed-purpose/other web sites were defined as web sites intended for commercial or informational purposes, but not entirely commercial; nor are they "formal" sources of information (government or institutional). Blogs, as an example, are separated from the informational category because they are typically not institutionally backed, may have higher potential for bias, and are commonly motivated by commercial entities through product placement or affiliate links that generate revenue. Extensions expected are ".org" and ".com." Wikipedia, lake associations, and even educational blogs may be primarily motivated by education, but are not considered a formal resource of educational material and were categorized as mixed purpose rather than formally institutional. Blogs, which post about products to generate commissions or advertisement money from the producer/seller, were not categorized as commercial unless they have a place to shop within their domain, but were categorized as mixed purpose. This category may make money through the promotion of products and make money through advertisement, but not by soliciting money directly from consumers for products or services.

Data analysis

Data were analyzed using GraphPad Prism Software 8.2b (GraphPad Software Inc., La Jolla, CA) or using RStudio software (version 2023.06.2 + 561) to determine the relationship between web-site categories and key-word categories. Prior to the use of parametric statistics, the assumption of normality was tested with a Shapiro-Wilks test and the assumption of homoscedasticity was tested with Bartlett's test. Nonparametric analyses were performed using a Kruskal-Wallis test, followed with a Dunn's multiple comparison analysis (X statistic presented). A Pearson R correlation of multivariate multiple linear regression was performed to determine correlation values of traffic and web sites, and we used a multinomial logistic regression model for additional analysis. Likelihood ratios (LR) were determined using chi-squared approximation (LR statistic presented). Data are presented as means ± standard error of the mean (SEM; n = sample size). Significance was set at $P < 0.05$.

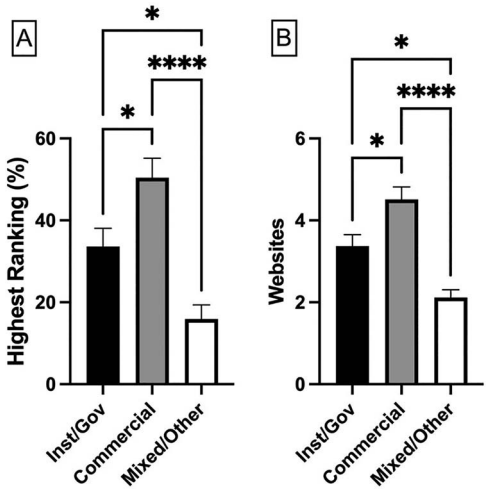

Figure 1. (A) The percentage of times each web-site category was ranked the highest in the search-engine results page. (B) The average number of web sites out of 10 that was associated with each of the key words. Commercial web sites tended to rank highest and most often in the aquatic plant management searches, followed by institutional/government sites, and followed by mixed purpose/other. Data are shown as means ± standard error mean. *P value < 0.05 as determined by Kruskal-Wallis with a Dunn's post hoc test. ****P value < 0.0001 as determined by Kruskal-Wallis with a Dunn's post hoc test.

Results

Commercial web sites were ranked the highest in significantly more of the key words' SERPs compared to institutional/governmental web sites and mixed-purpose/other web sites ($X = 30.20$; $P = 0.022$, $P < 0.001$, respectively) (Figure 1a). Commercial web sites recorded a significantly higher number of web sites in the top 10 SERP order associated with each of the key words compared to institutional/governmental web sites and mixed-purpose/other web sites ($X = 30.51$; $P = 0.016$, $P < 0.001$, respectively) (Figure 1b). We observed a strong negative correlation between institutional/governmental and commercial categories and a moderately negative correlation between commercial and mixed-purpose/other categories (Figure 2). We observed a weak negative correlation between institutional/governmental and mixed-purpose/other categories (Figure 2). We did not observe a strong correlation between key-word traffic and web-site categories, which suggests a well-rounded selection of key words based on traffic (Figure 2).

When key words were broken into categories, commercial web sites displayed the highest results in key words that were vernacular terms, were control or management oriented, and were negatively framed (Figures 3 and 4). Institutional/governmental results performed highest with certain types of key

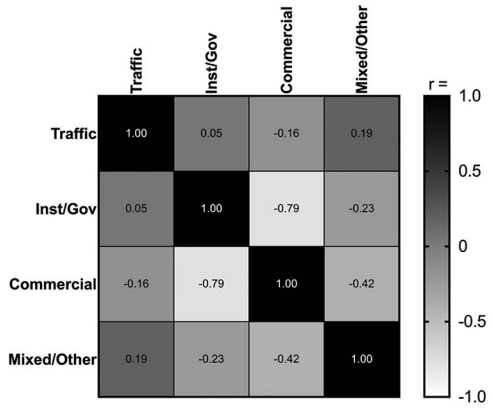

Figure 2. Correlation values of each web-site category next to their correlation with key-word traffic. Commercial web sites tended to appear less with institutional/governmental web sites, whereas institutional/government web sites and mixed-purpose/other web sites co-occurred more often than with commercial. Number in each box is equivalent to the r value. Correlation values were determined using a Pearson R correlation of multivariate multiple linear regression.

words, such as those related to invasive species, scientific key words, and specific key words (Figure 3 and 4). Mixed purpose/other did not display the highest results in any key-word category tested.

