

**Education and Outreach****Communications, outreach and citizen science: spreading the word about invasive alien species**Eithne Davis<sup>1,\*</sup>, Joe M. Caffrey<sup>2</sup>, Neil E. Coughlan<sup>1,3,4</sup>, Jaimie T.A. Dick<sup>3</sup> and Frances E. Lucy<sup>1</sup><sup>1</sup>Centre for Environmental Research, Innovation & Sustainability, Institute of Technology Sligo, Ash Lane, Co. Sligo, Ireland<sup>2</sup>INVAS Biosecurity, 6 Lower Ballymount Road, Walkinstown, Dublin 12, Ireland<sup>3</sup>Queen's University Marine Laboratory, 12-13 The Strand, Portaferry BT22 1PF, Co. Down, Northern Ireland<sup>4</sup>Institute for Global Food Security, School of Biological Sciences, Queen's University Belfast, Belfast BT9 7BL, Northern IrelandAuthor e-mails: [Eithne.Davis@mail.itsligo.ie](mailto:Eithne.Davis@mail.itsligo.ie) (ED), [joecaffrey@invas.ie](mailto:joecaffrey@invas.ie) (JMC), [ncoughlan02@qub.ac.uk](mailto:ncoughlan02@qub.ac.uk) (NEC), [j.dick@qub.ac.uk](mailto:j.dick@qub.ac.uk) (JTAD), [lucy.frances@itsligo.ie](mailto:lucy.frances@itsligo.ie) (FL)

\*Corresponding author

Received: 31 May 2018 / Accepted: 4 October 2018 / Published online: 29 October 2018

Handling editor: Sarah Bailey

**Co-Editors' Note:**

This study was contributed in relation to the 20th International Conference on Aquatic Invasive Species held in Fort Lauderdale, Florida, USA, October 22–26, 2017 (<http://www.icaais.org/html/previous20.html>). This conference has provided a venue for the exchange of information on various aspects of aquatic invasive species since its inception in 1990. The conference continues to provide an opportunity for dialog between academia, industry and environmental regulators.

**Abstract**

Outreach is an important element of scientific communication and a prescribed element of many projects, but few scientists have training in communications. This paper describes the outreach element of a project on invasive alien species. A communications plan was drawn up to streamline communications efforts, allowing us to take advantage of unanticipated opportunities to engage with the public, while still maintaining the desired focus, using minimal resources. Here, we use two simple metrics—"passive reach" and "interactions"—to measure the extent and the intensity of communications, and we also look at the advantages and limitations provided by different media. Broadcast media and social media have the capacity to reach a wide audience, but have a low percentage of interaction. Workshops and citizen science events tend to reach a much smaller audience, but generate greater levels of engagement. Understanding these dynamics is important in designing an effective communications plan, which uses the minimum number of resources to generate maximum impact. Building the credibility of the researcher or the project means that your research will reach a wider audience, and your message is more likely to have an impact.

**Key words:** science communication, engagement, awareness, ecology, social media**Introduction**

The principle objective of this study was to measure and evaluate the reach achieved by the strategic and dynamic use of a communications plan within a specific project. Many scientists are reluctant to involve themselves in public engagement (Besley 2015). Good scientific communication is essential to breaking down barriers between research and practice, but it requires careful planning in both the execution and the evaluation (Spicer 2017). Invasive Alien Species (IAS)

are internationally recognised as one of the highest ranked threats to global biodiversity (Invasive Species Specialist Group 2000; Caffrey et al. 2014). The speed at which this problem is increasing in recent years is directly associated with the increase in global movement of people and goods (Perrings et al. 2005; Hulme 2009; Seebens et al. 2017). Prevention of IAS spread by man is dependent on changing the behaviour of a wide variety of stakeholders (García-Llorente et al. 2008; Lucy et al. 2012; Anderson et al. 2014; Pagad et al. 2015; Rouget et al. 2016). The

concept of “Biosecure Citizenship” involves the two-fold process of defining the spatial borders and boundaries within which species are considered to be “alien” or “native”, in conjunction with generating an understanding of biosecurity and a sense of responsibility amongst citizens to act towards controlling invasive alien species. (Barker 2010; Campbell et al. 2017) Clear information on IAS that delivers a consistent message, is locally relevant and accessible to all stakeholders can be difficult to produce and difficult to find (Lehmborg and Hicks 2018). Even when relevant information exists, the detail and the context may not be communicated to the relevant audience in an effective manner, and can lead to the misidentification of species (Campbell et al. 2017). In addition, species impacts and the public perception of those impacts vary greatly according to habitat and geographic location, even at a local level (Bonanno 2016; Russell and Blackburn 2017). Outreach in the context of IAS and biosecurity involves bringing what has been learned through IAS scientific research to relevant stakeholders in an engaging and understandable way, and using the feedback received to inform IAS management systems (Wright et al. 2015; Illingworth 2017).

Communication on invasive species is challenging for a range of reasons. Individual species can be difficult to reliably identify without specialist skills and/or equipment. There is often a conflict between economic, societal and ecological priorities (Campbell et al. 2017). Conflicting scientific opinions around native/non-native species, and arguments for the beneficial impacts of invasive species cause confusion amongst the lay audience (Campbell et al. 2017). The complexity and expense of management and control measures makes commitment to management programmes daunting, and undermines attempts to familiarise the general population, practitioners and policy makers with the importance and urgency of undertaking these measures in a correct and effective manner (Barker 2010).

Peer-reviewed publications are central to the scientific method, but both the results and the key messages must be made readily available *via* a range of channels appropriate to the intended audience (Carr et al. 1997; Sunderland et al. 2009). In this age of communications, more types of media than ever are available (Seaward et al. 2015; Wright et al. 2015; Rania 2017). Working on new research in parallel with delivering established knowledge to a wide variety of stakeholders requires a communications strategy, and the obvious document to underpin this complex workload is a bespoke and effective communications plan (Jarnevich et al. 2015; Bennett et al. 2017; Hu et al. 2018).

