RESEARCH ARTICLE

Blacklists do not necessarily make people curious about invasive alien species. A case study with Bayesian structural time series and Wikipedia searches about invasive mammals in Italy

Jacopo Cerri[1], Lucilla Carnevali[2], Andrea Monaco[2],
Piero Genovesi[2], Sandro Bertolino[3]

1 *Faculty of Mathematics, Natural Sciences and Information Technologies, University of Primorska, Glagoljaška 8, 6000 Koper, Slovenia* **2** *Istituto Superiore per la Protezione e la Ricerca Ambientale, Via Brancati 48, 00144, Rome, Italy* **3** *Dipartimento di Scienze della Vita e Biologia dei Sistemi, Università degli Studi di Torino, Via Accademia Albertina 13, 10123, Torino, Italy*

Corresponding author: Jacopo Cerri (jacopo.cerri@famnit.upr.si)

Abstract

Blacklists of invasive alien species (IAS) are a popular tool for managing and preventing biological invasions. Moreover, blacklists also have the potential to make the general public more curious about biological invasions, usually by benefiting from media coverage and providing accessible examples of IAS.

We have tested if the implementation of the first List of IAS of Union concern by the European Union increased visits to Wikipedia pages on invasive alien mammals in Italy. We adopted causal impact analysis to quantify changes in the overall volume of visits to pages about invasive alien mammals that appeared on the list, by using pages about native mammals as a control. Following the publication of the first Union list, there was no increase in the amount of visits to Wikipedia pages on invasive mammals, regardless of their inclusion in the Union list. Rather, visits to Wikipedia were irregular in time, coinciding with media coverage of single, charismatic species. Our results indicate that important policymaking initiatives do not necessarily increase curiosity about biological invasions, even when they are covered by generalist media and are relatively easy to understand. We would therefore emphasise that policymaking initiatives should be coupled with adequate communication campaigns and should adopt communication guidelines for generalist media.

Keywords

Bayesian structural time-series, Europe, invasive mammals, Italy, negative-list, Wikipedia

Introduction

In recent years, blacklists and accept-lists have become standard policy tools for tackling biological invasions (Genovesi and Shine 2004). Blacklists, also known as "negative lists", identify invasive alien species (IAS) – alien species whose introduction or spread has been found to threaten or have an adverse impact on biodiversity and related ecosystem services (EU 2020) – whose introduction is forbidden and for which trade bans, management initiatives and eradication should be enforced. On the other hand, accept-lists (or "white" or "positive" lists) identify those alien species which carry a low risk of becoming invasive, or impacting, and which are able to be traded, maintained in captivity or present in nature (Kaiser 1999; Perrings 2005). Both blacklists and accept-lists are based on risk assessments: in the former case, the aim is to ban a species from a country or a geographic area; in the latter case, the purpose is to demonstrate its "safety" for the environment and/or human well-being.

While the two approaches have different benefits, limitations and costs, blacklists have become far more common worldwide, with accept-lists being limited to a few countries (e.g. Australia, https://www.environment.gov.au/biodiversity/wildlife-trade/live-import-list and New Zealand, Brenton-Rule et al. 2016). For example, the July 2016 European Regulation on invasive alien species (no. 1143/2014) produced an initial list of 37 IAS of European concern (hereafter "*Union list*"; EU Regulation no. 1141/2016), which was then updated in 2017 (49 species, no. 1263/2017) and in 2019 (66 species, no. 1262/2019). Following these Regulations, 25 EU Member States implemented at least one type of national blacklist, with 4 States (Austria, Croatia, Germany and Spain) also implementing regional blacklists. On the other hand, 5 Member States and another European country (Norway) developed accept-lists, mostly for specific taxa (Eurogroup for Animals 2020; Toland et al. 2020).

To date, blacklists have been evaluated in terms of their effectiveness in preventing introductions (Maceida-Vega et al. 2019) and as blueprints for prioritising control and eradication initiatives (Tollington et al. 2017; Bertolino et al. 2020). However, we are still in the dark as to whether blacklists also increase the curiosity of the general public towards IAS. In principle, they should be capable of doing so: they imply the removal of IAS from the environment or captivity, which can trigger conflicts between stakeholders and institutions (e.g. Crowley et al 2017), and sometimes also benefit from media coverage (Lioy et al. 2019). Furthermore, as blacklists offer concrete examples of IAS, which are sometimes also popular species, laypeople can understand their practical importance, easily incorporating them into networks of pre-existing beliefs about wildlife, animal welfare or the environment. This combination of media echo and ease of understanding can increase the curiosity in some segments of the general public about biological invasions. Similar potential was recognised by the International Union for the Conservation of Nature (IUCN), which set up, in 1999, a list of 100 high-profile invasive species (list of 100 of the world's worst invasive alien species, Lowe et al. 2000) as a communication tool to address this issue. A similar list with 100 of the worst invasive alien species was drawn up in Europe (Vilà et al. 2009) and extended by Nentwig et al. (2018).

If blacklists really do have this impact, this would make them a valuable conservation tool, going far beyond the intention to regulate introduced species. For environmental topics, generating a public debate is often fundamental in order to enter the political agenda (e.g. climate change, Dunlap and McCright 2010) and to achieve long-term endorsement by politicians and by society (Heberlein 2012). Considering that some policies on biological invasions now include blacklists (Outhwaite 2017; Young et al. 2006), measuring whether they increase the curiosity of laypeople towards IAS is fundamental in order to predict whether those policies will be supported in the long-term. In this study, we aim to bridge this gap by estimating the causal effect of the publication of the first List of IAS of Union Concern on the number of Wikipedia searches on invasive alien mammals in Italy.

