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Perspective

A framework for optimising opportunistic collaborative syntheses to propel ecological conservation

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A B S T R A C T

Ecological data are being opportunistically synthesised at unprecedented scales in response to the global biodiversity and climate crises. Such syntheses are often only possible through large-scale, international, multidisciplinary collaborations and provide important pathways for addressing urgent conservation questions. Although large collaborative data syntheses can lead to high-impact successes, they can also be plagued with difficulties. Challenges include the standardisation of data originally collected for different purposes, integration and interpretation of knowledge sourced across different disciplines and spatio-temporal scales, and management of differing perspectives from contributors with distinct academic and cultural backgrounds. Here, we use the collective expertise of a global team of conservation ecologists and practitioners to highlight common benefits and hurdles that arise with the development of opportunistic collaborative syntheses. We outline a framework of "best practice" for developing such collaborations, encompassing the design, implementation, and deliverable phases. Our framework addresses common challenges, highlighting key actions for successful collaboration and emphasizing the support requirements. We identify funding as a major constraint to sustaining the large, international, multidisciplinary teams required to advance collaborative syntheses in a just, equitable, diverse, and inclusive way. We further advocate for thinking strategically from the outset and highlight the need for reshaping funding agendas to prioritize the structures required to propel global scientific networks. Our framework will advance the science needed for ecological conservation and the sustainable use of global natural resources by supporting proto-groups initiating new syntheses, leaders and participants of ongoing projects, and funders who want to facilitate such collaborations in the future.

1. Introduction

The natural world is currently facing a range of global-scale economic, social, and environmental challenges, posing increasingly complex "wicked problems" (DeFries and Nagendra, 2017; Levin et al., 2012; Maxwell and Benneworth, 2018). Problems such as, how to halt human-induced extinctions (e.g., Kunming-Montreal Global Biodiversity Framework; 15th Conference of Parties – COP15 – of the UN