Clarifying the focus of your message at the beginning of any outreach programme is important for maintaining consistency throughout the life of the programme. The extent of your reach with this message will be dependent on the choice of medium, the human and material resources available, and the capacity to be flexible enough to take advantage of unexpected opportunities that arise. It is important to include all available forms of communication, even the simplest, in the communications plan. In an outreach campaign which includes the use of online channels and social media, many metrics are available which, if carefully analysed, can give important insights into what is working best and where the most value is seen for efforts expended (Constantinides 2014; Thelwall and Kousha 2015; Wolf 2017).

This study was undertaken as part of a larger project on the prevention, control and eradication of IAS. In this study, the purpose of the outreach programme was to disseminate the importance of IAS prevention, control and eradication to all relevant stakeholders. The stakeholders in question are from all strata of society and all activity types, from infrastructure designers to academics, local authorities and the general public. The main objective was to maximise outreach throughout the island of Ireland by taking advantage of all available media in a dynamic fashion and measuring the reach achieved. Wherever possible, all the various strands of communication used were monitored as a whole, and an opportunistic approach was taken in order to “piggyback” on events and broadcasts, keeping the project in the public eye and increasing the audience at every opportunity (Illingworth 2017). The outreach programme described here includes a citizen science recording initiative, the Winter Heliotrope Challenge, which was an Irish nationwide competition that was run in two successive years.

## Methods

This research was carried out as part of an Irish Environmental Protection Agency (EPA) Medium Scale Project (2015-NC-MS-4) on the prevention, control and eradication of invasive alien species, from 2016 to 2019. Communications was just one of four work packages in the project. Key stakeholder groups were identified by referring to the literature (Caffrey et al. 2014) and by consulting experts in the field.

The list of relevant stakeholders was drawn up and divided into three categories – public, professionals and policy-makers. The full details of the individuals and organisations identified were listed in the communications plan.

**Table 1.** Three main stakeholder categories were identified, and the various sub-categories of stakeholders were sorted appropriately, for the purpose of communications.

Stakeholder Category	Sub-category
Public	
Professionals	Communities of practice
	Technical Experts
	Port and Airport Authorities
	Industry organisations
Policy-makers	Project team, sponsors, steering committee
	Research organisations and funding bodies
	Relevant Non Governmental Organisations
	Relevant current research projects
	Relevant national policy-making bodies

**Table 2.** An appropriate method for communicating with each stakeholder category was identified, through matching accessible communications methods with the categories as defined in Table 1. This is not a conclusive method, but was informed specifically for this particular project by the experience of the project team members.

Medium	Public	Professional	Policy-makers
Email	√	√	√
Formal meetings	√	√	√
Informal meetings		√	√
Website	√	√	√
Social media	√	√	√
Broadcast media	√	√	√
Print media		√	√
Signage	√		
Workshops	√	√	√
Reports		√	√
Shared folders			√
Academic papers			√
Conferences			√

The limited resources available to the project (including time and manpower) were taken into account, and only communication resources that were already available or easily established were considered. By discussion with the members of the project team, stakeholders, in their groups, were then matched with what we felt would be appropriate media for communicating with that particular group (Table 1). Using this format, we identified the different stakeholders, the general category that they fit into, and appropriate media by which to contact them (Table 2). The table was reviewed and adjusted at fortnightly intervals for the first three months of the project based on our experience during that time.

Once the stakeholder groups and their relevant media were identified, we then chose three keywords which we judged (1) to clearly identify the problem (*Invasive Species*), (2) what we are aiming to protect (*Biodiversity*), and (3) the management mechanism being promoted (*Biosecurity*). The keywords were then used as a focal point for social media postings, regularly cross-checked, to keep the message clear and consistent. These keywords were used as search

terms in Google, filtered to “news” items. News articles and academic papers were scheduled for daily posting via the free “Buffer” web service, with an appropriate comment and image.

A schedule of communications was drafted to list all deliverables, which were identified at the beginning of the project. Designed as a living document to span the three years of the project, this schedule was reviewed and updated monthly, with new opportunities for dissemination added as they arose.

Outreach efforts were targeted at as broad an audience as possible, without compromising the quality of the message (Hart and Larson 2014; Jefferson et al. 2015). In order to engage a broad audience, the project team chose to keep the message simple and clear, sharing only articles which were supported by scientific research, and which could be readily understood by the general public. Social media accounts were set up on a range of platforms – namely Facebook, Twitter and Instagram. All social media accounts were streamlined with the title “Invasive Aliens” (a simple title that was available across all platforms) and were given identical cover images and profile pictures.

This, coupled with the focus on keywords, gave the Invasive Aliens “brand” a recognisable and stable image (Hartmann et al. 2005; Jin 2012). An online resource (<https://buffer.com/>) was used to schedule automated posts, which were monitored for issues and interactions arising (Lua 2017; Hwong et al. 2017). After the first month, it was decided to focus mainly on Twitter, with Facebook posting by default, and leaving the Instagram account on hold for future development, as there was not time to tailor posts appropriately to all platforms.

As opportunities arose to contribute to mainstream broadcast and print media productions, these were integrated into the schedule of communications, and viewed holistically to see how added value could be gained. This media work was taken on by the project team, in addition to scientific research, without engaging professional media, so resources were limited. We made contact with programme makers and developed a relationship with the main environmental broadcasts nationally. Upcoming programmes and publications were promoted on the Invasive Aliens platforms before broadcast/publication, and links were shared post-broadcast.

The project team contributed to “10 Things You Should Know About Aliens”, “Ear to the Ground” and “Eco Eye”, all television programmes which were shown on Radio Telefís Éireann (RTE), the Irish national broadcaster. Radio programmes which the project featured on were “Drivetime” and “Mooney Goes Wild” (RTE), and a primetime programme on Castlebar Radio (Local radio). The “10 Things You Should Know About Aliens” (New Decade TV 2017) programme was used to launch a citizen science campaign, the Winter Heliotrope Challenge, which was then driven by social media. The Winter Heliotrope Challenge was managed in conjunction with Ireland’s National Biodiversity Data Centre, which provided a dedicated online reporting platform. The National Biodiversity Data Centre has both a mobile phone application and a web-based reporting platform, dedicated to gathering biodiversity records in Ireland. The NBDC created a dedicated page for reporting sightings of Winter Heliotrope (*Petasites fragrans*), and this page was left live for the duration of the challenge. Participants were asked to take a photo of the plant and provide details of location and abundance. At the end of the allotted time, all records generated were absorbed into the NBDC’s database for the national record, and these national records are routinely fed into the Global Biodiversity Information Facility (GBIF) database.