These days, people regularly seek information online, particularly in those countries with good Internet penetration. Such behaviour is more common for those topics that are also debated in traditional media (Tizzoni et al. 2020) and whose nature is controversial and open to multiple interpretations (Yenikent et al. 2017), such as environmental issues (Anderegg and Goldsmith 2014; Burivalolva et al. 2018; McCallum et al. 2013; Mittermeier et al. 2019). Information retrieval on the Internet occurs across multiple platforms, such as search engines like Google, dedicated websites and social networks. However, it also takes place on Wikipedia, the largest online encyclopaedia (Okoli et al. 2014). An analysis of visits to Wikipedia pages is particularly interesting, for two reasons. Firstly, because Wikipedia contains open data on the daily visits to each page (https://pageviews.toolforge.org/). This information is far more transparent than any such data provided by search engines, such as Google, which do not disclose overall searches but, rather, offer indirect metrics, such as the GoogleTrends index. Moreover, information seeking on the Internet can be regarded as a hierarchical process: once people become curious about a particular topic, they look for it on search engines, check and evaluate outputs, then decide whether or not to access pages, such as Wikipedia, where they can find further information. Of course, some users do not search for in-depth information or access Wikipedia or dedicated websites. Therefore, the analysis of visits to Wikipedia pages on IAS can truly capture changes in the number of persons whose curiosity about the topic is genuine, thus being a more truthful measure of public interest than overall Google searches. Dedicated websites would, of course, be another valuable source of information but the number of daily visits to the same is almost never made public.

The publication of the Union list was announced by the EU (https://ec.europa.eu/environment/efe/news/first-eu-list-invasive-alien-species-2016-08-04_it), as well as by the Italian media (Suppl. material 1). Mammals are, on average, iconic vertebrates, salient even to laypersons: it is reasonable to assume that, once it was announced that a certain mammal had been included in the Union list, some people became curious and searched for information on its dedicated Wikipedia page. Testing for the existence of this dynamic could be important, as it would mean that blacklists also contribute to invasive alien species becoming more well-known, at least superficially, by laypersons.

Therefore, we predicted that: (*i*) H_1: the implementation of the Union list increased the number of Wikipedia searches for invasive mammals included on the list, compared to native species, (*ii*) H_2: this effect declined rapidly over time, in the absence of a dedicated budget for permanent outreaching initiatives (Turbelin et al. 2017), (*iii*) H_3: Wikipedia views also increased in August 2017 and 2019, due to Union list updates, (*iv*) H_4: the implementation of the Union list also increased the number of searches for invasive mammals that were not included, due to the increased interest in IAS in general.

Methods

In this study, in assessing the causal effect of the Union list on visits to Wikipedia pages about invasive mammals, we compared their volume of visits with that of pages on native mammals. The entry into force of the Union list was regarded as a natural experiment, with some time-series (Wikipedia pages on invasive mammals) receiving such treatment, and other time-series (Wikipedia pages on native mammals) being unaffected and able to be used as a control. Native mammals were a suitable synthetic control as, prior to the Union list, visits to their Wikipedia pages correlated well with those of invasive mammals (Pearson's correlation coefficient = 0.63), due to seasonal patterns in human-wildlife interactions and a long-term growth in Internet searches about wildlife caused by increased Internet access. The use of a control group allowed us to rule out the effect of long-term trends in interest towards wildlife, as well as seasonal effects in Wikipedia usage, estimating differences in Wikipedia visits between the two groups that could only be attributed to the Union list.

Indeed, we distinguished between two groups of invasive mammals. The first one (adopted to test for H_1, H_2 and H_3) included IAS that appeared on the Union list and that were established in Italy in July 2016: the coypu (*Myocastor coypus*), the raccoon (*Procyon lotor*), the Eastern grey squirrel (*Sciurus carolinensis*) and the Siberian chipmunk (*Tamias sibiricus*). The second one (adopted to test for H_4) included IAS that did not appear on the Union list and that were present in Italy in August 2016: the Eastern cottontail (*Sylvilagus floridanus*), the American mink (*Neovison vison*), the Barbary sheep (*Ammotragus lervia*) and Finlayson's squirrel (*Callosciurus finlaysonii*) (Loy et al. 2019).

The control group with native Italian mammals included 81 native species and 4 species that were introduced in historic times, as these are traditionally deemed to be part of Italian fauna by the general public (Table 1). To respect the assumptions of the synthetic control approach, some species were discarded. From the IAS, we excluded Pallas's squirrel (*Callosciurus erythraeus*), which has no page on Italian Wikipedia, as well as the raccoon dog (*Nyctereutes procyonoides*) and the muskrat (*Ondatra zibethicus*), which appeared on the second update of the blacklist. We also excluded the common genet (*Genetta genetta*), which, in 2016, was still present only occasionally in Italy, with few records.

Table 1. List of invasive and native species of mammals that were considered for data analysis.

