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Uncovering patterns of public perceptions towards biodiversity crime using conservation culturomics

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Abstract

This paper examines aspects of the relationship between (1) the recently typified form of biodiversity crime, (2) information made available to the public through the Internet, and (3) cultural dynamics quantified through info-surveillance methods through Culturomics techniques. We propose two conceptual models: (1) the building-up process of a biodiversity crime *culturome,* in some language, and (2) a multi-stage biodiversity conservation chain and biodiversity-crime activities relating to each stage. We use crowd search volumes on the Internet on biodiversity crime-related terms and topics as proxies for measuring public interest. The main findings are: (1) the concept of biodiversity-crime per se is still immature and presents low penetration to the general public; (2) biodiversity-crime issues,not recognized as such, are amalgamated in conservation-oriented websites and pages; and (3) differences in perceptions and priorities between general vs. niche public with particular interest(s) in environmental issues- are discernable.

Keywords Biodiversity crime · Conservation culturomics · Conceptual construction of crime culturome

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Introduction

The *Convention on Biological Diversity* (Rio de Janeiro 1992) is the epitome of liberal conservation strategy, a compromise between the designation of Protected Areas (PAs *henceforth*), re-regulation of the environment, and commodification of biotic resources (Secretariat of the Convention on Biological Diversity, 2005). Real-world results in implementing this conservation strategy are relatively weak (e.g., Blicharska et al., 2016; Butchart et al., 2010; Perrings et al., 2010; Tittensor et al., 2014; Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) 2019; Troumbis, 2021). Research on the so-called biodiversity conservation implementation gap or space (e.g., Maas et al., 2019), i.e., disciplinary and geographical biases and limited communication between scientists, practitioners, and decision-makers, is actively developing. Overall, there are *ca* 450 papers cataloged in the *Web of Knowledge/ Science (*WoK/S *hereafter)* as of July 2021 responding to the search string "conservation AND implementation AND gap AND biodiversity"; and the Web of Knowledge/Science (WoK/S *henceforth*) lists > 155,000 papers tagged with the term biodiversity, during 1987–2021. The academic effort repeatedly highlights the divergent directions of (1) political commitments, Conventional and legal framework (> 700 International Agreements and domestic conservation accords, e.g., Chester & Moomaw, 2008) and (2) capacity building, awareness campaigns, or funding (hundreds of International/local ENGOs and billions of US$ or € invested, e.g., Fulton & Vercammen, 2014; European Commission/Neemo/Ernst and Young, 2016) versus the meager advances in the field. Several causes, ranging from opportunism in protected areas designation (e.g., Meir et al., 2004) to administrative incapacities and institutional weaknesses (e.g., Mascia & Pailler, 2011), to reduced public participation in decision-making (e.g., Irvin & Stansbury, 2004), have been proposed for this ineffectiveness, i.e., the measure of actual conservation achievement per cost (e.g., Arponen et al., 2010). Environmental and biodiversity crime is gaining currency in the interdisciplinary study of human-nature interactions as a proximate cause of threat to biodiversity conservation (e.g., Elliott, 2017; Moreto, 2017; Rose, 2011; Sundstrom, 2016). Biodiversity crime is considered as a specific class of pressure(s) upon (1) biological entities, i.e., genes, individuals, and populations of species and their habitats; (2) the ecosystem functions and services they support and generate; and (3) conservation policies of communities, societies, or States (e.g., Hoggt & Carrington, 1998).

As a criminological issue per se, the sparse biodiversity-crime literature attempts to integrate narrative and normative (e.g., Biber, 2017), legal and statutory (e.g., Apel, 2013), sociological (e.g., Kavish & Boutwell, 2018), or economic (e.g., Lacey et al., 2018; Pogarsky et al., 2018) definitions and explanations of individual or syndicate deviations from the commonly adopted norm of social order. The cultural dimensions of the multivalent problem of anti-social behavior and unlawful acts (e.g., Eysenck, 1996) in the domain of biodiversity conservation are, however, often neglected. Biodiversity crime, situated at the interface of multiple disciplines, including common Law (e.g., Do Vale, 2015;

Zhu, 2014), environmental and green criminology (e.g., Beirne et al., 2018; Brisman, 2020; Brisman & South, 2019; Rodriguez Goyes & Sollund, 2018; Tosun, 2012), economics (e.g., Le Gallic, 2008; Lynch et al., 2017), sociology (e.g., Huebschle, 2017) and conservation science (e.g., Cafaro, 2015; Maas et al., 2019; Solomon et al., 2015; Troumbis & Zevgolis, 2020), presents interesting conceptual and methodological peculiarities. For instance, in terms of ethical judgments, biodiversity crime is often difficult to grasp, for it offends intrinsic and inherent values of nature (e.g., Diaz et al., 2015) that are culturally defined but not ecumenically protected by human Law. The controversial example of circus animals, bullfighting in Hispanic countries, or bear-subduing in the Balkans until some decades ago generated the layman legend of tamers and are (or were) considered a cultural event, heritage, or entertainment attraction. What differentiates bullfighting and bear-subduing is that the latter is an endangered species, overpassing the mistreatment per se of both animals. What makes the difference between the illegal trade of a lion vs. its exposition in a zoo is the existence of an incumbent scientific discourse considering the latter as conservation-positive. Such ambivalences might blur distinctions in the fuzzy conservation value system (e.g., Pascual et al., 2017). Moreover, the average citizen is exposed to complex scientific and legal discourses to assess criminal harms and damages caused to biological beings after the accumulative deterioration of biotopes or illicit appropriation of scarce biotic resources. Such harms and damages are not immediately visible, are often 'victimless' (Cardwell et al., 2011), and 'voiceless' indeed (Solomon et al., 2015).