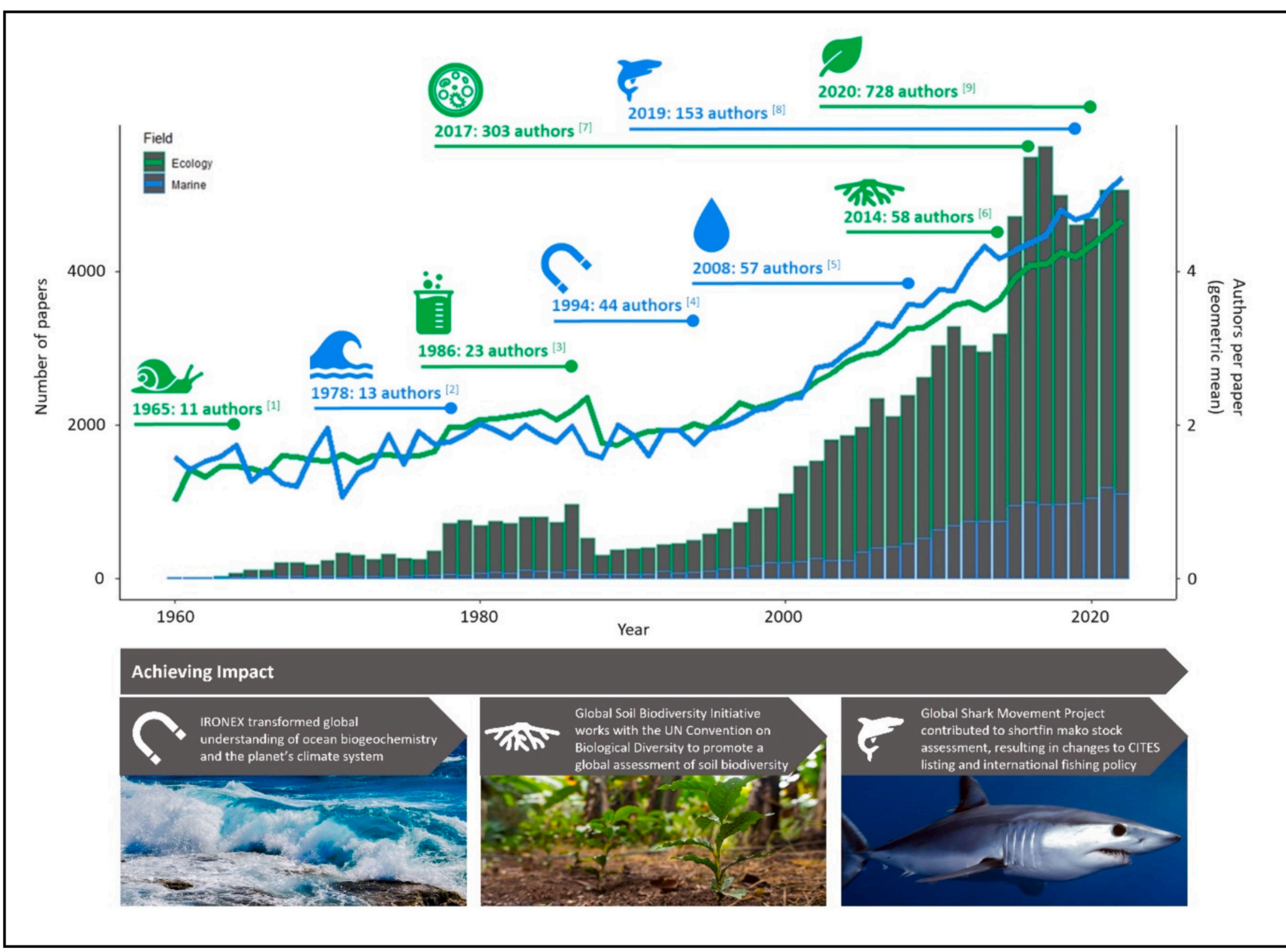

Fig. 1. Trends in number of authors in published papers since 1960.
Trends in collaborative authorship of peer-reviewed scientific articles between 1960 and 2022, based on a Scopus search of the keywords "Ecology" and "Marine AND Ecology" restricted to published journal articles in English. Overall publication numbers (bars) and average number of authors per paper (lines) are shown, with example big collaborations highlighted.

Convention on Biological Diversity – CBD; 19th December 2022; cbd.int/cop), mitigate climate change (UNFCCC report; https://unfccc.int/process-and-meetings/what-is-the-united-nations-framework-convention-on-climate-change), and achieve sustainable use of natural resources (e.g., blue economy; Cisneros-Montemayor et al., 2021), are now present in agendas across global initiatives. These global challenges encompass large geographical scales and require integration of multiple knowledge sources, driving the need for increasingly large and multidisciplinary collaborations in the natural and social sciences.

The practice of running planned, well-funded, large collaborations is long-established, particularly in the "hard" sciences (e.g., physics), and has produced notable outcomes that are now embedded in everyday-life and popular culture. An example is *The Apollo* program by the US National Aeronautics and Space Administration (NASA). This program involved close to half a million engineers, scientists, and technicians, and led to the televised feat of humans landing on the moon watched by an estimated 650 million people worldwide (nasa.gov/mission_pages/apollo/missions/apollo11.html), which popularized the saying "one small step for (hu)man, one giant leap for (hu)mankind". CERN (the European Organization for Nuclear Research) is another well-known endeavour that includes thousands of scientists from multiple countries working on universal questions (https://home.cern). CERN has led to major scientific advances, such as the discovery of the Higgs boson particle (Cho, 2012) and the invention of the World Wide Web (Berners-Lee et al., 2010).

Although not yet reaching the scale or achievements of those in physics or astronomy, planned big collaborations have also been well developed in some ecological fields since the mid-20th century - see Aronova et al. (2010) discussing the historical connections between global data-driven scientific initiatives connecting Geophysics and Biology as a way of promoting Big Science in ecology. Developed big collaborations in ecology have led to high-impact scientific outputs (Fig. 1). For example, the International Union for Conservation of Nature (IUCN; www.iucn.org) draws upon a network of over 15,000 international experts to serve as the global authority on the extinction risk status of species and guide numerous ecological conservation studies worldwide. The Global Soil Biodiversity Initiative (GSBI; www.globalsoilbiodiversity.org) and the Amazon Forest Inventory Network (RAINFOR; www.rainfor.org) are translating key soil and forest research into sustainability policy (Hubau et al., 2020; Phillips et al., 2009; Tedersoo et al., 2014; van den Hoogen et al., 2019). Syntheses centres are also increasing around the world (see progression time and list: The International Synthesis Consortium, https://synthesis-consortium.org/) following the model provided by The National Center for Ecological Analysis and Synthesis (NCEAS; https://www.nceas.ucsb.edu).