Common name	Scientific name	Wikipedia page
Invasive alien species included in the first Union List		
Coypu	*Myocastor coypus*	https://it.wikipedia.org/wiki/Myocastor_coypus
Raccoon	*Procyon lotor*	https://it.wikipedia.org/wiki/Procyon_lotor
Eastern gray squirrel	*Sciurus carolinensis*	https://it.wikipedia.org/wiki/Sciurus_carolinensis
Siberian chipmunk	*Tamias sibiricus*	https://it.wikipedia.org/wiki/Tamias_sibiricus
Invasive alien species that were not included in the first Union List		
Eastern cottontail	*Sylvilagus floridanus*	https://it.wikipedia.org/wiki/Sylvilagus_floridanus
American mink	*Neovison vison*	https://it.wikipedia.org/wiki/Neovison_vison
Barbary sheep	*Ammotragus lervia*	https://it.wikipedia.org/wiki/Ammotragus_lervia
Finlayson's squirrel	*Callosciurus finlaysonii*	https://it.wikipedia.org/wiki/Callosciurus_finlaysonii
Native species		
European hedgehog	*Erinaceus europaeus*	https://it.wikipedia.org/wiki/Erinaceus_europaeus
Bicolored shrew	*Crocidura leucodon*	https://it.wikipedia.org/wiki/Crocidura_leucodon
North African white-toothed shrew	*Crocidura pachyura*	https://it.wikipedia.org/wiki/Crocidura_pachyura
Sicilian shrew	*Crocidura sicula*	https://it.wikipedia.org/wiki/Crocidura_sicula
Lesser white-toothed shrew	*Crocidura suaveolens*	https://it.wikipedia.org/wiki/Crocidura_suaveolens
Eurasian water shrew	*Neomys fodiens*	https://it.wikipedia.org/wiki/Neomys_fodiens
Alpine shrew	*Sorex alpinus*	https://it.wikipedia.org/wiki/Sorex_alpinus
Eurasian pygmy shrew	*Sorex minutus*	https://it.wikipedia.org/wiki/Sorex_minutus
Apennine shrew	*Sorex samniticus*	https://it.wikipedia.org/wiki/Sorex_samniticus
Etruscan shrew	*Suncus etruscus*	https://it.wikipedia.org/wiki/Suncus_etruscus
Blind mole	*Talpa caeca*	https://it.wikipedia.org/wiki/Talpa_caeca
Roman mole	*Talpa romana*	https://it.wikipedia.org/wiki/Talpa_romana
Common bent-wing bat	*Miniopterus schreibersii*	https://it.wikipedia.org/wiki/Miniopterus_schreibersii
European free-tailed bats	*Tadarida teniotis*	https://it.wikipedia.org/wiki/Tadarida_teniotis
Mediterranean horseshoe bat	*Rhinolophus euryale*	https://it.wikipedia.org/wiki/Rhinolophus_euryale
Greater horseshoe bat	*Rhinolophus ferrumequinum*	https://it.wikipedia.org/wiki/Rhinolophus_ferrumequinum
Lesser horseshoe bat	*Rhinolophus hipposideros*	https://it.wikipedia.org/wiki/Rhinolophus_hipposideros
Mehely's horseshoe bat	*Rhinolophus mehelyi*	https://it.wikipedia.org/wiki/Rhinolophus_mehelyi
Western barbastelle	*Barbastella barbastellus*	https://it.wikipedia.org/wiki/Barbastella_barbastellus
Northern bat	*Eptesicus nilssonii*	https://it.wikipedia.org/wiki/Eptesicus_nilssonii
Serotine bat	*Eptesicus serotinus*	https://it.wikipedia.org/wiki/Eptesicus_serotinus
Savi's pipistrelle bat	*Hypsugo savii*	https://it.wikipedia.org/wiki/Hypsugo_savii
Alcathoe bat	*Myotis alcathoe*	https://it.wikipedia.org/wiki/Myotis_alcathoe
Brown long-eared bat	*Myotis bechsteini*	https://it.wikipedia.org/wiki/Myotis_bechsteini
Lesser mouse-eared bat	*Myotis blythii*	https://it.wikipedia.org/wiki/Myotis_blythii
Brandt's bat	*Myotis brandtii*	https://it.wikipedia.org/wiki/Myotis_brandti
Long-fingered bat	*Myotis capaccinii*	https://it.wikipedia.org/wiki/Myotis_capaccinii
Daubenton's bat	*Myotis daubentonii*	https://it.wikipedia.org/wiki/Myotis_daubentonii
Geoffroy's bat	*Myotis emarginatus*	https://it.wikipedia.org/wiki/Myotis_emarginatus
Mouse-eared bat	*Myotis myotis*	https://it.wikipedia.org/wiki/Myotis_myotis
Whiskered bat	*Myotis mystacinus*	https://it.wikipedia.org/wiki/Myotis_mystacinus
Felten's myotis	*Myotis punicus*	https://it.wikipedia.org/wiki/Myotis_punicus
Greater noctule bat	*Nyctalus lasiopterus*	https://it.wikipedia.org/wiki/Nyctalus_lasiopterus
Lesser noctule	*Nyctalus leisleri*	https://it.wikipedia.org/wiki/Nyctalus_leisleri
Common noctule	*Nyctalus noctula*	https://it.wikipedia.org/wiki/Nyctalus_noctula
Kuhl's pipistrelle	*Pipistrellus kuhlii*	https://it.wikipedia.org/wiki/Pipistrellus_kuhlii
Nathusius' pipistrelle	*Pipistrellus nathusii*	https://it.wikipedia.org/wiki/Pipistrellus_nathusii
Common pipistrelle	*Pipistrellus pipistrellus*	https://it.wikipedia.org/wiki/Pipistrellus_pipistrellus
Brown big-eared bat	*Plecotus auritus*	https://it.wikipedia.org/wiki/Plecotus_auritus
Gray big-eared bat	*Plecotus austriacus*	https://it.wikipedia.org/wiki/Plecotus_austriacus
Sardinian long-eared bat	*Plecotus sardus*	https://it.wikipedia.org/wiki/Plecotus_sardus
Parti-coloured bat	*Vespertilio murinus*	https://it.wikipedia.org/wiki/Vespertilio_murinus
Golden jackal	*Canis aureus*	https://it.wikipedia.org/wiki/Canis_aureus
Red fox	*Vulpes vulpes*	https://it.wikipedia.org/wiki/Vulpes_vulpes
European wildcat	*Felis silvestris*	https://it.wikipedia.org/wiki/Felis_silvestris
Eurasian lynx	*Lynx lynx*	https://it.wikipedia.org/wiki/Lynx_lynx
Eurasian otter	*Lutra lutra*	https://it.wikipedia.org/wiki/Lutra_lutra
Beech marten	*Martes foina*	https://it.wikipedia.org/wiki/Martes_foina
Pine marten	*Martes martes*	https://it.wikipedia.org/wiki/Martes_martes
Eurasian badger	*Meles meles*	https://it.wikipedia.org/wiki/Meles_meles