According to Europol, the European Law enforcement Agency, environmental and biodiversity crime intensifies, especially during the Covid-19 circumstances (Europol (SOCTA), 2021). Recent environmental and criminological literature might identify partial causes of biodiversity-crime dynamics (e.g., Brisman, 2020). At first, one could note the likely lack of substantial public interest in conservation issues (e.g., Burivalova et al., 2018; Ficetola, 2013; Mccallum & Bury, 2013; Nghiem et al., 2016; Novacek, 2008; Troumbis, 2017a, 2017b; 2019). Second, cultural and linguistic differences in people's perceptions of nature (e.g., Funk & Rusowsky, 2014; Roll et al., 2016; Troumbis, 2021) often estrange them with scientific terminology and conservation concepts (e.g., Fischer & Young, 2007). Third, the mismatches between scientific effort and conservation needs (Fisher et al., 2010). Fourth, the weak correspondence between biodiversity crime ontologies and legal typification, as in the case of ordinary crime (e.g., Brantingham, 2016), might make it challenging to integrate into the penal system, the prosecution procedures, and its fuzzily functioning green benches. Fifth, the inefficiency in international cooperation is an additional cause for navigating the conservation implementation space unsuccessfully (e.g., Elliott, 2017; Rose, 2011; Troumbis & Zevgolis, 2020). As Elliott (2017) eloquently stated, the complexity per se of the conventional international framework on environmental and biodiversity crime leads to legal indeterminacy, normative ambiguity, and regulatory uncertainty.

However, although the above significantly determine cultural human-nature interactions, the repercussions of such indirect drivers upon the public interest in biodiversity crime issues have not yet been studied or remain partially unexploited, to our

best knowledge. Understanding people's perceptions, awareness, and interest in the benefits of biodiversity and the costs of biodiversity crime are of primary importance for determining whether crime-combatting policies will succeed in curveting it in the long term. We hypothesize that this challenge might be approached methodologically through the emergent *Culturomics* epistemology (Michel et al., 2011), i.e., the quantitative investigation of cultural trends through the automated linguistic and lexicographic analysis of millions of digitized books (*ca* 16 M as of the end of 2019; data available through *Google Books Ngrams Viewer* service). Michel et al. (2011) made further the point that "*culturomics extends the boundaries of rigorous quantitative inquiry to a wide array of new phenomena spanning the social sciences and the humanities*" (p. 176). Further, *Conservation Culturomics* (CC henceforth) is an epistemology *per se* that seeks to understand the evolution of human-nature relationship(s) through discursive expressions that define human acts and behavior (e.g., Ladle et al., 2016, p. 269; Sutherland et al., 2018; Troumbis & Iosifidis, 2020).

We will utilize data from *Google* crowd searches on biodiversity crime-related words and topics to uncover patterns of perceptions across time, possible behavioral change over time, and pinpoint drivers of the public's behavioral uptake. This approach might complement the fragmentary yet use of big online data (Web, mass media, social media), although they represent a rich opportunity to investigate public perceptions on emerging topics such as conservation and biodiversity (e.g., Correia et al., 2016; Correia et al., 2017; Troumbis, 2017a; Toivonen et al., 2019). We expect that bridging this gap could be important for improving the efficacy and success of conservation and biodiversity crime prosecution in the long term.

In this paper, we attempt (1) to define a biodiversity-crime *culturome*, i.e., a linguistic set of words, terms, or topics that encapsulate its various meanings, aspects, and domains at the reach of people "Conceptual model 1: a mechanism for the public construction of biodiversity crime culturome"; (2) to explore general trends of public interest in biodiversity crime themes using *Google Trends*-crowd search data as a well-established technique of CC "Conceptual model 2: the conservation implementation chain, gaps, and crime" and "Results"; (3) to propose a hierarchical ontology of acts one could consider as biodiversity crimes "Discussion"; and (4) to discuss ontological correspondences between modern forms of crime "Discussion".

Methodological issues: setting the scene

We base our overall approach upon two conceptual models. These models serve as explanatory bases for constructing a specialized pool of associated terms (or phrases) on biodiversity criminal issues addressable through conservation culturomics epistemology. The first model introduces a mechanism explaining the assembly of words or terms in the kernel lexicon of a language encapsulating the biodiversity crime phenomenon. The second model introduces a typified form of the conservation implementation chain and its sequential stages governing biodiversity components and conservation policy conditions against which criminal activities and acts occur. We expect that the CC methodology would help understanding how initial public interest – or curiosity—expressed through crowd

searches on the Internet might reflect sustained public adherence to biodiversity crime importance; and, therefore, to be investigated as a significant component-into the overall biodiversity-conservation strategy implementation, in the future.

Conceptual model 1: a mechanism for the public construction of biodiversity crime culturome

Petersen et al. (2012) qualify a language as an *ecosystem of words* permeable to other languages; they further distinguish time scales in its evolution. One can identify three primary sources of words (terms) –and phrases- relating to biodiversity crime issues: (1) the *kernel* lexicon consisting of words emanating from scientific vocabulary and more frequently used words; (2) the *unlimited* lexicon comprising terms and phrases commonly used in public communication channels, (e.g., mass media, social media) and, most importantly, vernacular names or expressions of biodiversity entities; and, (3) *exotic* terms to the reference language, incoming from other languages. Altogether, they form a pool of words (terms) focusing on this specific issue. The public, i.e., the Internet users, searches massively for information on a subset of this pool: it is a sampling process constructing a culturome after the systematic association of terms in large volumes of crowd searches. In direct analogy to the concepts of *gene* and *Genomics*, individual words, i.e., terms conveying a concept, are discrete inherited units of a language. Linguistics refers to the study of etymology and the expressive evolution of terms in a language's lexicon. In contrast, besides its neological character, culturomics aims to develop computational lexicography to investigate cultural phenomena by analyzing digitized texts and data mining on the Internet (Michel et al., 2011).

Specialized Internet services provide collections of associated terms (e.g., *Google Adwords Tool, Wordstream Free Keywords Tool, Keywords Everywhere*). Such associations present crowd search volumes trend lines and altogether form evolving culturomes with a series of properties (Fig. 1). Two issues are calling for caution in this mechanism. First, several scientific terms correspond to broader topics, e.g., climate change, global warming, greenhouse gases and effects, *et cetera*. Second, although vernacular names of species are essential components of a culturome and eventually semantically identical in the public's mindscape regarding their scientific names (e.g., Correia et al., 2016; Jaric et al., 2019), they might hide taxonomic differentiations: e.g., the African elephant corresponds to two species, *Loxodonta africana,* and *Loxodonta cyclotis*.