Big collaborative projects have also been used to overcome difficulties that arise when studying the marine environment. The ocean's vast nature, ephemeral features, and extreme conditions present a challenge for research. This in turn encourages collaborative approaches to overcome the associated logistical and financial constraints of sampling the marine environment, with a steady rise observed in multi-author marine research articles (Fig. 1). Early large-scale marine science projects include the classic IRONEX experiments to test if iron was the key limiting nutrient in oligotrophic ocean regions that cover much of the world (Boyd et al., 2007; Boyd et al., 2000; Martin et al., 1994), the Joint Global Ocean Flux Study (JGOFS) programme on the fluxes of carbon between the atmosphere and ocean (http://ijgofs.whoi.edu/), and the Global Ocean Ecosystem Dynamics (GLOBEC) programme to understand how global change would affect abundance, diversity and productivity of marine populations (Barange et al., 2010). Marine biodiversity research also includes projects that push the boundaries for collaborative data-based studies, bringing together extensive networks to address questions at larger spatial scales and continuous monitoring that would not be possible with small teams. For example, the Continuous Plankton Recorder (CPR) survey, established in 1931, is regarded as the longest-running and most geographically extensive marine monitoring programme in the world. It has collected millions of biological records and underpinned multiple high-impact publications (e.g., Edwards and Richardson, 2004; Thackeray et al., 2016). More recently, the project Census of Marine Life (CoML; 2000–2010) included collaborations of more than 2700 scientists and 80 countries (e.g., Costello et al., 2010), leading to the collection of a huge amount of data and to the development of the Ocean Biodiversity Information System (OBIS) and the World Register of Marine species (WoRMS). Many other marine biodiversity collaborative projects are now emerging, including: fisheries sustainability assessments (Illuminating Hidden Harvests report, 2023; https://www.fao.org/voluntary-guidelines-small-scale-fisheries/illuminating-hidden-harvests/en), and collaborative working groups focused on informing policy change (lenfestocean.org/en/research-projects/the-importance-of-marine-fisheries-and-ecosystems-for-food-security-in-china).

The value of a holistic, large-scale approach to environmental monitoring and conservation is clearly recognized, but establishing new targeted, long-term monitoring programs is often too slow to address challenges that are already underway and need immediate action. A much faster approach can be to leverage already existing data, which is providing the impetus for the development of "spontaneous", opportunistic, or bottom-up big collaborative projects, aimed at expanding and combining existing datasets to produce big data syntheses. These projects, henceforth referred to as *opportunistic collaborative syntheses*, are markedly different from the big, top-down efforts mentioned above because they often form organically and are fuelled by substantial volunteer efforts from a small group of individuals. However, they also have the potential to lead to large and high impact outputs that are achieved faster than those dependent on new data collection. Key examples include recent evaluations of impacts from the global COVID-19 pandemic (Bates et al., 2020), global marine forest mapping (www.marineforests.com), and vast animal tracking networks that extend the collaborative ethos to global analyses of animal movements, including seabirdtracking.org (e.g., Beal et al., 2021), globalsharkmovement.org (Queiroz et al., 2019), and megamove.org (Sequeira et al., 2018). Combined, these broad-scale, long-term projects are producing high-impact outcomes that can guide the future sustainable management of natural environments and resources. Given the environmental crises currently underway, the value of such *opportunistic collaborative syntheses* stands to provide considerable conservation impact at a global scale.

Despite the high potential of opportunistic collaborative syntheses that can leverage datasets collated around the world, there are a number of inherent challenges associated with building and sustaining such networks that need to be overcome. Questions such as 'how to start?', 'how to collaborate with people we don't know and be more inclusive?', 'how to know they are the right people?', 'who will do the analyses?', and 'how to share recognition and navigate through intellectual property issues?', are just a few examples of the challenges that must be carefully addressed for large opportunistic collaborative syntheses to succeed.