Common name	Scientific name	Wikipedia page
Native species		
Stoat	*Mustela erminea*	https://it.wikipedia.org/wiki/Mustela_erminea
Least weasel	*Mustela nivalis*	https://it.wikipedia.org/wiki/Mustela_nivalis
European polecat	*Mustela putorius*	https://it.wikipedia.org/wiki/Mustela_putorius
Alpine ibex	*Capra ibex*	https://it.wikipedia.org/wiki/Capra_ibex
Apennine chamois	*Rupicapra pyrenaica ornata*	https://it.wikipedia.org/wiki/Rupicapra_pyrenaica_ornata
Alpine chamois	*Rupicapra rupicapra*	https://it.wikipedia.org/wiki/Rupicapra_rupicapra
European roe deer	*Capreolus capreolus*	https://it.wikipedia.org/wiki/Capreolus_capreolus
Red deer	*Cervus elaphus*	https://it.wikipedia.org/wiki/Cervus_elaphus
Wild boar	*Sus scrofa*	https://it.wikipedia.org/wiki/Sus_scrofa
European water vole	*Arvicola amphibius*	https://it.wikipedia.org/wiki/Arvicola_amphibius
European snow vole	*Chionomys nivalis*	https://it.wikipedia.org/wiki/Chionomys_nivalis
Common vole	*Microtus arvalis*	https://it.wikipedia.org/wiki/Microtus_arvalis
Alpine pine vole	*Microtus multiplex*	https://it.wikipedia.org/wiki/Microtus_multiplex
Savi's pine vole	*Microtus savii*	https://it.wikipedia.org/wiki/Microtus_savii
European pine vole	*Microtus subterraneus*	https://it.wikipedia.org/wiki/Microtus_subterraneus
Common red-backed vole	*Myodes glareolus*	https://it.wikipedia.org/wiki/Myodes_glareolus
Forest dormouse	*Dryomys nitedula*	https://it.wikipedia.org/wiki/Dryomys_nitedula
Garden dormouse	*Eliomys quercinus*	https://it.wikipedia.org/wiki/Eliomys_quercinus
Edible dormouse	*Glis glis*	https://it.wikipedia.org/wiki/Glis_glis
Hazel dormouse	*Muscardinus avellanarius*	https://it.wikipedia.org/wiki/Muscardinus_avellanarius
Striped field mouse	*Apodemus agrarius*	https://it.wikipedia.org/wiki/Apodemus_agrarius
Alpine field mouse	*Apodemus alpicola*	https://it.wikipedia.org/wiki/Apodemus_alpicola
Yellow-necked field mouse	*Apodemus flavicollis*	https://it.wikipedia.org/wiki/Apodemus_flavicollis
Wood mouse	*Apodemus sylvaticus*	https://it.wikipedia.org/wiki/Apodemus_sylvaticus
Eurasian harvest mouse	*Micromys minutus*	https://it.wikipedia.org/wiki/Micromys_minutus
Alpine marmot	*Marmota marmota*	https://it.wikipedia.org/wiki/Marmota_marmota
Cape hare	*Lepus capensis*	https://it.wikipedia.org/wiki/Lepus_capensis
Corsican hare	*Lepus corsicanus*	https://it.wikipedia.org/wiki/Lepus_corsicanus
European brown hare	*Lepus europaeus*	https://it.wikipedia.org/wiki/Lepus_europaeus
Mountain hare	*Lepus timidus*	https://it.wikipedia.org/wiki/Lepus_timidus
Species that were introduced in historic times (considered altogether with native species)		
Fallow deer	*Dama dama*	https://it.wikipedia.org/wiki/Dama_dama
African crested porcupine	*Hystrix cristata*	https://it.wikipedia.org/wiki/Hystrix_cristata
House mouse	*Mus musculus*	https://it.wikipedia.org/wiki/Mus_musculus
Wild rabbit	*Oryctolagus cuniculus*	https://it.wikipedia.org/wiki/Oryctolagus_cuniculus

Among the IAS, we also disregarded the brown rat (*Rattus norvegicus*) and the black rat (*Rattus rattus*), as they are mostly managed by rodent control companies and their search volumes could be ascribable to infestation levels in urban areas. We also excluded the red squirrel (*Sciurus vulgaris*) from the list of native species, as its news coverage was related to the management of *S. carolinensis* (Bertolino et al. 2014; Lioy et al. 2019) and two large carnivores, the grey wolf (*Canis lupus*) and the brown bear (*Urus arctos*), whose news coverage was complex and volatile, due to their interaction with humans and the political debate around their management. We also excluded marine mammals, as they could have stronger seasonal patterns than other mammal species, due to summer tourism and mortality events. Time series were downloaded from 29 June 2015 to 3 February 2020.