Individual terms correspond to specific segments of the conservation implementation chain (see Conceptual model, "Conceptual model 2: the conservation implementation chain, gaps, and crime". here below). Some of them contribute conceptual emphasis: e.g., biodiversity, ecosystem, species, or conservation. Others are complementary within the same segment: e.g., scientific and vernacular names of species; others complement segments: e.g., PAs vs. EU Natura 2000 conservation sites.

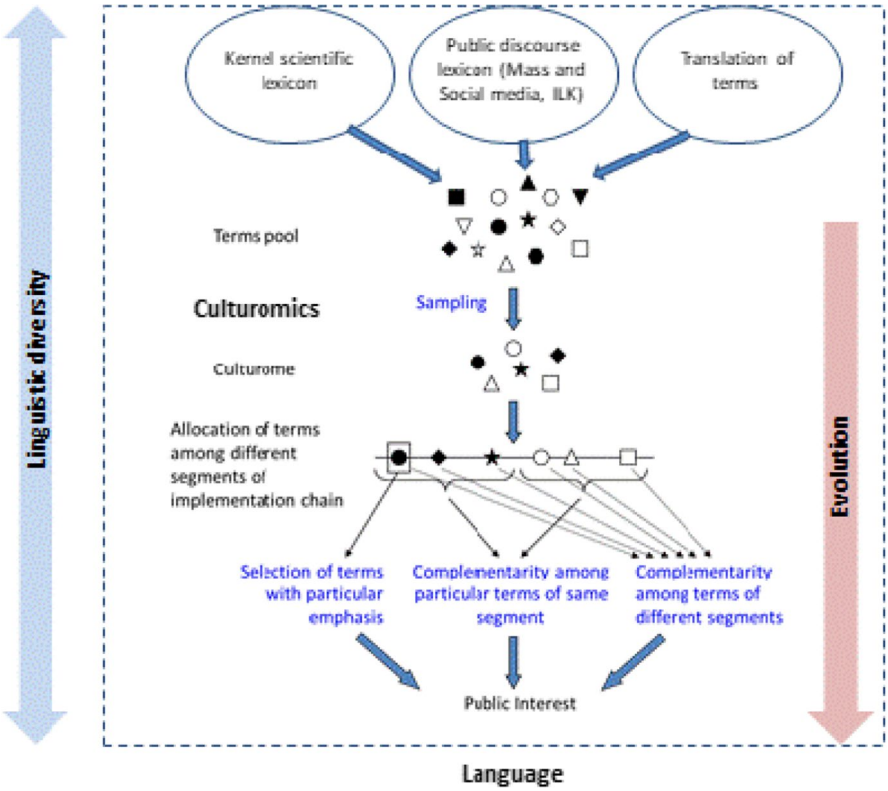

Fig. 1 A depiction of the mechanism of construction of a culturome studied through the metaculturomics approach, inspired after Hooper et al. (2005). See text for detailed explanations

Conceptual model 2: the conservation implementation chain, gaps, and crime

The linear conceptual model depicts a 5-stage ideal implementation process for conservation strategy (Fig. 2). The stages identified include science, rhetoric, gazettement or institutionalization, policy instrument building, and confirmation. The model also includes dominant processes per stage, actors, and major drivers. The science stage corresponds to identifying biodiversity *objects* such as species or habitats. Rhetoric is the stage where social processes of argument construction in favor of biodiversity conservation occur; scholars or Environmental NGO experts are the main actors who establish the basis of biodiversity conservation needs through a cognitive process. If science and rhetoric are efficiently combined, then decisions on gazettement (or institutionalization) are taken through political processes; there is a shift in dominance from actors to drivers since the economy, or national sovereignty issues play a core role in shaping the procedure. Technology and technocratic knowledge dominate and drive the stage of policy instruments building; decisions on spatial planning or selection of sites for protection or organizational structures and functions of governance systems are the critical issues at this stage. Finally, confirmation

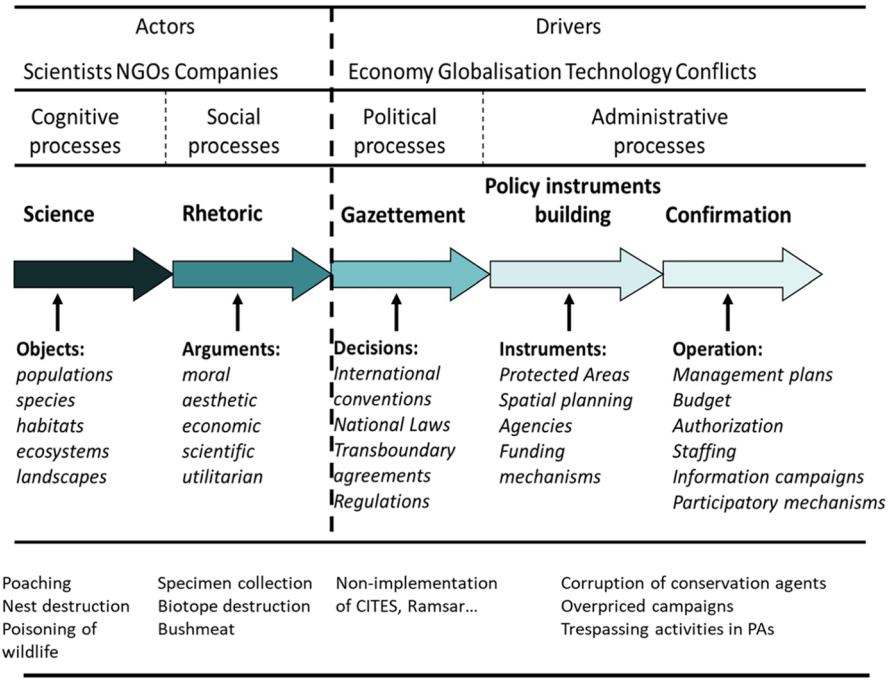

Fig. 2 A conceptual model describing a 5-stage implementation chain of biodiversity conservation strategy. Actors and Drivers, Processes and Stages are translated into a segmented dominant lexicographic space. Internet users' interest is expected to shift from flag-terms in early stages – science and rhetoric- to more specific ones as their information/knowledge-related experience increase

is the stage of action on the ground; drafting specific management plans, authorizing and hiring personnel, securing budget and cashflows, *et cetera*. One might expect that several feedbacks among constituent stages of the implementation chain that speed it up or slow it down in actual conditions might exist. If the implementation process fails or does not perform efficiently, there should be *cracks* or *chasms* between the stages (Fig. 2). For instance, there might be inefficient communication of scientific knowledge and message, the Sc-Rh crack; or, resistances in transboundary agreements, collaboration and coordination, the Rh-Gz crack; or, difficulties and lack of political and administrative will to confirm in the ground the previous stages, the Gz-PIb crack; or, capacity building issues, the PIb-Con crack; or, most likely some combination of all these conditions.