General key words

For key words defined as general, we observed no significant differences in the average quantity of web sites (Figure 3A) or highest ranking (Figure 4A) across all groups ($X = 0.2630$, $P > 0.05$; $X = 5.383$, $P > 0.05$, respectively).

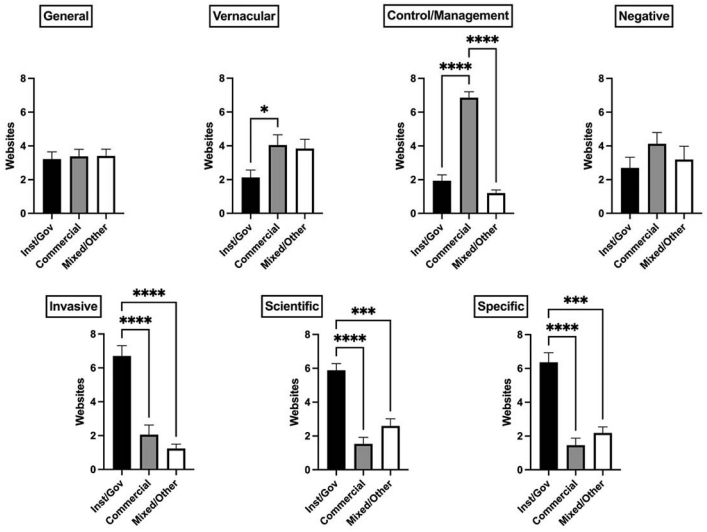

Figure 3. The average number of web sites in the search-engine results page results for key words based on web-site categories. Although most key-word categories had multiple web-site types appear in the top 10 search results, they often had more of one type of web site. This could make it difficult to find institutional information when looking for information on aquatic plant management. Data are shown as means ± standard error mean. ns indicates nonsignificant. *P value < 0.05 as determined by as determined by Kruskal-Wallis with a Dunn's post hoc test. ****P value < 0.0001 as determined by as determined by Kruskal-Wallis with a Dunn's post hoc test.

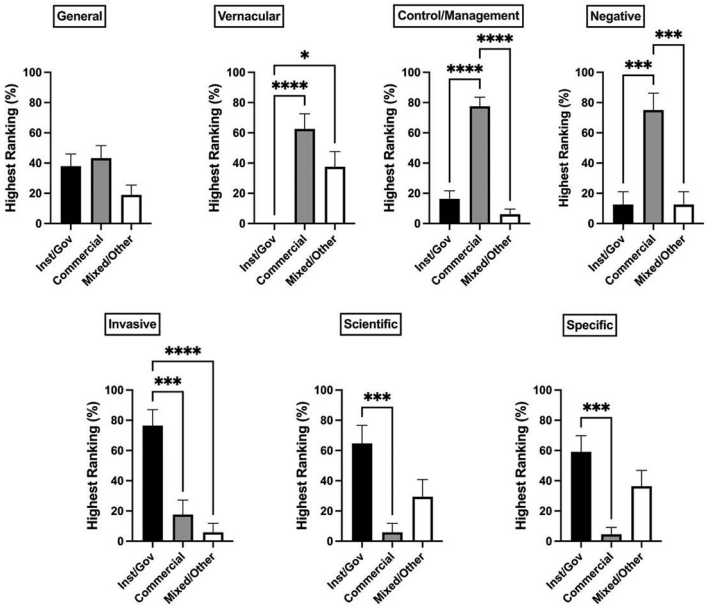

Figure 4. The percentage of the highest-ranked web-site category in the search-engine results page results for key words. Generally, outside of general key words, a single web-site category tended to be the top search result for a given key-word category. Data are shown as means ± standard error means. *P value < 0.05 as determined by Kruskal-Wallis with a Dunn's post hoc test. ***P value < 0.001 as determined by Kruskal-Wallis with a Dunn's post hoc test. ****P value < 0.0001 as determined by as determined by Kruskal-Wallis with a Dunn's post hoc test.