We adopted Bayesian structural time series (BSTS, Brodersen et al. 2015) to compare differences in time-series after the Union list. BSTS can estimate the causal effect of an intervention over a single target time-series, by comparing its post-treatment values with a counterfactual constructed from a synthetic control, constituted by untreated time series that were predictive of the target time series in the pre-treatment period. The post-treatment difference between the target time-series and the counterfactual represents the causal effect of the treatment.

BSTS are state-space models, whose mathematical structure is rather sophisticated and beyond the scope of this research article. However, we refer to Brodersen et al. (2015) for a comprehensive overview on the underlying mathematics of our approach and for documentation of the "CausalImpact" package, which was adopted to implement causal impact analysis in R (https://google.github.io/CausalImpact/CausalImpact.html). The reproducible software code is available at: https://osf.io/9yb8w/.

Bayesian structural time series for causal impact analysis are suitable only to compare single target time series with one or more control series. Therefore, Wikipedia views were added together in each group (invasive species in the Union list, invasive species not in the Union list, native species). Aggregation also measured interest in invasive species as a whole, rather than interest in specific species. This choice improved the use of Wikipedia as a proxy for public attention on the topic of IAS, as visits to individual pages could have been more prone to fluctuations caused by species-specific factors, which would have masked important post-treatment patterns. Moreover, daily visits were aggregated on a weekly basis, to increase the signal-to-noise ratio (Fig. 1).
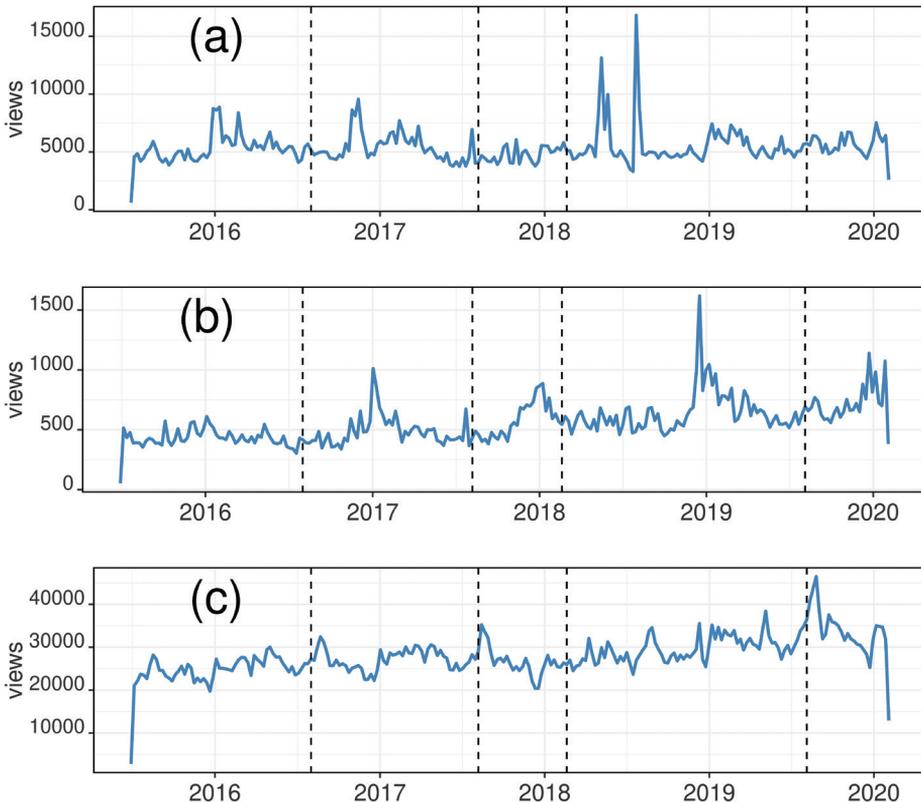

Figure 1. Number of visits to Wikipedia pages on invasive alien mammals included in the Union list (a), invasive alien mammals not included in the Union list (b) and native mammals (c). Dashed lines, from left to right, represent the publication of the first blacklist (July 2016), its first update (July 2017), the implementation of the first Italian law on invasive species (February 2018) and the second update of the blacklist (July 2019).

Results

Our findings do not highlight any effect of the implementation of the first Union list over the volume of visits to Wikipedia pages on invasive alien mammals that were included in the list (Fig. 2). The visits did not systematically increase, compared to what would have been expected from our control group containing native species. There were more visits than expected only during some weeks in October/November 2016, as well as in May and August 2018.