Biodiversity crime actions or activities are identifiable in each stage. Each one might affect components of a particular stage or, most importantly, it might energize the cracks that block the sequence of the conservation implementation process.

Conservation culturomics and biodiversity crime

Ladle et al., (2016, p. 269) established a 5-axes epistemic program of Conservation Culturomics. This program's conceptual translation or correspondence into

Table 1 A potential scheme on conceptual relationship between Conservation Culturomics epistemic program/agenda and environmental/biodiversity crime. The five horizontal fields reflect the core epistemology of Conservation Culturomics as defined by Ladle et al., 2016. The complementary annotations on Culturomics fields describe actual relationships with conservation discourse and actors involved in biodiversity crime, either positively or negatively

Conservation Culturomics Program (Ladle et al., 2016)	Conservation significance	Biodiversity crime actors/ players (examples)
Recognizing conservation-oriented constituencies and demonstrating public interest in nature	Creation of Internet/Social Media communities, identification of Conservation adepts, NGOs militants, political supporters and thinkers, environmental-friendly citizens, …	Hunters' Associations, Rangers, Forestry Department Officials, NGOs activists, media reporters, …
Identifying conservation emblems	Protection of keystone -species, species with wide-range territories and/or historical/ cultural symbolism	Species with appeal in common public/media discourse: elephant, tiger, rhino, monk seal, endemics, ethno-diversity species, …
Providing new metrics and tools for near-real-time environmental monitoring and to support conservation decision making	Complementary but no-substitutive information on public opinion evolving at various time scales and cultural entities	Analyses of biodiversity crime approximate information through Internet-based crowd search services, such as *Google Trends, Adwords, N-gram viewer, Wikipedia, Twitter, FB, …*
Assessing the cultural impact of conservation interventions	Role of culture-driven human-biodiversity relationship in terms of appropriation of biotic/ ecosystemic resources	Regional/local (mostly) economy platforms relating to primary, secondary and tertiary production (e.g. green/ biological agriculture, circular economy, low carbon industry), etc
Framing conservation issues and promoting public understanding	Environmental education, awareness and information activities…	Typical and a-typical activities within environment-related groups such as scouts, school pupils, outdoor activities associations, tourism promoters, …

non-compliance conservation concepts, i.e., biodiversity crime, is attempted or summarized in Table 1. This attempted correspondence might have various connotations, from recognition –and valuation- of crime activities *per se* to educative schemes against criminal activities.

Worldwide trends of public interest in biodiversity crime

In order to approximate public interest in biodiversity crime issues, we accessed Internet crowd-search activity (specifically through *Google* search engine and *Google Trends* service, *GTs* hereafter) from January 1, 2004, to August 31, 2020. We targeted explicitly (1) *collections of animal species*, under both their vernacular/popular names and scientific names, in most cases; this information was meant to trace the evolution of public interest in species that the International Union for Conservation of Nature (IUCN) lists as vulnerable, threatened, endangered, or critically endangered. The status of such listed species is highly related to various forms of biodiversity-crime types. Notice that the two collections do not match precisely since the vernacular sub-group emphasizes the popularity of species (e.g., Correia et al., 2016). Interestingly, 80% of queried species returned consistent time series. (2) The *biodiversity crime-related pool of terms*; we queried *GTs* service for > 150 terms or sentence search strings, of which just 30 crime-related crowd-searched terms and phrases (*ca* 20% of a hypothetical unlimited lexicon, in the sense of Petersen et al., 2012) returned consistent time-series. The selection of searched terms obeys two criteria: (i) terms are addressing the five ideal stages of the conservation implementation process, i.e., science – rhetoric – institutionalization—capacity-building—policy confirmation; (ii) selected terms serve as broad conceptual generalizations/stage, albeit occasionally overlapping in meaning. (3) The *identification of web pages* dedicated to themes and issues (1) and (2) here above; we contrasted these findings to the number of relative publications in the *WoK/S*, during the same period. The most significant observation is the low specialization of web pages since many of them refer to multiple biodiversity-crime types and conservation implementation issues.

All search strings are in English; therefore, the information collected is coarse-grained from a Culturomics perspective. Results presented hereafter are bound to a worldwide vocabulary that sidesteps linguistic, cultural, societal, and technological variations (e.g., Funk & Rusowsky, 2014; Troumbis, 2019). In other words, we used no geographical and linguistic restrictions when investigating *GTs*, so our data strictly reflect worldwide results from those users searching the Internet with *Google* in English (see Conclusions section for further details).

Results

We provide four configurations of *GTs* analyses hereafter:

(1). Figure 3 presents the ordination in a 2D slope (x-axis) – r^2 (y-axis) plane of the two vocabulary collections of species: (a) charismatic species after their vernacular name; (b) species after their scientific names. We assumed that this