Here, we draw a global team of marine conservation academics and practitioners, distinguished by their efforts to bring together large collaborative teams, to develop a framework to propel opportunistic collaborative syntheses and advance global conservation. The initial team came together at the 2022 annual meeting of the Pew Marine Fellows (funded by The Pew Charitable Trusts) and was extended by invitation to nominated scientists known to lead collaborative teams. Together, we identify key considerations for planning the design, implementation, and deliverable phases of opportunistic collaborative syntheses (using underlined italic font to represent key terms discussed at the meeting) and propose strategies for pre-empting and overcoming the most common challenges that arise at each phase. Although our original focus was on marine projects, the considerations we present are applicable across all realms. We present our vision for pathways that better support the needs for global collaborative syntheses in ecology to meet the nexus between conservation, sustainability, and climate change science.

2. The value of opportunistic collaborative syntheses

Opportunistic collaborative syntheses can provide a valuable basis for addressing global ecological challenges by leveraging the collective knowledge, skills, and resources (including data) of diverse contributors. Here, we define '*opportunistic collaborative syntheses*' as those projects that begin organically with a small group (or an individual) and lead to the creation of a large network of people representing multiple teams (from similar or different disciplines) and organisations (of different types and purposes) from different regions and jurisdictions (with different perspectives and interests), to work together towards a common research goal. Usually, scientific endeavours involving these types of big collaborative syntheses are needed when (i) the question to address is beyond the skill, data, and knowledge that can be provided by individual (or small groups of) researchers, (ii) the complexity of the problem involves multiple disciplines or different types of data, (iii) the spatial footprint of the issue being addressed and length of the time series datasets need to span (e.g., cyclical climate cycles) is large, needing multiple inputs across groups or organisations (see Briscoe, 2008), or (iv) multiple teams working on similar goals want to share resources and join efforts to enhance scope and reduce redundancy (e.g. https://fishaiconsortium.org). Here, we specifically identify opportunistic collaborative syntheses as bottom-up processes, where the multiple people involved keep ownership and stewardship of the work or data provided by being included in the outcomes (e.g., included as co-authors in scientific publications). These projects differ from top-down, well-funded projects where large teams are assembled through funding allocation. The '*big opportunistic collaborative syntheses*' we focus on here, tend to form based on voluntary contributions of a group who has a shared vision and aims to work towards a common goal, and are by their very nature more responsive to new emerging opportunities to address global challenges. We do not refer to projects that involve large groups of people but do not sustain a continued academic collaboration, as is the case for example in outcomes from some citizen science projects.

The opportunistic collaborative syntheses we focus on here should be built on the principle of *inclusivity*, bringing together a diverse group of experts and stakeholders from different disciplines and backgrounds to grow a much larger dataset than would otherwise be possible. The expectation is that a more comprehensive and *holistic* understanding of the problem needing to be addressed is reached, which in turn should enable the development of realistic, applicable solutions. Such projects are fundamental for *transboundary and global coordination*, supporting alignment of efforts and resources across different regions where the development of conservation and management strategies are required. Such coordination can bring together expert opinions for *rapid assessments*, serve to quickly collate resources, expertise, knowledge, and large amounts of data to help identify key areas of concern and potential solutions more efficiently. The typically *wide engagement* of opportunistic collaborative syntheses can further raise awareness and understanding of the targeted ecological challenge, building capacity that leads to the enhancement of locally appropriate and sustainable solutions. *Innovation* is thus possible by bringing together diverse perspectives and resources to work towards a common goal, generating new ideas and approaches to tackle ecological challenges, often with greater success at influencing policy and management. Such efforts can build trust and continued engagement through experienced equitable, fair treatment of collaborators who share a common purpose, in addition to *increased transparency and reproducibility*, as well as long-lasting solutions.

Overall, bottom-up opportunistic collaborative syntheses represent an opportunity for the ecological community to unite knowledge, experiences, ideas, and resources (including data). Whilst they should preferably be built upon the principles described above, projects can struggle to achieve these ideals due to inherent challenges that are unique to opportunistic collaborative syntheses. For these projects to be successful, there is a need to clearly identify these challenges and share suggestions of best practice.