Winter heliotrope (*Petasites fragrans*) is a terrestrial plant, native to North Africa and the Mediterranean coastal region. Introduced to Britain, and then to Ireland in the mid-19<sup>th</sup> century, it has become

invasive, particularly along roadside verges and waste ground (Presl 2017). The winter heliotrope records generated during the Winter Heliotrope Challenge in December 2016 and December 2017/January 2018 subsequently fed into the GBIF database (Presl 2017; NBDC 2018).

Wherever possible, invitations to attend community events that could potentially lead to outreach impact were accepted by the team and recorded in the schedule of communications.

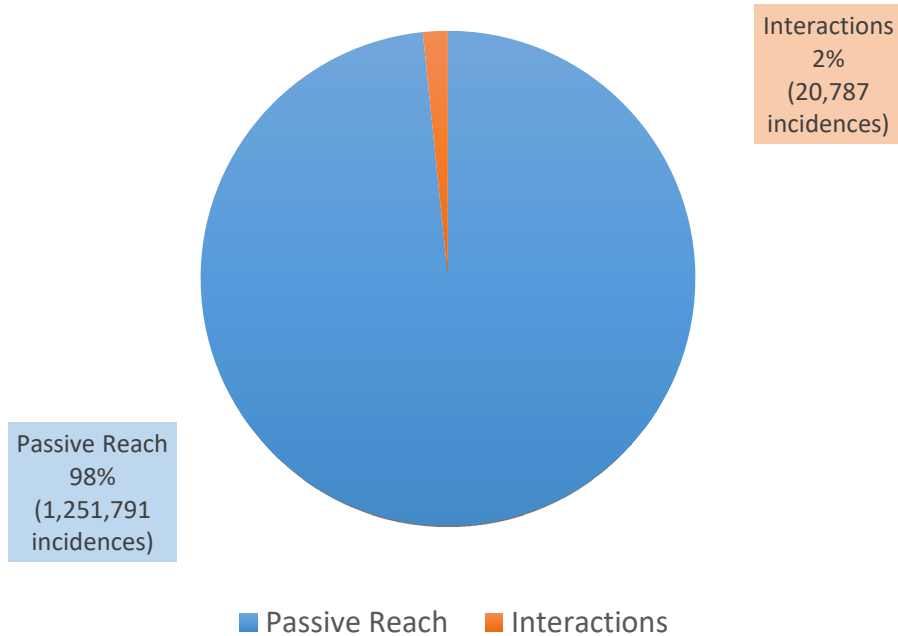
For the purpose of this study, a simple metric was used to differentiate between quantitative and qualitative outreach. Media channels were categorised as either static or interactive. The extent of the outreach of each medium was identified under two headings: “passive reach” and “interactions”, depending on whether a message was simply delivered to the audience member (passive reach), or whether the audience members measurably engaged with that message in some way (interaction) (Sigerson and Cheng 2018). Twitter and Facebook data were gathered at monthly intervals from the analytics function on those sites, audience figures for broadcast media were provided by the programme producers from the TAM ratings, and attendance at workshops and public events were recorded at the event.

All measured data were imported into a spreadsheet and analysed according to the medium used, whether they represented “passive reach” or “interactions”, and whether and where growth was achieved. Comparisons were made between the number of individual incidences of “passive reach” and “interactions”. For clarification, “passive reach” is defined, for the purpose of this study, as the number of users passively exposed to a message, image or link where it appears on their Twitter or Facebook feed, or is presented to them on broadcast media. On the other hand, “interactions” reflect the number of users who engaged with message, image or link by “liking”, commenting, or by following the link. Passive reach may be nothing more than a subliminal message, whereas interactions involve genuine engagement by the stakeholder with the message being disseminated.

The Winter Heliotrope Challenge was viewed as a standalone event. Metrics gathered from the event were restricted to location of the record, as data protection prevented us from accessing more detail on the participants.

After two years of the communications plan being in place, the results to date were assessed. In analysing the impact of the various media outputs, a spreadsheet was populated and graphs produced to illustrate the various results. Trends were observed for consistency or deviation in patterns of activity and for positive or negative growth in activity.

## PROPORTION OF OVERALL OUTREACH MOMENTS IDENTIFIED AS INTERACTIONS OR PASSIVE REACH



Channel of Communication	Total no. of incidences of reach	% of incidences which were interactive	Details
Broadcast media	593,000	0	Total of 7 broadcasts, including television and radio
Workshops	118	58	Total of 4 workshops, averaging 30 people
Public events	820	33	Total of 2 public events, averaging 420 people
Citizen science	152	100	Total of 2 events

**Figure 1.** The chart shows the very small proportion of media outreach moments which were identified as being interactive (2%). The channels of communication which generated the most extensive reach (broadcast media and social media) gave proportionally the smallest number of interactions, while the smaller events gave a high percentage interaction with the audience.