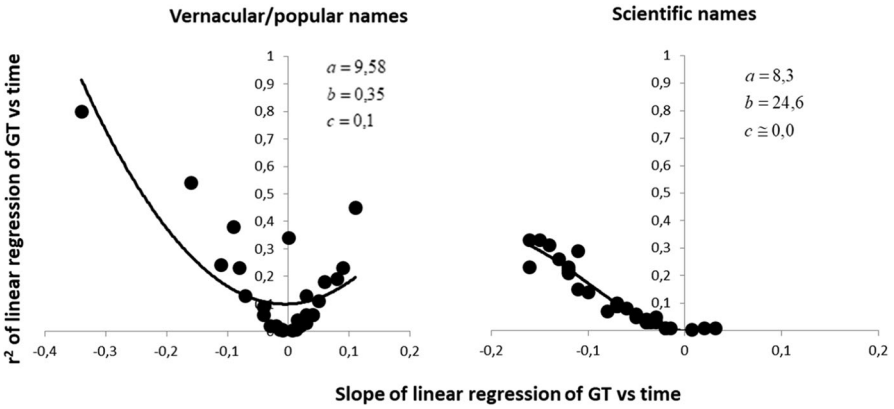

Fig. 3 Ordination in a 2D slope/r^2 plane of *Google Trends* metric of public interest in two vocabulary collections of species. Left panel: charismatic species after their vernacular name. Right panel: species after their scinetific names

comparison signalizes differences in public interest between the general public and some *niche* public, which most likely represents scientists, officials of Non-Governmental Environmental Organizations, members of various animal-watching groups, zoophilic charities, *et cetera*. In our terminology (see "Conceptual model 1: a mechanism for the public construction of biodiversity crime culturome" above), the culturomes constructed after vernacular/popular and the scientific names ordinated in the slope/r^2 plane present a U-shape distribution. We suggest that a 2nd-degree polynomial or parabola might approach such a U- slope/r^2 curve; and that the coefficients *a, b, c* of the corresponding $f(GT) = aGT^2 + bGT + c$ equations have specific physical meaning to comparing these culturomes. For instance, the coefficient *a* controls the curvature of the parabola, with higher values indicating stronger internal coherence of the culturome. The coefficient *b,* in combination with *a* in the form $x = -\frac{b}{2a}$, indicates the x-ordinate of the U-curve (the slope component). Moreover, coefficient *c* indicates the y-ordinate (the r^2 component); higher *c* indicates increased linearity of *GTs* of constituent terms.

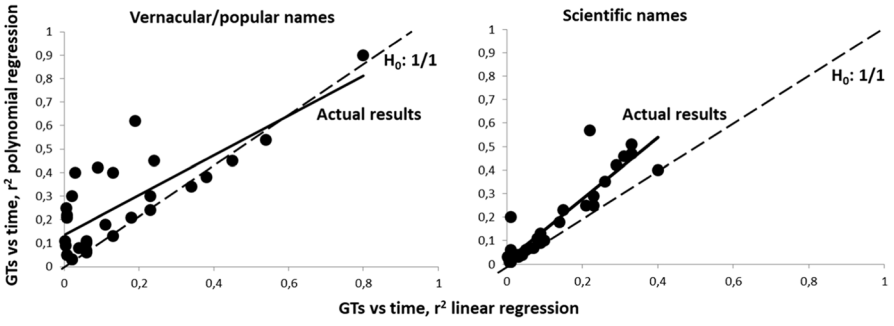

Fig. 4 Linear vs. cyclical trends of public interest in two collections of species nomenclature

(2). Figure 4 presents linear vs. cyclical trends of public interest in the two collections of species nomenclature. In both cases, the predictor of individual term results was time, and the response variable was search-volume/term as expressed by corresponding *GTs*. The deviation of *ca* 38 [r^2 linear vs. r^2polynomial] points from the 1:1 diagonal in the corresponding plane show that the overall public interest in species under pressure from biodiversity crime-related activities follows time cycles analogous to the core concept of biodiversity (Troumbis, 2017b). This graphical representation complements results presented in Fig. 3: niche public seems more reactive to variations in crime pressures upon conservation flag species.

(3) Figure 5 presents normalized *GTs* crowd-search data to identify –mostly-long-term linear evolution of the global public interest in the selected topics of the conservation implementation chain during 1/2004–8/2020. This configuration is typical of early publications in Conservation culturomics (e.g., Ficetola, 2013; Mccallum & Bury, 2013; Proulx et al., 2013; Wilde & Pope, 2013). The merits and flaws of such an approach are discussed in Troumbis and Iosifidis (2020).

(4) Figure 6A, B, C presents a synthesis of long term evolution of an ensemble of *ca* 30 biodiversity crime-related concepts available in two different media environments: (1) scientific publications cataloged in *WoK/S,* the *scholar pool of knowledge*; and, (2) number of web pages, the *public pool of knowledge*, dedicated to the same issues. The search period extends from January 1, 1990, to August 31, 2020. The starting date corresponds to almost all core environmental meta-concepts, i.e., biodiversity, sustainability, and planetary change in the late '80 s. *Poaching* is the

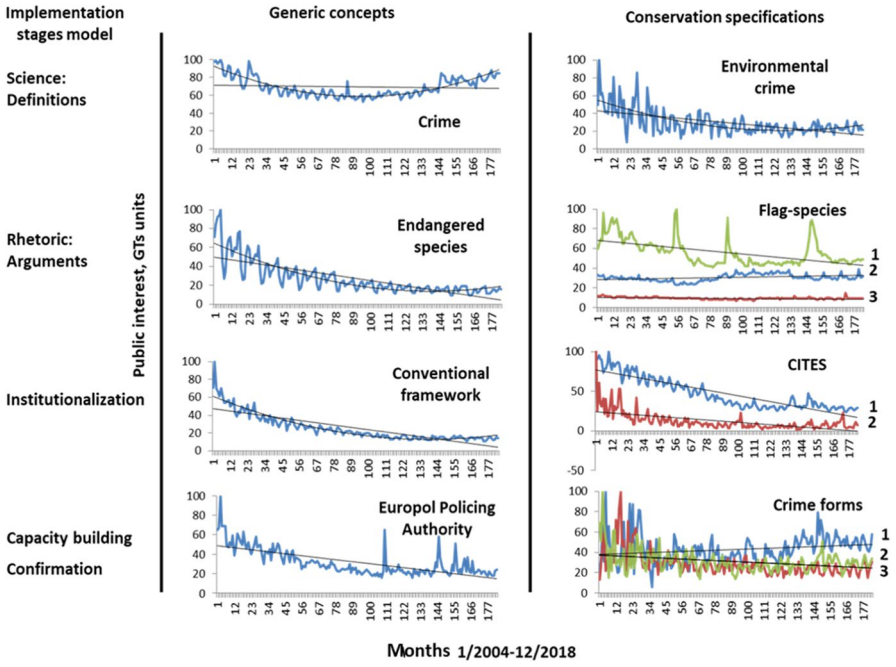

Fig. 5 Normalized *Google Trends* crowd-search data representing linear evolution of public interest in selected topics of the conservation implementation chain