Vernacular key words

For key words defined as vernacular, we observed a significantly higher number of web sites that were categorized as commercial web sites as compared to institutional/governmental web sites ($X = 7.835$, $P = 0.039$). We did not observe a significant difference between mixed-purpose/other web sites and institutional/governmental web sites or commercial web sites (7.835, $P > 0.05$, $P > 0.05$, respectively) (Figure 3B). Additionally, commercial web sites and mixed-purpose/other web sites were ranked first significantly more often as compared to institutional/governmental web sites ($X = 21.08$, $P < 0.001$, $P = 0.019$, respectively). We did not observe a significant difference between the highest-ranked web sites between commercial web sites and mixed-purpose/other web sites ($X = 21.08$, $P > 0.05$) (Figure 4B).

Control/management key words

For key words defined as control/management, we observed higher amounts of web sites that were categorized as commercial web sites as compared to institutional/governmental or mixed-purpose/other web sites ($X = 78.49$, $P < 0.001$). We did not observe a significant difference between mixed-purpose/other web sites and institutional/governmental web sites ($X = 78.49$; $P > 0.05$) (Figure 3C). Additionally, commercial web sites were the highest ranked significantly more often as compared to institutional/governmental and mixed-purpose/other web sites ($X = 65.37$; $P < 0.001$). We did not observe a significant difference between the highest-ranked web sites between

institutional/governmental and mixed-purpose/other web sites ($X = 65.37$; $P > 0.05$) (Figure 4C).

Negative key words

For key words defined as negative, we observed higher amounts of web sites that were categorized as commercial web sites as compared to institutional/governmental or mixed-purpose/other web sites, but not at significant values ($X = 3.002$; $P > 0.05$) (Figure 3D). However, commercial web sites were ranked first significantly more often as compared to institutional/governmental and mixed-purpose/other web sites ($X = 3.002$, $P < 0.001$). We did not observe a significant difference between the highest-ranked web sites between institutional/governmental and mixed-purpose/other web sites ($X = 18.36$, $P > 0.05$) (Figure 4D).

Invasive key words

For key words defined as invasive, we observed more web sites that were categorized as institutional/governmental web sites as compared to commercial or mixed-purpose/other web sites ($X = 26.77$, $P < 0.001$). We did not observe a significant difference between mixed-purpose/other web sites and commercial web sites ($X = 26.77$, $P > 0.05$) (Figure 3E). Additionally, institutional/governmental web sites were ranked first significantly more often as compared to commercial and mixed-purpose/other web sites ($X = 21.45$, P < 0.001). We did not observe a significant difference between the highest-ranked web sites between commercial and mixed-purpose/other web sites ($X = 21.45$, $P > 0.05$) (Figure 4E).

Scientific key words

For key words defined as scientific, we observed significantly higher amounts of web sites that were categorized as institutional/governmental web sites as compared to commercial web sites or mixed-purpose/other web sites ($X = 27.43$, $P < 0.001$, $P = 0.001$ respectively). We did not observe a significant difference between the number of commercial web sites and mixed-puropse/other web sites ($X = 27.43$, $P > 0.05$) (Figure 3F). Additionally, institutional/governmental web sites were ranked first significantly more as compared to commercial web sites ($X = 13.15$, $P = 0.001$). We did not observe a significant difference between the highest-ranked web sites between institutional/governmental and mixed-purpose/other web sites or commercial web sites and mixed-purpose/other web sites ($X = 13.15$, $P > 0.05$) (Figure 4F).

Specific key words

For key words defined as specific, we observed higher amounts of web sites that were categorized as institutional/governmental web sites as compared to commercial or mixed-purpose/other web sites ($X = 30.29$, $P < 0.001$). We did not observe a significant difference between mixed-purpose/other web sites and commercial web sites ($X = 30.29$, $P > 0.05$) (Figure 3G). Additionally, institutional/governmental web sites were ranked first significantly more as compared to commercial ($X = 14.64$, $P < 0.001$). We did not observe a significant difference between the highest-ranked web sites between mixed-purpose/other web sites and institutional/governmental or commercial ($X = 14.64$, $P > 0.05$) (Figure 4G).