Our findings also do not highlight any clear effect of the Union list on invasive mammals that were not included in the list. The visits did not increase, except until early 2017, and there were more visits than expected at irregular times, from 2017 to mid 2018, peaking between December 2018 and February 2019 (Fig. 3).
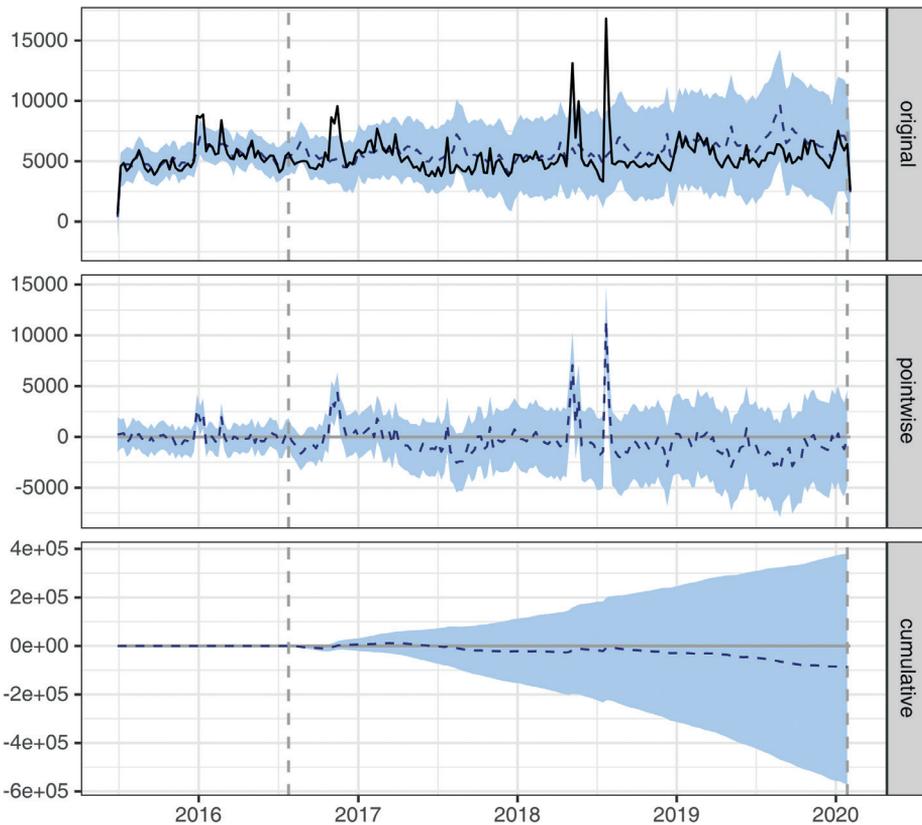

Figure 2. Causal impact of the first Union list (vertical dashed line) on visits to Wikipedia pages about invasive alien mammals that were included in the list. Upper plot: visits to pages of invasive mammals in the list (solid line) versus the counterfactual, obtained from visits to pages of native mammals (dashed line and highlighted area). Middle plot: estimated causal effect, expressed as the difference between treated and control time series. The causal effect was significant if its 95% credibility interval did not include zero. Lower plot: cumulative causal effect in time, significant only when the 95% credibility interval did not include zero.
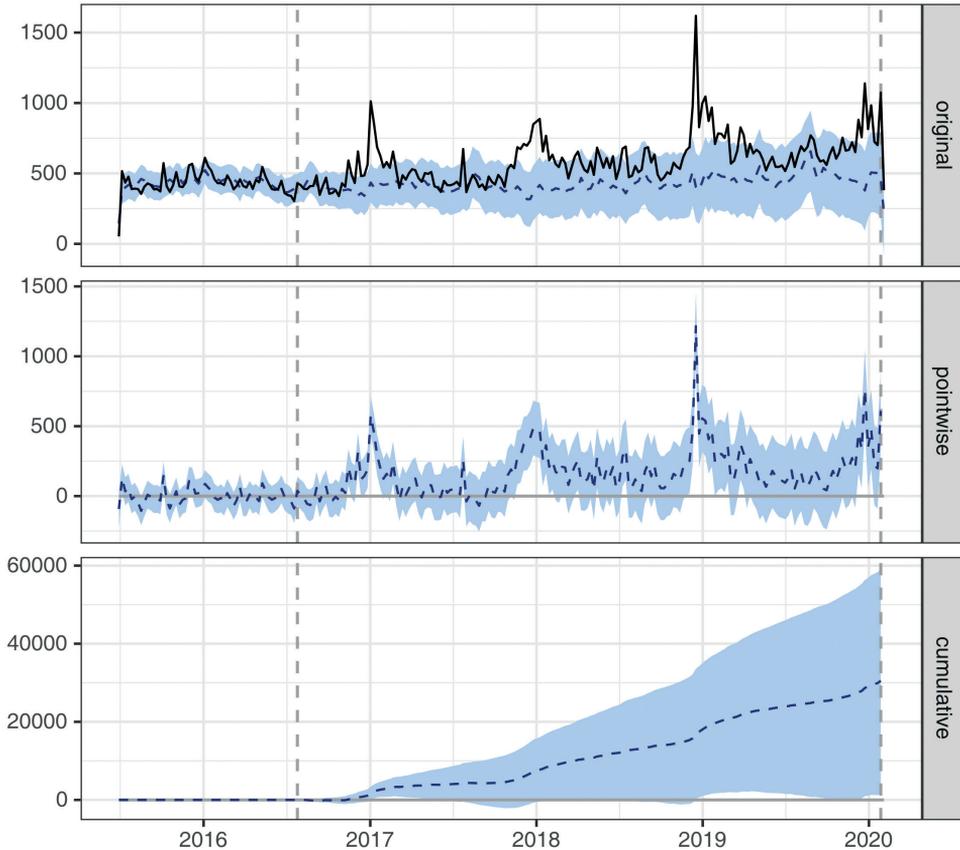
Figure 3. Causal impact of the first Union list on visits to Wikipedia pages about invasive alien mammals that were not included in the list. Upper plot: visits to pages of invasive mammals not in the list (solid line) versus the counterfactual, obtained from the visits to pages of native mammals (dashed line and highlighted area). Middle plot: estimated causal effect, expressed as the difference between treated and control time series. The causal effect was significant if its 95% credibility interval did not include zero. Lower plot: cumulative causal effect in time, significant only when the 95% credibility interval did not include zero.