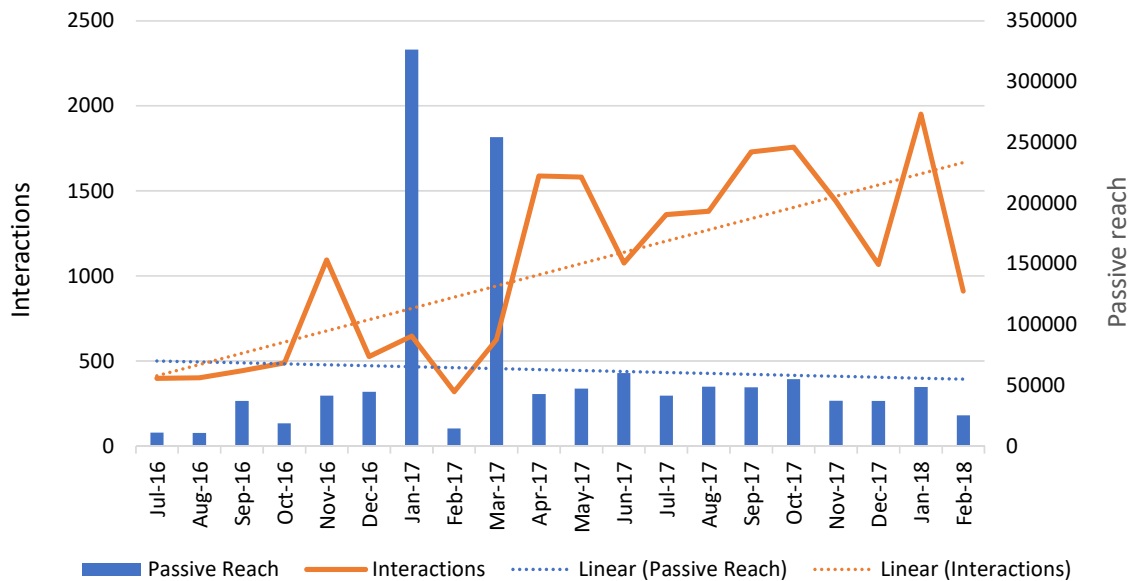
### Results

#### *Evaluating the success of the outreach campaign*

The results presented in Figure 1 showed that the channel of communication which achieved the greatest reach had the least number of interactions. Conversely, the channel of communication that

achieved the smallest reach had the greatest percentage of interactions.

The overall results of the study showed a wide variance in the extent of passive reach at different stages. The months in which television and radio programmes were broadcast gave a high reach, leading to an apparent decrease in overall passive reach over the two-year period in question. In contrast, there was a steady growth in interactions,



**Figure 2.** Relative comparison of growth rates in incidences of passive reach and interactions per month. Peaks in passive reach reflect times when programmes were broadcast, reaching a large audience. A steady overall growth in interactions can be seen over the period.

**Table 3.** Results of analysis on Winter Heliotrope Challenge show growth in all areas measured. The Winter Heliotrope Challenge in Year 2 resulted in a 97% increase in average recordings of heliotrope per day, or an overall increase of 457 recorded sightings.

Year	No of records	No of recorders	No of Counties	No of tweets	No of days run	Avg records per day
2016/17	188	38	18	13	31	6
2017/18	645	114	28	20	54	12
Change	+457	+76	+10	+7	+23	+6
% Change	+243%	+200%	+56%	+74%	+74%	+97%

illustrating a growing engagement from the audience (Figure 2).

Table 3 shows an analysis of the trends in outreach achieved over the period of the study.

The Winter Heliotrope Challenge in Year 2 resulted in a 97% increase in average recordings of heliotrope per day, or an overall increase of 457 recorded sightings.

*Overall findings*

The results from this study show that a strategic communications plan is a considerable asset in focussing and monitoring an outreach campaign. This outreach campaign delivered a broad outreach message in a passive manner, as well as engaging relevant stakeholders at more localised, focussed, interactive events. The media that generated the greatest reach resulted in the lowest percentage rate of interaction with stakeholders, while the more localised, focussed events generated the greatest level of interaction.

**Discussion**

Our results confirm that a communications plan is a practical and relatively effective way to maintain the primary focus of a cohesive outreach programme, while allowing for flexibility in reacting to opportunities which arise. At the beginning of this outreach programme we identified our key stakeholders and the media type by which they would most probably be reached. Our principle target audiences were the general public along with professional ecologists. Our aim was to communicate issues around IAS in an appropriate manner and to raise awareness. Awareness is a necessary precursor to instigating prevention measures against the introduction and spread of IAS (Bremner and Park 2007; Eiswerth et al. 2011). Quantitative measurement of the effectiveness of communication was difficult to achieve. We identified the strengths and weaknesses of the various channels of communication used by measuring the “passive reach” (reflecting the extent of dissemination), and “interactions” (reflecting the intensity of the disse-

mination) and comparing the two (Figure 2). Passive reach reflected the most extensive communications, but may only have influenced the audience on a subliminal level. Passive users see social media as a way to gather news by following other accounts and reading what is shared by sources they trust on social media. (Wolf 2017)

In relying on the general public to engage in any management or control measures for IAS, or even for reporting the presence of IAS, there is an inherent risk of mis-identification by a non-expert group. This can result in misreporting of IAS, non-recognition of IAS. Awareness of IAS amongst the public does not reflect accuracy in identifying and reporting IAS. There is, therefore, and inherent risk in relying on citizen science participation in IAS programmes without supplying adequate supports (Cohn 2008; Campbell et al. 2017).

In observing the type of engagement in this outreach programme, interactions implied that the audience engaged with the information and, therefore, had a more intense or conscious experience of their awareness being raised, implying deeper learning (Jucan and Jucan 2014). We used a range of media forms and each of these facilitated the delivery of the message to a different extent and intensity.

### *Broadcast media*

The greatest passive reach came from the broadcast media (860,000 individual incidences). After being broadcast once, the television and radio programmes were generally not viewed again and, therefore, the message is a once-off moment in time, and there was no recorded interaction from these broadcasts. The wide variance in the  $R^2$  value recorded (see Figure 2) reflected the spikes in audience figures from broadcast media events. We addressed this limitation in two ways. Firstly, we used social media to prime our followers in preparation for the broadcast, and to drive traffic back from the broadcast to our social media platforms. Secondly, one short piece of video was broadcast on YouTube and, at the time of writing, had achieved 119 views. This was a much smaller number than the programme itself, but reflected an engaged audience who sought out the piece and viewed it intentionally. In the future, further use of online platforms to publish material which has already been broadcast can deliver greater value for resources and increase the longevity and the quality of the dissemination.