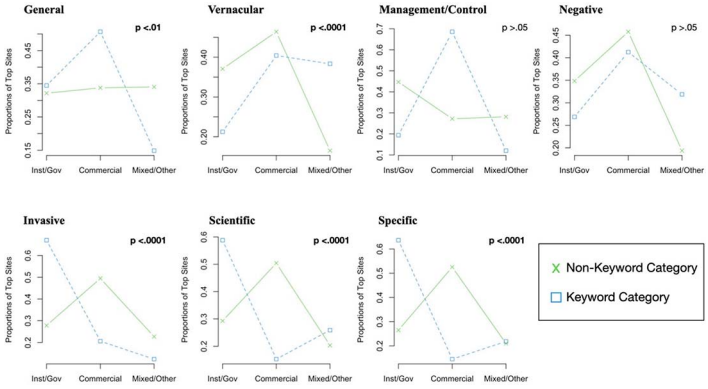

Figure 5. The key-word categories plotted against corresponding non-key-word categories with web-sites categories on the x-axis, and the proportion of the web-site categories on the y-axis. Non-key-word categories include every key word that is not in the named category. Each plot shows how a specific key-word category performed for each web-site type against every other key-word category combined. Generally, a web-site category performed better in one of the key-word categories than the other, suggesting that these web-site categories better utilize these key-word categories. *P* value is located in top right corner of each panel. *P* value is bold if statistically significant as determined by the chi-square test.

Key-word categories and non-key-word categories

For each key-word category we examined a respective non-key-word category, which contains every key word excluded from the named key-word category (e.g., scientific vs. the six other nonscientific categories). *Scientific* key words were significantly different for all web-site categories compared to non-scientific words (LR = 50.21, df = 2, $P < 0.0001$) (Figure 5). Although commercial web sites were more likely to appear for the nonscientific key words, institutional/governmental were more likely to appear for the scientific terms. Vernacular, specific, general, and invasive were significantly different from their respective "noncategories" (LR = 22.52, df = 2, $P < 0.0001$, LR = 23.22, df = 2, $P < 0.0001$, LR = 9.81, df = 2, $P < 0.01$, LR = 48.69, df = 2, $P < 0.0001$, respectively). However, the *negative* and *control* term categories did not show significant differences (LR = 3.46, df = 2; $P > 0.05$, LR = 0.08, df = 2, $P > 0.05$, respectively).

DISCUSSION

With a variety of terms about APOs and APM in use across the United States and the globe, it can be difficult to engage the public using language understandable to everyone. Future outreach should not be limited to filling perceived gaps of knowledge (McDivitt 2016), but adding a connection that puts priority on key-word and search-term relevancy to a target audience. Although engaging the public through new avenues can be informed by search-engine analysis, it is important to consider that increased knowledge of a subject issue may not correlate with agreement on solutions (Johnson et al. 1993, Malka 2009). This is true with aquatic invasive species and APM options such as mechanical methods versus chemical methods, as well as monitoring an organism's status. The

elaboration likelihood model suggests that relevance to the target audience and repetition is key to increasing audience engagement (Petty et al. 2009). As the message increases in relevance and repetition, active information seekers using search engines to learn more about APM will likely spend more effort in consideration of the information. If education is a goal, information regarding aquatic invasive species, APOs, and APM should be communicated repeatedly with high relevance to searchers or the intended audience by being deliberate about how key words are selected and framed for the target audience. Using the target audience's own terms may increase the likelihood they will find IPM information from institutional/governmental resources, improving the effectiveness of their outreach and increasing access to scientifically informed APM practices.

Many of the key words in the study were found to be strongly associated with either commercial web sites or institutional/governmental web sites. This distinction could also be looked at as scientifically authoritative web sites (institutional/governmental) and nonauthoritative web sites, which could be found by simply adding together the commercial and mixed-purpose/other categories. However, scientific authority can be subjective and some mixed-purpose/other web sites could be considered authoritative. Therefore subdividing the web sites into institutional/governmental, commercial, and mixed-purpose/other categories reduced the risk of subjective interpretations about how scientifically authoritative each of these were, where the scientific quality varied widely—making our typology helpful in our analysis. For example, analyzing the commercial category sheds light on the potential transactional nature of certain key words, seeing as many of the search queries could lead to financial transactions. Further studies on authoritative versus nonauthoritative web sites, as well as on transactional intent of key-word queries, may help researchers expand on the topic of this study and better inform educational outreach.

Although strong associations between some key words were expected, informational texts presented by institutional web pages often repeat information from other institutional web pages, causing these web sites to compete against each other in the SERPs. Our data suggest institutional/governmental web sites might be competing for traffic with specific, scientific, and invasive key words SERPs, but not participating as much in the SERPs of nonspecific, nonscientific, and noninvasive key words (Figure 5). To increase and diversify the audience for institutional/governmental web sites, institutional/governmental categories may benefit from ranking higher in different key words rather than ranking high for the same ones. For example, the key word "hydrilla" which is *invasive*, *scientific*, and *specific* expectedly had a SERP dominated by institutional/governmental web sites (9/10), yet the key word "aquatic plant," which describes "hydrilla," had little institutional/governmental web-site representation in the top 10 SERP results (1/10). For educationally motivated web sites such as institutional and governmental sites, competing among each other for key-word ranking may not be needed to achieve successful outreach, except that they could be keeping noneducationally motivated web sites out of the SERP on the terms they are ranking for.