Discussion

To the best of our knowledge, this study constitutes the first attempt to evaluate blacklists as a tool for making the general public more curious about IAS. Although, in Italy, the first Union list included some invasive alien mammals that were relatively well-known, and although it was covered in the media, it failed to increase the number of visits to the Wikipedia pages on those mammals.

Following the publication of the first Union list, the number of visits to Wikipedia pages on invasive mammals in the two groups, namely those that had been included in and those that had been excluded from the Union list, did not demonstrate any particu-

lar increase, compared to native mammals. For both groups we did not observe any systematic change, but only individual weeks with significantly more views than expected. Those weeks with anomalous volumes of visits to Wikipedia did not coincide with the publication of the first Union list or any of its updates, or with media coverage. As media coverage boosts people's interest in a certain topic in the short-term, with a subsequent decline over time (e.g. pandemics, Bento et al. 2020; wildlife, Fernández-Bellon and Kane 2020), we expected an increase in visits to Wikipedia soon after the publication of the Union list, in July/September 2016, and on some random occasions in the following months. Therefore, we argued that there was no appreciable causal effect of the Union list, and its associated media coverage, and all our hypotheses were rejected.

Rather, individual weeks with anomalous volumes of visits to Wikipedia aligned with news about some particular species unrelated to the Union list. For example, peaks aligned with news about the coypu, the species raising the most serious concerns among public administrations in Italy, due to its effects on the stability of riverbanks. This news item covered the publication of the national management plan for the species (May 2018, Bertolino and Cocchi 2018), an official note from the Lombardy region about the implementation of a regional management plan (July 2018, https://www.regione.lombardia.it/wps/portal/istituzionale/HP/lombardia-notizie/DettaglioNews/2018/07-luglio/23-29/emergenza-nutrie-rolfi-sindaci), and the publication of a viral video of the species (November 2016, https://www.cremonaoggi.it/2016/11/04/nutria-via-xi-febbraio-paura-curiosita-passanti-catturata/). Similarly, in relation to IAS that had not been included in the Union list, the peak observed between late 2018 and February 2019 was probably caused by news about the release of 4,000 minks (*Neovison vison*) from a fur factory in Northern Italy in December 2018, an event that attracted considerable attention in the national and regional media (see, for example, https://parma.repubblica.it/cronaca/2018/12/09/news/mille_visoni_in_fuga_raid_animalista_nel_parmense-213849071/; Fig. 4).

It should be noted that we also observed various peaks of visits to the Wikipedia pages of the various species of invasive mammals which did not coincide with any major news that could be found on the Internet. These peaks may have been caused by local outreach initiatives from individual conservation projects about IAS, such as the LIFE ASAP project (https://lifeasap.eu/index.php/it/), or by some media coverage that could not be found on the Internet. Unfortunately, at the time of the study, comprehensive data on television news and newspaper articles in Italy did not exist. There was also no dataset regarding outreaching initiatives from conservation projects on IAS. We believe that such a gap should be addressed in future, to test the effectiveness of local communication initiatives at raising public interest in biological invasions.