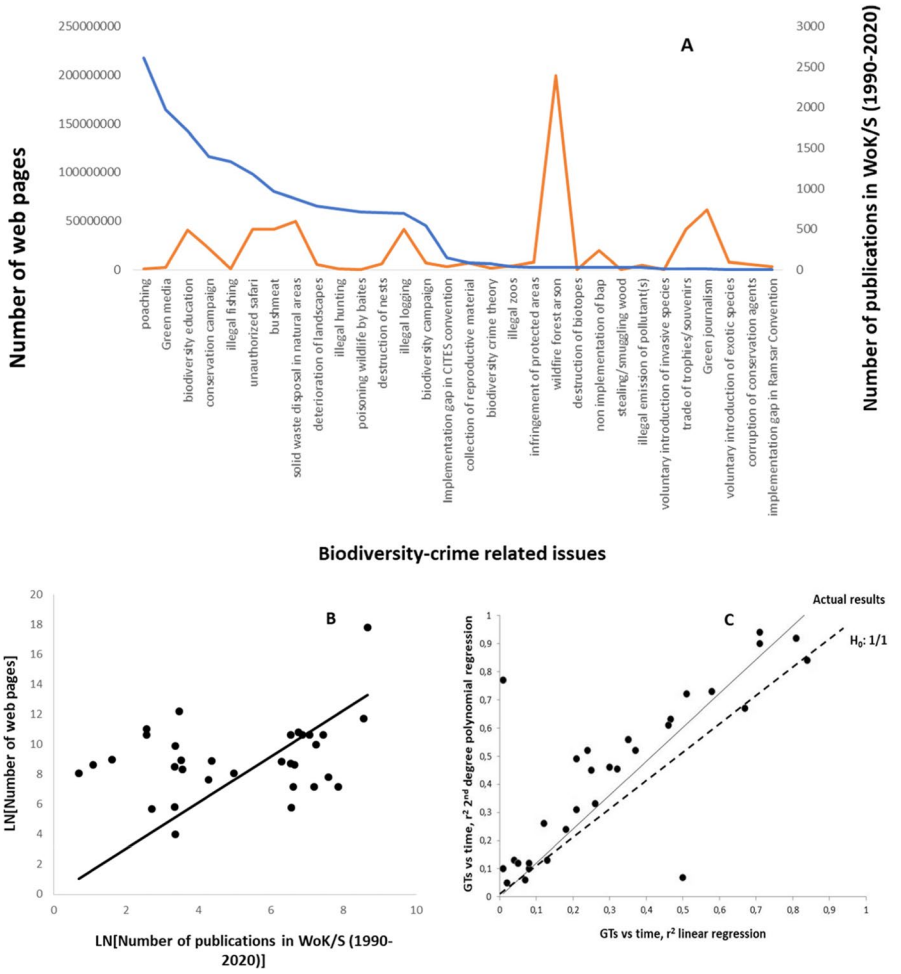

Fig. 6 Synthesis of long-term evolution of appearance of biodiversity crime-related concepts in scientific publications (Web of Knowledge/Science) vs. web pages

term attracting most interest in academic literature; *wildfire forest arson(s)*, a criminal activity, is by far the phrase repeatedly appearing in environmental/biodiversity oriented web pages.

Discussion

The discussion extends into three directions based on the findings here above. The first direction relates to drivers of biodiversity crime and its situation into a framework of social-ecological systems under exogenous vs. endogenous pressures. Within the incumbent conceptual framework of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Diaz et al., 2015),

core literature proposes long series of higher-order multiple and interdependent causes of- and effects upon- social-ecological systems that drive the failing implementation of conservation policies. External abrupt shocks or transient pressures upon individuals and their communities' economic and social status are shown to provoke significant endogenous pressures upon the state of biodiversity and ecosystem service provision units (e.g., Rounsevell et al., 2010). Misbehavior against- and misappropriation of- biotic resources have been related to the economic downturn in various biomes and human development conditions (e.g., South East Asia, Dauvergne, 1999; Venezuela, Rodriguez, 2000; Greece, Lekakis & Kousis, 2013; Troumbis & Zevgolis, 2020). Further, change of regime (e.g., Robinson & Milner-Gulland, 2003), war (e.g., Geist & Lambin, 2001; Duffy, 2014; Douglas & Alie, 2014; Runhovde, 2017; Lievano-Latorre et al., 2021), corruption (e.g., Gore et al., 2013), but also culture and religion (e.g., Grainger, 1993) and the abrupt penetration of science and technology into local socio-ecological setups (e.g., Lambin et al., 2006) are proposed as disruptive conditions altering the effectiveness of public conservation policy implementation. Recently, the Covid-19 pandemic and global human confinement conditions, including the ban of hunting and fishing, have also been related to ambivalent conservation efficiency issues (e.g., Bates et al., 2020). Such empirical cases are related to various degrees to biodiversity crime, e.g., poaching, illegal logging, and fishing, in the sense of non-compliance to- or voluntary violation of—conservation rules (e.g., Solomon et al., 2015) through mechanisms relating to market distortions and administration incapacities (Troumbis & Zevgolis, 2020). Interestingly, similar criminogenic mechanisms have been proposed or predicted to apply during and after the Covid-19 pandemic human confinement, even within protected areas (e.g., Koju et al., 2021).