These communications were delivered in a passive fashion, to a non-interactive audience. After the broadcast, many people indicated personally to us that they watched or listened with interest and expressed

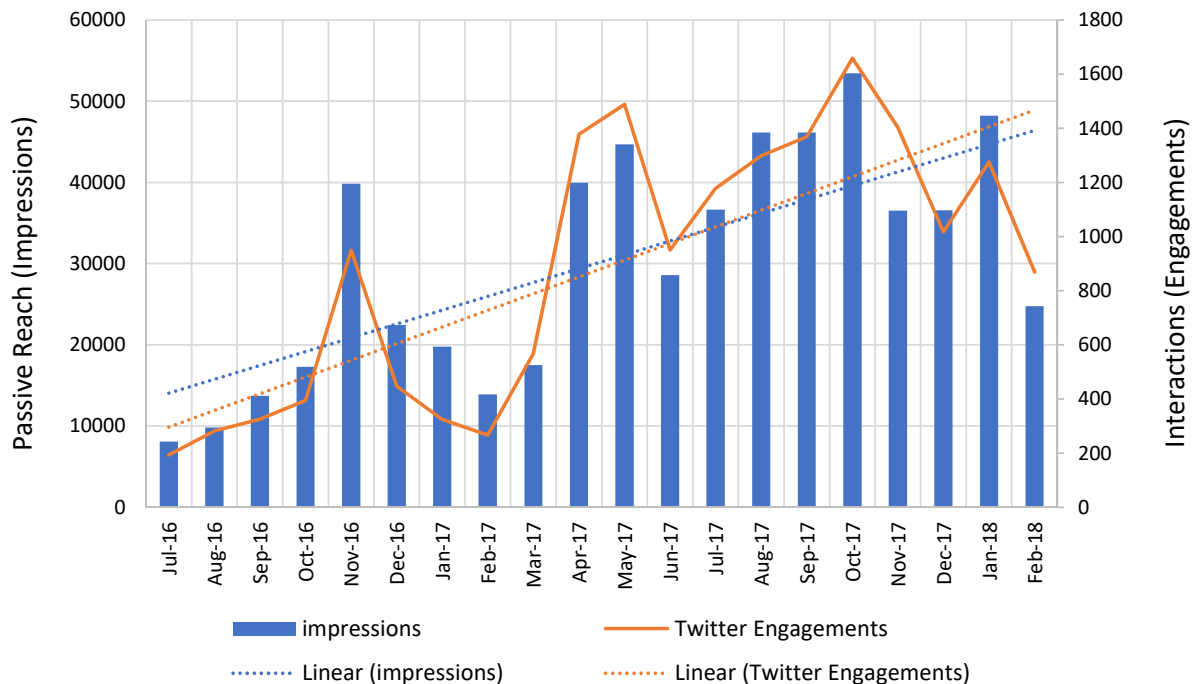
a curiosity about the topics discussed. This engagement was not possible to measure within the scope of this study, but implied that there was a value in broadcast media communications to raise awareness around IAS issues. The communications plan facilitated the opportunistic nature of broadcast media communications. It allowed us to plan and integrate elements of the campaign through a coordinated network of social media posts and promotional efforts, thus increasing the impact.

### *Social media*

During the study period, our social media platforms (Facebook and Twitter) generated both passive reach (657,822 incidences) and interactions (3% of the passive reach). From early in the project Twitter generated most success; hence, we focussed resources on that platform, maintaining Facebook by default only, and holding, but never using, the Instagram account which had been established. Unlike broadcast media, the impact of social media can be consistently maintained and improved upon over time. As cumulative tweets build up, so did the number of followers (see Figure 3). The more tweets over time, the more followers were attracted. The more followers gained, the greater became the incidence of both passive reach and interaction. The erratic results of passive reach (see Figure 2) indicate that the timing of posts may not be capturing the largest possible audience. Better timing of postings would therefore improve all other metrics. Timing of posts is difficult when addressing a global audience, as different time zones are being considered.

Growth is steady by following a plan of regular postings, and can be maintained indefinitely, making social media a sustainable communications method in the long-term. New platforms are constantly emerging and trends change quickly in online communications (Wolf 2017), so the appropriate platforms may well change regularly in the future.

It was important to maintain a consistent tone and to balance the frequency of posting so that our presence was regular, but not so frequent that less-engaged followers would be overwhelmed and leave. This took a little time to get right for our audience. To begin with, several tweets were posted per day, but after some trial and error, this was reduced to a single post per day, plus some less formal engagement with other posts, such as commenting and retweeting. This combination resulted in a satisfactory growth rate, which saw very few followers “unfollowing” the Invasive Aliens page. This process was done in an intuitive manner, with daily, weekly and monthly monitoring of follower numbers.



**Figure 3.** The data illustrates how the number of interactions on Twitter are related to the number of impressions. The more people see a tweet, the more of the audience engage with the information being communicated.

### *Citizen Science*

Our experiment with Citizen Science was the “Winter Heliotrope Challenge”, repeated over two seasons (Figure 4). One hundred and fifty-two people participated in this event. Interactions were measured as 100%. The only results that could be reliably measured by this study were the validated records gathered over the course of this citizen science event. It was beyond the scope of this study to further interrogate the data to recognise the passive interest that was generated by the “Winter Heliotrope Challenge”. The dynamic and interactive nature of the outreach strategy made it difficult to avoid double-recording some of the data. As it was driven by social media, and Twitter in particular, the metrics for the passive reach were accredited to Twitter, and not accredited to the “Winter Heliotrope Challenge”. The event generated important new records for the Irish National Biodiversity Data Centre and introduced members of the public to the process of recording biodiversity. In the context of the project as a whole, this event was small and localised, but it highlighted winter heliotrope as a problem species, and led to direct enquiries from individuals, community groups, and public authorities with regard to management and control techniques.