Although repetition can be a good thing for getting audience attention, the relevance of this information is often not tailored to specific audiences, nor does it address many key words and information people are searching about APM. Our results suggest branching out and using other key words to reach new audiences seeking APM info online. This could be beneficial in the creation of web pages that are designed to encourage ecologically informed APM decisions, as even the most scientifically authoritative APM information will not be found by online information seekers if it is not reflecting search terms potential visitors are using. Existing prominent pages could continue using similar key words and retain their SERP ranking for these search terms; however, they might benefit from adjusting or adding key words that are not typically used by their category to attract more or different traffic from organic searches about APM to their web sites.

To increase web-site reach, even small nuances in key words should not be overlooked. Although it is not surprising that commercial web sites had higher-ranking results than the other web sites for most key words using the term "weed," this becomes complicated when a similar key word can have different meanings. As examples, we can point to "pondweed" (without a space) and "pond weed" (with a space). Note that "pond weed" or "pond weeds" are commonly used as *general* terms for aquatic plants, whereas "pondweed" is more specific and refers to the genus "*Potamogeton*" or family "*Potamogetonaceae*." This distinction performed as expected in the SERPs, where the key words "pond weed" and "pond weeds" were dominated by commercial web sites, and "pondweed" was dominated by institutional/governmental web sites.

Additionally, by adding vernacular terms (e.g., "cabbage weed") institutional/governmental web sites could reach a different audience. Although some of these key words may bring in less traffic, they could reach an audience who was previously unreached by institutional/governmental web sites. Considering that some mixed-purpose/other web sites encountered in this study contained misinformation and promoted the purchase and outdoor planting of nonnative species, diversifying the audience could be a valuable cause. Whether diversifying traffic or increasing traffic in general, outreach should be prepared for target audiences (e.g., anglers), messaging should be curated (Hutchins et al. 2023), and effort should be allocated to selecting key words strategically, to ensure their web-site content can be found by the target audience. This means to be most effective in reaching the target audience, one should know the target audience's terminology and utilize it, rather than expect them to know and use the scientific terminology. Being open to using terms like "cabbage weed" in combination with ones like "*Potamogeton*" could help reach the target audience, but care must be taken to continue to present scientifically accurate information.

Invasive, specific, and scientific key words were most associated with institutional/government web-site results. Particularly, our data suggest limited search results for commercial web sites for key words defined as invasive, which could suggest that many search-engine users may not inquire whether an organism is invasive when searching aquatic plant management options. Other studies have indicated that invasive aquatic plants have more engagement online with educational sources

than commercial (Kay and Hoyle 2001) and that engagement is not increased on social media with the use of militaristic or xenophobic language (Shaw et al. 2021, Chinn et al. 2023). Yet the framing of invasive issues could be affecting the heuristic decision-making process for those who go straight to management options, considering framing has been shown to impact actions related to invasive species (Flusberg et al. 2018). Future work should explore whether some search-engine users think macrophytes and other APOs are a nuisance regardless of invasive status, or if users are aware of and concerned with the invasive status but do not use these terms in their searches.

Our results provide those working with aquatic invasive species and APM a knowledge base regarding how the general public searches for online information about APM. Institutional/governmental web sites are often missing out on key words that are *nonscientific*, *vernacular*, *nonspecific*, *noninvasive*, *negative*, and *control terms* compared to commercial web sites. Commercial web sites were more likely to appear for key words that are defined as *general*, *control and management*, *noninvasive*, *nonscientific*, and *nonspecific*, than they were for the respective key-word counterpart (i.e., either the key-word category or the combined non-key-word category) (Figure 5). By incorporating these types of key words into their web-based content, institutional/governmental web sites may broaden their audiences for accessing educationally motivated web sites. By understanding search behaviors, informational web sites can use these data to direct traffic to more ecologically informed solutions for APM. By understanding key words and competing web sites, informational sources can use these data to increase their rank in search-engine results. This could be valuable in the IPM-related motivation for more ecologically informed solutions to undesirable plant, algae, or cyanobacteria activity in water bodies. These results help inform natural resource managers tasked with conducting outreach to develop accurate and useful material for guiding online information seekers to learn more about scientifically informed APM practices.

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