However, the multivalent problem of biodiversity crime analysis should not rely upon episodic or short-term anomalies of social-ecological systems' trajectories. Instead, it should focus on long-term chronic pressures generated by illegal deviations in activities such as endemic or endangered species trade -including trophies or biological material collection, uncontrolled wet meat markets, the need for household food appropriation such as the bushmeat case, specialized industry interests -including equipment and services supply, or the operations of organized biodiversity-crime hierarchies. In that perspective, the discussion on biodiversity entrapment into poverty (e.g., Adams et al., 2004; Barrett et al., 2011) and the debate on price-determining vs. price-determined valuation of biodiversity (e.g., Farley, 2008) might constitute a guiding analytical framework relating to willingness-to-pay for illegal biological material or misuse of biotopes. It relates to the dominant assumption of Law enforcement authorities that environmental and biodiversity crime is directly linked to the search for illicit profits (e.g., Ayling, 2013; Leberatto, 2017). Under both conditions, i.e., transient vs. chronic pressures, it seems preferable to adopt a terminology of 'mechanisms enabling' biodiversity crime that allows avoiding the 'blaming of the poor' for biodiversity loss if criminal activities are decoupled from poverty and social justice issues (Lynch et al., 2017).

The second direction of the discussion relates to developing an ontology for biodiversity crime. Such ontology should be conceptually simple to reach, intrigue positively and energize the public interest in the connections between biodiversity crime

and unsuccessful conservation. It should be explicit, allowing for conceptual enrichment in a way that facilitates interdisciplinary collaboration, transnational coordination, and ultimately judge's decision, for it addresses cases that might carry built-in ambiguity in expert terminology and semantics if examined from the perspective of different scientific disciplines. It should also be formal to avoid Courts oscillating for justice between incumbent administrative policies and choices regarding conservation (e.g., Blicharska et al., 2016); theoretical mismatches of general penal and biodiversity crime cases (e.g., Barton & Moran, 2013); insufficient prosecution dossiers; insignificant judicial statistics, similar to those in unregistered crime (e.g., Stroh et al., 2016); and, theoretically unprepared benches and district attorneys (e.g., Rose, 2011).

Figure 7 presents such an ontology and a typology of biodiversity crime. Classes of biodiversity crime are sets of concrete concepts defined by the Law; for example, a Person or Offender is not necessarily meant in the physical identity of a 'biological individual' but as 'personification' through that individual of a rigorously defined criminal act. The same stands for the inverse case of the prosecuting law agent. Therefore, a Class represents a biodiversity crime concept relating to offense or prosecution. To make operational the proposed ontology, three Classes are necessary.

First, the Class of Malicious_Act lists in some strict way categories of offenses. According to the classification scheme, one Class might be described using a series of first-order subClasses arranged in a sub-class/super-class hierarchy. For example, in Fig. 7, the Class Malicious_Act comprises five first-order subClasses, i.e., illegal hunting, illegal logging, illegal fishing, trade, and collection. Each first-order subClass is further divided into second-order subClasses. Therefore, a 'Person' who destroys nests of a bird species, be it Red-listed or not, is committing an offense of the subClass Collection of the Class Malicious_Act.

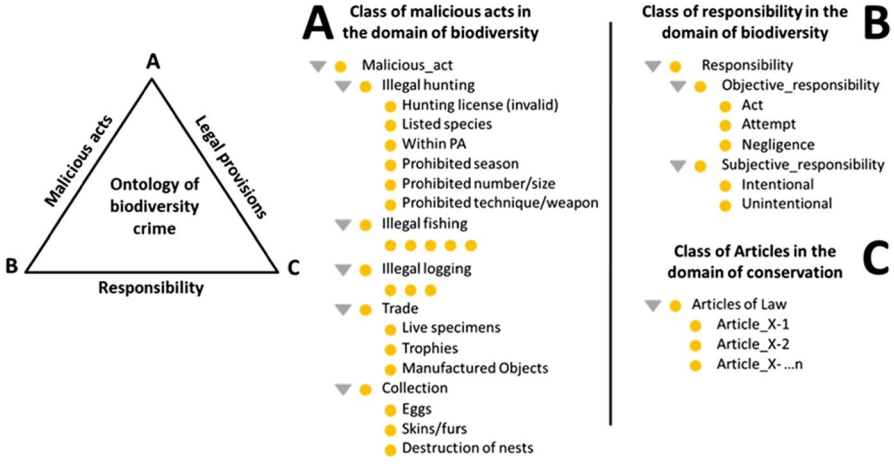

Fig. 7 **A**,**B**,**C** Description of Classes in Protégé format. The list of sub-Classes is indicative since several additions could be made according to amendments of Law prescriptions. For instance, Poisonous bates could be added to the sub-Class Illegal hunting if specifically described in the Law or Destruction of nests could be another class or a subClass of Collection. The same could be true for the Responsibility Class if Commission is added to the list of Objective_Responsibility sub-Classes

The boundaries of a Class, with its subclasses, relate to the classification of functionality, rigorousness of legal definition of acts, and similarity between them. For instance, viewed from the standpoint of conservation biology, the second-order subClass_Prohibited_technique in the subClass Illegal_hunting as a case of the Class Malicious_Act is functionally similar, not to say identical, to the correspondent in the subClass Illegal_fishing; for a poacher might use banned equipment to attract flocks of waterbirds to shoot massively or he might use dynamite to collect fishes massively in the same wetland. The only distinction between these acts lies with the relevant Law qualifying the act, the Law on Hunting in the first case and the Law on Fishing in the latter.

The second Class refers to Responsibility. The penal system recognizes two first-order subClasses: objective and subjective responsibility; they are too divided into second-order subClasses. Within the subClass Objective_responsibility, the distinction is made between Act, Attempt, and Negligence when a single individual perpetrates the crime. Commission as a second-order subClass involves a third person and is usually treated through prescriptions included in another range of the criminal Law. The Commission might be of critical importance in organized crime cases –a class repeatedly observed in the illegal logging/smuggling case where a hierarchy of roles should be judged. Within the subClass Subjective_responsibility, the distinction is made between Intentional and Unintentional crime.

The third Class refers to the actual provisions of the Law, i.e., the Articles that define the specific crime and predict criteria of application and sanctions. It should be noticed that both national and international legal framework governing forests, fisheries, various categories of protected areas and species, land use, and spatial planning predicts hundreds of Articles, clauses, and sub-categories about all probable and improbable situations. It indeed leads to Elliott's (2017) conclusions on legal system mis-performance due to its inherent complexity, indeterminacy, and ambiguity.