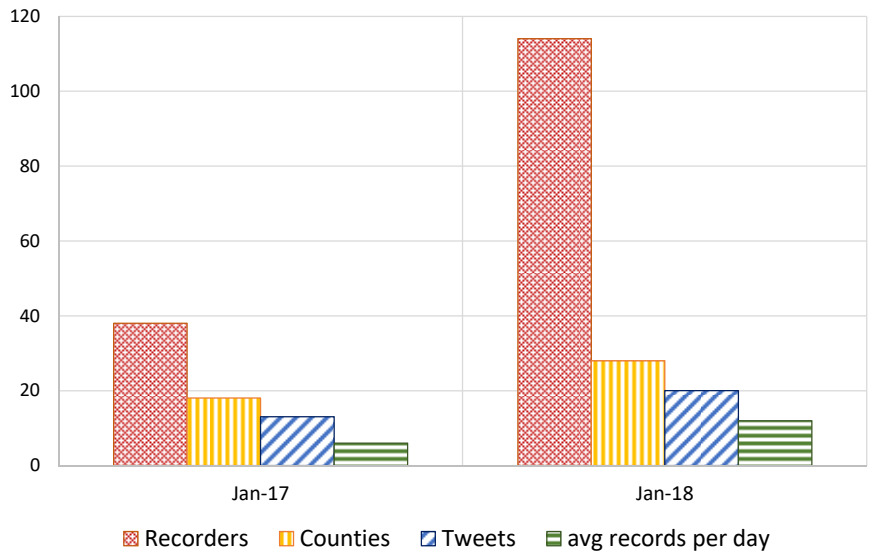
### *Public events*

Public events generated an estimated audience of 820, an estimated 33% of whom interacted with the project *via* questions or follow-up contact. We attended as many local community events as possible, presenting to audiences when asked and engaging with attendees. The impacts of face-to-face communication are very effective in comparison to broadcast and social media (Schüttler et al. 2010). Our objective in attending these events, during the life of the project, was to establish the project as an approachable source of trustworthy information about IAS at a local and national level, encouraging people to ask questions and discuss the issues, and to lead them to stay in contact with us for future queries. From the results shown in this research study, 270 people engaged directly with us over these events. Many of these attendees were members of community groups such as Tidy Towns Committees, in a position to further disseminate the information that they received and take control measures in their locality.

### *Workshops*

During the course of the study period, local workshops brought us in contact with 118 people, 58% of whom





**Figure 4.** The Winter Heliotrope Challenge – results compared from 2017 and 2018 show an increase in all measured data.

actively engaged in conversation with the presenter around the subject of IAS, either during the event or in follow-up. The average attendance at these workshops was 17 people. These groups were drawn from a wide range of people with varying levels of previous knowledge and interest in ecology, from student teachers to community groups. Some of the participants had a specific interest in managing IAS, while others were broadening their general understanding of ecology and scientific research. All were in a position to bring the knowledge they gained to a broader audience. The high level of engagement illustrates the capacity for these small events to deliver a deeper level of understanding amongst participants. This type of direct knowledge-sharing at a community level has the capacity to gradually change awareness-levels and, therefore, behaviour in the general population, which is the principle objective of any outreach programme (Schüttler et al. 2010).

The results showed a clear distinction between two types of outreach. Broadcast media and social media reached a very wide audience and raised awareness in the population at large. They were also used to drive more intense, deeper dissemination of knowledge by directing interested participants towards citizen science projects, public events and workshops. These events allowed people to engage directly with the material. A better understanding of these dynamics means that we can focus resources (in the form of time and materials) to take advantage of the unique opportunities presented by each of the outreach methods. Future plans will include a query for workshop attendees to identify where they heard

about the event. This will allow researchers to make direct connections on the impact of broadcast media on face-to-face communication. Designing a communications plan with this understanding will greatly enhance the impact of any future outreach programme and help to maximise the value of any time and resources spent.

Results of the outreach as a whole, including all the various media, showed that only 2% of the total passive reach resulted in meaningful interactions (Figure 1). We now know that the extent of deeper interaction with the information being disseminated is proportionally linked to the extent of the passive reach. Knowing this, future iterations of the communications plan can focus on increasing the extent of the passive reach through broadcast and social media. This in turn will drive an increase in general awareness and promote greater engagement in events. The limited scope of this element of the project gave us insight into the different media, their ease of use and their impacts. Future projects such as this can incorporate social media analysis, using software such as NodeXL or Gephi to analyse the reach of communications in a more systematic manner.

It was not considered in the beginning that social media would be suitable for reaching policy-makers, but this experience has shown us that it has put us directly in contact with international groups such as EASIN and CABI, and some of our followers include Junior Ministers in the Gov Dept responsible for Environment. This implies that there is a certain validity in having a visible presence on social media as a means of influencing policy-makers.

Mindful planning and focussing of citizen science and public events and workshops allows us to take advantage of valuable opportunities and maximise their impact and the potential “ripple effect” through communities (Illingworth 2017; Spicer 2017).

## Conclusion

Our world is saturated with communication outputs of many types, and it is difficult for the general public to discern between reliable information and “fake news”. As scientists, we have a responsibility to share the findings of our research with the public in a way that they trust and understand. This limited study showed that, by devoting human resources to outreach and structuring efforts around a robust communications plan, it is possible to establish a large audience and become a trusted resource for information on an environmental topic. Each medium has its strengths and weaknesses, but if the broad reach of broadcast media and social media is cleverly used to support more focussed outreach events such as citizen science, public events and workshops, a momentum can be generated around topics such as IAS, which can be sustained.

In the end, it is this sustained delivery of a focussed message from a trusted source that sets the seed for behavioural change. A carefully constructed communications plan is the foundation that underpins an effective outreach programme.

## Acknowledgements

This work has been greatly enhanced by the comments of the two anonymous reviewers, and we are very grateful for their generous and considered advice. We would like to thank Colette O’Flynn and Barry O’Neill of the National Biodiversity Data Centre (Ireland) for their help and support in running the Winter Heliotrope Challenge. This project, The Prevention, Control and Eradication of Invasive Alien Species (2015-NC-MS-4), is funded by the Environmental Protection Agency (Ireland), and is a collaboration between the Institute of Technology, Sligo, Queens University Belfast, and INVAS Biosecurity, Dublin. The authors would also like to acknowledge the kind support of the Marine Institute (Ireland) in the form of Researcher Travel Awards, which allowed this work to be presented at International Conference on Aquatic Invasive Species (ICAIS), 2017. The publication of this article is supported by the Open Access Publishing Fund of the International Association for Open Knowledge on Invasive Alien Species (INVASIVESNET).