Our study also had some intrinsic limitations. The first was our focus on a single measure of public curiosity, Wikipedia. As we explained in the Introduction, people search for information on the Internet on multiple platforms, including search engines, social networks and dedicated websites. We chose Wikipedia as it was the only one to provide open data on visits, and as it is likely to reflect accurately changes in the behaviour of Internet users who are truly interested in a given topic. Moreover,
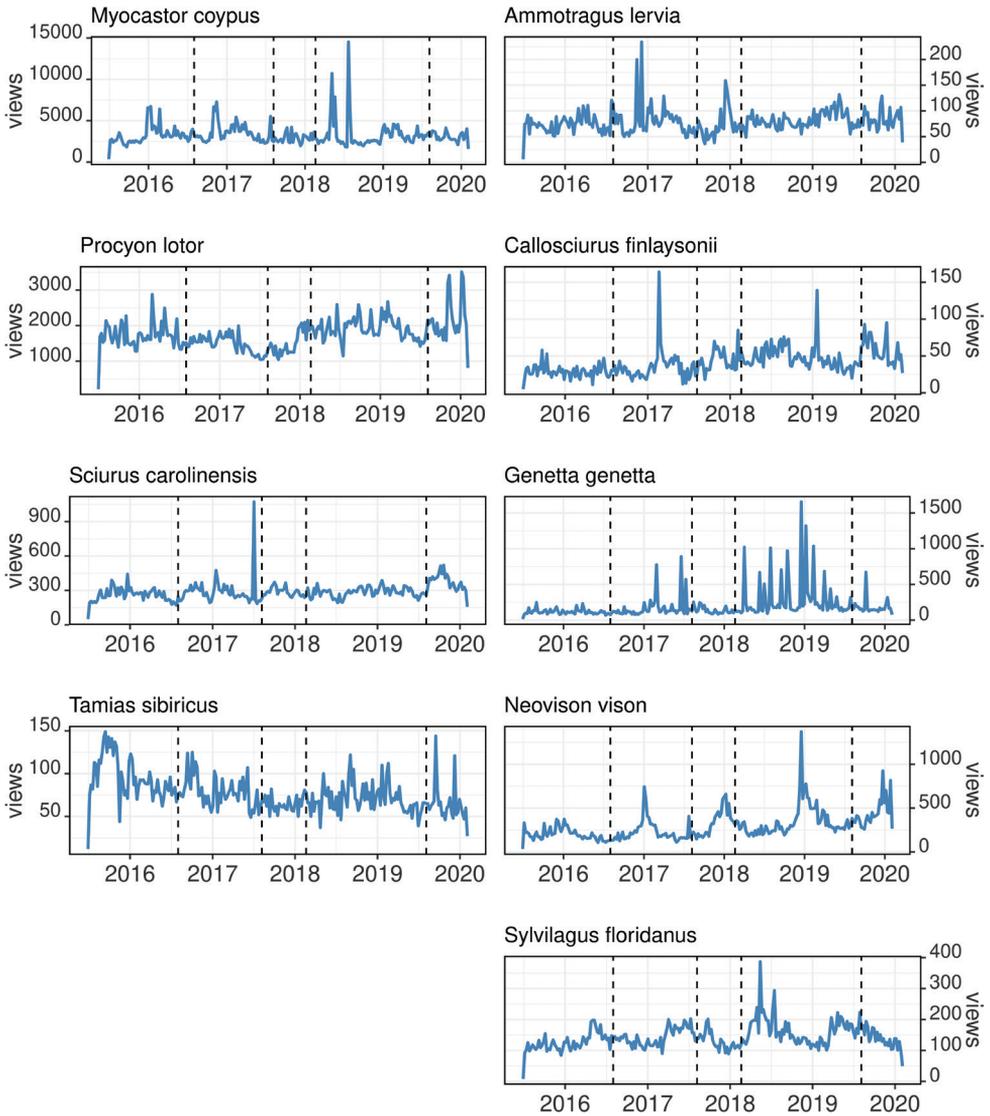
Figure 4. Number of visits to Wikipedia pages on invasive alien mammals included in the Union list (left column) and invasive alien mammals not included in the list (right column). Dashed lines, from left to right, represent the publication of the first blacklist (July 2016), its first update (July 2017), the implementation of the first Italian law about invasive species (February 2018) and the second update of the blacklist (July 2019).

Wikipedia data could be aggregated into a treatment and control time series, a prerequisite for causal impact analysis, which was not possible using GoogleTrends. However, this choice excluded dedicated websites, which can be an important source of information about IAS and biological invasions. Combining visits to Wikipedia and dedicated websites can provide a more comprehensive picture on changes in public curiosity and

future studies should attempt to access and combine these two sources of information to obtain a more comprehensive metric of public interest that would produce a reliable picture of different social groups and geographical areas.

The second limitation of our study was our decision to focus on invasive alien mammals, which limits the validity of our findings for other taxa. However, compared to invasive alien plants or invertebrates, vertebrates (Jaric et al. 2020), especially mammals, are more salient to people as they can be assimilated to human beings (Manfredo et al. 2020), also based on their evolutionary similarity (Batt 2009). Our decision should therefore have magnified the impact of the Union list on the volume of visits to Wikipedia. We believe that any study replicating our approach to other groups of IAS would reach similar conclusions, at least for Italy, as it will deal with species that are less salient than vertebrates to laypersons.

Interestingly, Cerri et al. (2021) showed that Google searches for general terms about biological invasions, such as "invasive species" or "alien species", increased over time in Italy and even after the entry into force of EU Regulation no. 1143/14 in January 2015. On the other hand, they did not detect any change in visits to three Italian Wikipedia pages about general terms related to IAS. This might indicate that policymaking initiatives about biological invasions can sometimes change the volume of searches on search engines, such as Google, but not on more specialist websites, such as Wikipedia. Moreover, media coverage and outreach initiatives on biological invasions might have different effects on information seeking behaviour, in the case of abstract concepts, such as "invasive alien species" or in the case of practical examples, such as alien species on a blacklist. Future studies, combining in-depth qualitative interviews with manipulative approaches, such as factorial survey experiments, might be useful to ascertain whether these differential patterns exist and how they affect Internet searches.

Finally, this study emphasises the influence that the media have on public interest about IAS and aims to encourage policymakers to exploit media coverage to produce effective communication on biological invasions. Online searches were clearly not affected by news about the Union list, but they peaked in coincidence with sensational news about individual invasive alien mammals, such as viral videos, news about large-scale control initiatives or mass escapes from captivity. Although it is unlikely that traditional media will alter their coverage of these sensational events, we believe that policymakers should exploit them to communicate information on IAS. For example, following the media echo associated with a viral video of an invasive alien mammal in an urban area, environmental agencies could publish a post on their official social media channels, citing the original news, giving information on the characteristics and impacts of the species, together with existing regulations about its management at national and European scale. By doing so, they would exploit the media echo to disseminate knowledge about IAS, their impacts and their management. Moreover, agencies could strengthen their cooperation with traditional media, pushing for the inclusion of expert interviews whenever sensational news about IAS is to be broadcast and adopting established codes of conduct for scientific communication (MacFarlane and Rocha 2020).

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Supplementary material 1

Supplementary information

Authors: Jacopo Cerri, Lucilla Carnevali, Andrea Monaco, Piero Genovesi, Sandro Bertolino

Data type: pdf. file

Explanation note: Newspaper and television news related to the publication of the Union list (The list of invasive species of Union concern connected to the European Regulation on invasive alien species no. 1143/2014).

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