The three Classes share a common characteristic; they describe the conditions to be satisfied, so an individual case is assigned to a specific type of biodiversity crime. Therefore, links between classes are necessary; these links are common properties within a given domain of knowledge. A given set of properties characterizes a group of individuals treated equally by the penal system. For example, all hunters who intentionally shot a listed brown bear within a PA pertain in the same group of penal treatment. On the contrary, hunters who shot a wild boar intentionally in the same PA are not, but they might pertain in other Classes or subclasses of the same legal framework; for they all committed the crime of hunting within the PA, but one species is Red-listed, and the other is not. This Class should be further enriched with twin Laws on Hunting and Conservation.

The third direction relates to conceptual similarities of biodiversity crime with other modern forms of crime, as typified by Europol (SOCTA), (2021). As shown in Table 2, we propose a scheme of correspondence between crime types to which the public is conceptually acquainted and their ontological equivalent in the domain of biodiversity. We assume that such an approach might help overcome the public's limited interest in and understanding the various facets of biodiversity crime, individual responsibility issues, and the mechanics of organization, operation, financing, or money laundering of such criminal activities and networks.

Table 2 Examples of correspondence between modern criminal activities, as typified by Europol (SOCTA 2021), and biodiversity crime

Criminal activities	Biodiversity crime equivalent	Examples
Genocide	Interspecies genocide	6th mass extinction
Cyber-dependent crime	Intrusion to sites of conservation importance	Hunting in protected areas
Trafficking of human beings	Trafficking of protected species	Violation of CITES Convention
Smuggling of people	Smuggling of biotic resources	Transborder commerce of stolen wood
Waste crimes	The commerce of banned and hazardous substances/materials	Violation of the Vienna Convention and the Montreal Protocol for the ban of ozone-depletion substances
Organized property crime	Trespassing private game refuges	Illegal fishing in aquaculture installations
Trade in illegal firearms and explosives	Hunting and fishing gear and equipment	Fishing with dynamite and banned nets

Conclusions

This paper proposes an approach of the relationship between (1) a recently typified form of crime, i.e., biodiversity crime; (2) information made available to the public through alternative media, i.e., the Web, social media, and specialized academic bibliography; and, (3) cultural dynamics quantified through Culturomics surveillance techniques.

Overall, biodiversity crime is at an embryonic stage within the typical penal law types, understanding, and perception(s) of the public (e.g., Brantingham, 2016). For example, the classic 'theft' culturome, i.e., the set of associated terms *in Google* crowd searches, comprises 511 keywords while the 'murder' one, 423 keywords. On the contrary, 'biodiversity conservation crime' comprises only 1. It is the word 'poaching', a term with a long cultural history and relating more to practices than crime per se, comprising 286 keywords.

Most precursory conservation culturomics research focuses on public interest trends using Internet-based services that provide data on search volumes for specific keywords—e.g., the *Google Trends* service—or on sets/collections of related keywords—e.g., *Google Adwords Keyword Tool* or the public domain *Wordstream Keyword Tool*. Such research has helped in better understanding both structural (size of search volumes, lexicographic composition and relative frequencies of keywords) and dynamic (trajectories in time) traits of culturomes (Troumbis & Iosifidis, 2020) as well as significant determinants of their diversification across cultural, linguistic and technological setups (Funk & Rusowsky, 2014). However, such integrated information cannot address whether punctual interest in a biodiversity-crime-related keyword is sustained in time and, more importantly, whether it evolves towards increased public sensitivity for strategic conservation issues.

Models 1 and 2 have been tested against real-world data on Internet searches in the specific context of biodiversity-crime-related searches in English worldwide (data source: *Google* search volumes provided by *WordStream Keyword Tool*). It is a weakness of our approach since it rules out cross-cultural comparisons. However, it was deemed necessary to adopt such a linguistic sample in order to drop variability and noise generated by cultural, linguistic, chronological/conjectural, social, and technological determinants of the phenomenon (e.g., Rizzolo et al., 2017) because of fuzzy and vague translations of core biodiversity-crime terms provided by web-based services – especially in languages where endangered species are located and criminal activities eventually occur, e.g., *Panthera tigris tigris* in Bhutan, *Andrias davidianus* in China, *Lemur catta* in Madagascar, or *Varanus komodoensis* in small Indonesian islands.

Segmentation of conceptual searching across the biodiversity conservation implementation chain (Model 2) is arbitrary. However, it represents a well-informed guess on articulating a suite of concepts that expresses rational progress and conceptual differentiation in the conservation science-policy gradient.

One might hypothesize that several mechanisms interfere with a shadow process of transforming the stochastic process of an individual's interest–e.g., new, additional, or expanded search(es) for associated biodiversity-crime-related

keywords – to a somehow deterministic predictable pattern of group-behavior. Such mechanism(s) might be, among others: (1) *search efficiency*: individuals become mentally more confident and spend less time hesitating, learning, or making disappointing mistakes in searching biodiversity-crime related information sources; (2) *replication*: as information and knowledge converge to standardized arguments on biodiversity-crime, efficiency in searches tends to increase; (3) *network-building*: as a keyword is more widespread in information networks, an individual *Google* searcher uses it more efficiently because s/he is familiar with it; (4) an analogy of *software engineering POLA principle* (Principle Of Least Astonishment), i.e., information gathered from didactic sources regarding biodiversity-crime should comply to a discursive manner consistent with how individual users of this information are likely to expect it to behave; that is, average users should not be estranged by complicated terminology and complex explanations (Fischer & Young, 2007; Novacek, 2008).

Finally, our results support the idea that there might be divergence(s) among culturally determined social perceptions of criminal acts and their effects upon biodiversity and ecosystems, expressed in natural language that may lead to different interpretations of biodiversity crime -and its drivers. The cases of observed differences between the general public and the niche public (U-shape slope/r^2 or the importance of recognition of cyclical trends in public interest) are characteristic, generating likely varying penal evaluation between them. It might prove pivotal in the case of inter-departmental and international collaboration for environmental/biodiversity law enforcement (e.g., Elliott, 2017; Meeus, 2010). In Conservation Culturomics, improved intelligence techniques are necessary to accurately predict public interest in conservation; in the biodiversity crime domain, strict ontologies are urgently needed to outline abstract crime concepts and support consequent objective judicial treatment.

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Declarations

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