## References

Anderson LG, White PCL, Stebbing PD, Stentford GD, Dunn AM (2014) Biosecurity and Vector Behaviour: Evaluating the Potential Threat Posed by Anglers and Canoeists as Pathways for the Spread of Invasive Non-Native Species and Pathogens. *PLoS ONE* 9: e92788, <https://doi.org/10.1371/journal.pone.0092788>

Barker K (2010) Biosecure citizenship: Politicising symbiotic associations and the construction of biological threat. *Transactions of*

*the Institute of British Geographers* 35: 350–363, <https://doi.org/10.1111/j.1475-5661.2010.00386.x>

Bennett NJ, Roth R, Clain SC, Chan K, Christie P, Clark DA, Cullman G, Curran D, Durbin TJ, Epstein G, Greenberg A, Nelson MP, Sandlos J, Stedman R, Teel TL, Thomas R, Verissimo D, Wyborn C (2017) Conservation social science: Understanding and integrating human dimensions to improve conservation. *Biological Conservation* 205: 93–108, <https://doi.org/10.1016/j.biocon.2016.10.006>

Besley JC (2015) What do scientists think about the public and does it matter to their online engagement? *Science and Public Policy* 42: 201–214, <https://doi.org/10.1093/scipol/scu042>

Bonanno G (2016) Alien species: to remove or not to remove? That is the question. *Environmental Science and Policy* 59: 67–73, <https://doi.org/10.1016/j.envsci.2016.02.011>

Bremner A, Park K (2007) Public attitudes to the management of invasive non-native species in Scotland. *Biological Conservation* 139: 306–314, <https://doi.org/10.1016/j.biocon.2007.07.005>

Caffrey JM, Baars JR, Barbour JH, Boets P, Boon P, Davenport K, Dick JTA, Early J, Edsman L, Gallagher C, Gross J, Heinimaa P, Horrill C, Hudin S, Hulme PE, Hynes S, MacIsaac HJ, McLoone P, Millane M, Moen TL, Moore N, Newman J, O’Conchuir R, O’Farrell M, O’Flynn C, Oidtmann B, Renals T, Ricciardi A, Roy H, Shaw R, van Valkenberg JLCH, Weyl O, Williams F, Lucy FE (2014) Tackling Invasive Alien Species in Europe: the top 20 issues. *Management of Biological Invasions* 5: 1–20, <https://doi.org/10.3391/mbi.2014.5.1.01>

Campbell ML, Bryant DEP, Hewitt CL (2017) Biosecurity messages are lost in translation to citizens: Implications for devolving management to citizens. *PLoS ONE* 12: 1–13, <https://doi.org/10.1371/journal.pone.0175439>

Carr TR, Buchanan RC, Adkins-Helieson D, Mettillle TD, Sorensen J (1997) The future of scientific communication in the earth sciences: The impact of the internet. *Computers & Geosciences* 23: 503–512, [https://doi.org/10.1016/S0098-3004\(97\)00032-0](https://doi.org/10.1016/S0098-3004(97)00032-0)

Cohn JP (2008) Citizen Science: Can Volunteers Do Real Research? *BioScience* 58: 192–197, <https://doi.org/10.1641/B580303>

Constantinides E (2014) Foundations of Social Media Marketing. *Procedia - Social and Behavioral Sciences* 148: 40–57, <https://doi.org/10.1016/j.sbspro.2014.07.016>

Eiswerth ME, Yen ST, Cornelis Van Kooten G (2011) Analysis Factors determining awareness and knowledge of aquatic invasive species. *Ecological Economics* 70: 1672–1679, <https://doi.org/10.1016/j.ecolecon.2011.04.012>

García-Llorente M, Martín-López B, González JA, Alcorlo P, Montes C (2008) Social perceptions of the impacts and benefits of invasive alien species: Implications for management. *Biological Conservation* 141: 2969–2983, <https://doi.org/10.1016/j.biocon.2008.09.003>

Hart SP, Larson BMH (2014) Communicating About Invasive Species: How “Driver” and “Passenger” Models Influence Public Willingness to Take Action. *Conservation Letters* 7: 545–552, <https://doi.org/10.1111/conl.12109>

Hartmann P, Apaolaza Ibáñez V, Forcada Sainz FJ (2005) Green branding effects on attitude: functional versus emotional positioning strategies. *Marketing Intelligence & Planning* 23: 9–29, <https://doi.org/10.1108/02634500510577447>

Hu S, Li Z, Zhang J, Zhu J (2018) Engaging scientists in science communication: The effect of social proof and meaning. *Journal of Cleaner Production* 170: 1044–1051, <https://doi.org/10.1016/j.jclepro.2017.09.210>

Hulme PE (2009) Trade, transport and trouble: Managing invasive species pathways in an era of globalization. *Journal of Applied Ecology* 46: 10–18, <https://doi.org/10.1111/j.1365-2664.2008.01600.x>

Hwong YL, Oliver C, Van Kranendonk M, Sammut C, Seroussi Y (2017) What makes you tick? The psychology of social media engagement in space science communication. *Computers in Human Behavior* 68: 480–492, <https://doi.org/10.1016/j.chb.2016.11.068>

- Illingworth S (2017) Delivering effective science communication: advice from a professional science communicator. *Seminars in Cell and Developmental Biology* 70: 10–16, <https://doi.org/10.1016/j.semdb.2017.04.002>
- Invasive Species Specialist Group (2000) IUCN Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species, Switzerland, International Union for Conservation of Nature, [http://www.issg.org/pdf/guidelines\\_iucn.pdf](http://www.issg.org/pdf/guidelines_iucn.pdf)
- Jarnevich CS, Simpson A, Graham JJ, Newman GJ, Barger CT (2015) Running a network on a shoestring - the Global Invasive Species Information Network. *Management of Biological Invasions* 6: 137–146, <https://doi.org/10.3391/mbi.2015.6.2.04>
- Jefferson R, McKinley E, Capstick S, Fletcher S, Griffin H, Milanes M (2015) Understanding audiences: Making public perceptions research matter to marine conservation. *Ocean and Coastal Management* 115: 61–70, <https://doi.org/10.1016/j.ocecoaman.2015.06.014>
- Jin SA (2012) The potential of social media for luxury brand management *Marketing Intelligence & Planning* 30: 687–699, <https://doi.org/10.1108/02634501211273805>
- Jucan SM, Jucan NC (2014) ScienceDirect The Power of Science Communication. *Procedia - Social and Behavioral Sciences* 149: 461–466, <https://doi.org/10.1016/j.sbspro.2014.08.288>
- Lehmberg D, Hicks J (2018) A “glocalization” approach to the internationalizing of crisis communication. *Business Horizons* 61: 357–366, <https://doi.org/10.1016/j.bushor.2018.01.002>
- Lua A (2017) ‘A Simple Framework for Testing Your Social Media Ideas (+ 87 Ideas)’, *Buffer, Social Blog - Social Media Marketing*. <https://blog.bufferapp.com/run-social-media-experiments> (accessed 19 March 2018)
- Lucy FE, Karatayev AY, Burlakova LE (2012) Predictions for the spread, population density, and impacts of *Corbicula fluminea* in Ireland. *Aquatic Invasions* 7: 465–474, <https://doi.org/10.3391/ai.2012.7.4.003>
- NBDC (2018) Invasive species - Biodiversity Ireland, National Biodiversity Data Centre (NBDC). <http://www.biodiversityireland.ie/projects/invasive-species/> (accessed 19 March 2018)
- New Decade TV (2017) Invasive Aliens - 10 Things To Know About Aliens. <https://www.facebook.com/1732898050300680/videos/1871559869767830/> (accessed 19 March 2018)
- Pagad S, Genovesi P, Carnevali L, Scalera R, Clout M (2015) IUCN SSC Invasive Species Specialist Group: invasive alien species information management supporting practitioners, policy makers and decision takers. *Management of Biological Invasions* 6: 127–135, <https://doi.org/10.3391/mbi.2015.6.2.03>
- Perrings C, Dehnen-Schmutz K, Touza J, Williamson M (2005) How to manage biological invasions under globalization. *Trends in Ecology & Evolution* 20: 216–215, <https://doi.org/10.1016/j.tree.2005.02.011>
- Presl C (2017) *Petasites fragrans* (Vill.) GBIF Backbone Taxonomy, <https://doi.org/10.15468/39omei>
- Rania Q (2017) ScienceDirect Using Social Hub Media to Expand Public Participation in Municipal Urban Plans. *Procedia Engineering* 198: 34–42, <https://doi.org/10.1016/j.proeng.2017.07.072>
- Rouget M, Robertson MP, Wilson JRU, Hui C, Essl F, Renteria JL, Richardson DM (2016) Invasion debt - quantifying future biological invasions. *Diversity and Distributions* 22: 445–446, <https://doi.org/10.1111/ddi.12408>
- Russell JC, Blackburn TM (2017) The Rise of Invasive Species Denialism. *Trends in Ecology & Evolution* 32: 3–6, <https://doi.org/10.1016/j.tree.2016.10.012>
- Schüttler E, Rozzi R, Jax K (2010) Towards a societal discourse on invasive species management: A case study of public perceptions of mink and beavers in Cape Horn. *Journal for Nature Conservation* 19: 175–184, <https://doi.org/10.1016/j.jnc.2010.12.001>
- Seaward K, Acosta H, Inglis GJ, Wood B, Riding TAC, Wilkens S, Gould B (2015) The Marine Biosecurity Porthole - a web-based information system on non-indigenous marine species in New Zealand. *Management of Biological Invasions* 6: 177–184, <https://doi.org/10.3391/mbi.2015.6.2.08>
- Seebens H, Blackburn TM, Dyer EE, Genovesi P, Hulme PE, Jeschke JM, Pagad H, Pysek P, Winter M, Arianoutsou M, Bacher S, Blasius B, Brundu G, Capinha C, Celesti-Grapo L, Dawson W, Dullinger S, Fuentes N, Jager H, Kartesz J, Kenis M, Kreft H, Kuhn I, Lenzner B, Liebhold A, Mosena A, Moser D, Nishino M, Pearman D, Pergl J, Rabitsch W, Rojas-Sandoval J, Roques A, Rorke S, Rossinelli S, Roy HE, Scalera R, Schindler S, Stajero K, Tokarska-Guzik B, Van Kleunen M, Walker K, Weigelt P, Yamanaka T, Essl F (2017) No saturation in the accumulation of alien species worldwide. *Nature Communications* 8: 1–9, <https://doi.org/10.1038/ncomms14435>
- Sigerson L, Cheng C (2018) Scales for measuring user engagement with social network sites: A systematic review of psychometric properties. *Computers in Human Behavior* 83: 87–105, <https://doi.org/10.1016/j.chb.2018.01.023>
- Spicer S (2017) The nuts and bolts of evaluating science communication activities. *Seminars in Cell and Developmental Biology* 70: 17–25, <https://doi.org/10.1016/j.semdb.2017.08.026>
- Sunderland T, Sunderland-Groves J, Shanley P, Campbell B (2009) Bridging the Gap: How Can Information Access and Exchange Between Conservation Biologists and Field Practitioners be Improved for Better Conservation Outcomes? *Biotropica* 41(5): 549–554, <https://doi.org/10.1111/j.1744-7429.2009.00557.x>
- Thelwall M, Kousha K (2015) Web Indicators for Research Evaluation. Part 2: Social Media Metrics, Researchgate.net. [https://www.researchgate.net/profile/Kayvan\\_Kousha/publication/284179443\\_Web\\_indicators\\_for\\_research\\_evaluation\\_Part\\_2\\_Social\\_media\\_metrics/links/564e504708ae1ef9296c8442.pdf](https://www.researchgate.net/profile/Kayvan_Kousha/publication/284179443_Web_indicators_for_research_evaluation_Part_2_Social_media_metrics/links/564e504708ae1ef9296c8442.pdf) (accessed: 11 March 2018)
- Wolf JM (2017) The Multipurpose Tool of Social Media: Applications for Scientists, Science Communicators, and Educators. *Clinical Microbiology Newsletter* 39: 75–79, <https://doi.org/10.1016/j.clinmicnews.2017.04.003>
- Wright AJ, Verissimo D, Piffold K, Parsons ECM, Ventre K, Cousins J, Jefferson R, Koldewey H, Llewellyn F, McKinley E (2015) Competitive outreach in the 21st century: Why we need conservation marketing. *Ocean & Coastal Management* 115: 41–48, <https://doi.org/10.1016/j.ocecoaman.2015.06.029>