3. Common challenges and concerns

Gathering groups of people and large volumes of data involves considerable logistical challenges throughout the life of opportunistic collaborative syntheses. In the first instance, issues may arise in reaching out to, selecting, and including different contributors, particularly deciding (or knowing) who should become part of the project. *Managing the contributions from multiple collaborators* (from tens to many hundreds) is particularly challenging, given the elevated potential for many differing perspectives, interests, priorities, and motivations. Such challenges can be compounded by differences in culture, language, use of terminology, preferred methods of analysis and software, communication, engagement, capacity limitations, and expectations. Compiling disparate datasets collected in different ways and for different purposes can also pose a problem for *data standardisation and interoperability* (see for example Sequeira et al., 2021). The varying processes of data collection, analysis, and decision-making need to be *transparent* to foster trust and reduce chances of project failure, allowing for study replication. Often, there may be differing concerns about potential *bias* in the data or its interpretation, and how it might affect the advancement of the project. Examples include lack of representation of the system under study or of access to data, spatial or system bias, different resolutions or level of detail provided in the different datasets gathered, or multiple possible interpretations of information provided as input data. Additionally, different countries and institutions often have different requirements for research permits or ethical approval, as well as differing protocols for fieldwork, sample transport, or data curation, which may result in additional bias to the data collated. Common concerns from data contributors are associated with how they can best be involved at each step of the project, and how will they be acknowledged for their contributions. They are often also concerned with how their data will be managed and secured, including if the data will be interpreted correctly and not misused, and whether it will be shared more widely or monetised.

As the project develops, differing opinions can also hinder progress and even lead to a breakdown in trust between collaborators, particularly if *communications and record-keeping* are not well-managed. However, communications and records can be challenging to manage over the lifespan of a project, especially keeping track of data ownership and associated requirements (how to use it or not) as the project develops, of changes affecting permissions for data use (which may occur due to changes at collaborating institutions or governments), and of the nature of specific contributions, which may be more or less relevant at different project stages. Keeping the list of contributors current and up to date to enable *continued communications* can also be challenging, depending on the timeline of the project and number of people involved. Over the course of a multi-year project, people may move jobs, switch roles, experience differing priorities or time availability, or have changes in their motivation to stay linked (for example, with the end of funding or retirement). Time commitment from collaborators might differ or be needed only at different stages, potentially leading to issues with *credit attribution* or even *conflict among collaborators* due to misunderstandings or changes to the project timeline, which may not align with the ideals, needs, or expectations of all contributors.

When considering the research findings, having a fixed initial goal for a particular aspect of large projects can be risky, as the final observed results might diverge from original predictions. Contributors may have preconceived *expectations* of project findings based on their expertise or on the data from their individual datasets and context-specific studies. The large scope of opportunistic collaborative syntheses that pool data from multiple studies and data types can lead to *generalisation and overstatement of patterns* that may not be occurring across an entire dataset (e.g., local versus regional). Also, idiosyncrasies of the ecology of different species can become averaged out or glossed over. This might lead to new challenges at the end of the project, as there may be concerns about the implementation of the solutions proposed, particularly at local scales. For example, the solutions presented may be or seem technically, logistically, or financially infeasible, or collaborators might be unhappy with results and disagree with their dissemination or publication. The latter might even result in collaborators *withdrawing their engagement* making it difficult to complete project tasks.

Finally, challenges can also arise in the after-life of a project. Collaborative projects often aim for lasting impacts, but even when a resolution is reached, impacts may not manifest if the outcomes or recommendations proposed are not feasible. This leads to another challenge related to ensuring *project sustainability*. Long-term projects require continued engagement from all team members, which ultimately rely on trust of the project leader(s), as well as support and resources that are difficult to maintain for long periods. Finally, it is also important to recognise the concerns that *assessors* (e.g., reviewers, journal editors, policy-makers, conservation practitioners) might have in relation to these types of opportunistic collaborative syntheses involving the analyses of large amounts of data given biases that are often introduced (as detailed above). Ensuring potential biases are considered and addressed is vital for *credibility and reproducibility*, as well as for knowledge transfer of project outcomes in applied contexts.

Opportunistic collaborative syntheses are multi-staged projects, with on-going considerations needed throughout the entire project and with specific challenges unique to the different project phases. To ensure the success of opportunistic collaborative syntheses and overcome the inherent challenges associated with sustaining work of a large team on a complex topic over potentially long periods of time, it is crucial that team members are well managed and supported throughout all project phases.

4. Lessons learned: a framework with solutions to propel opportunistic collaborative syntheses

We propose a framework for designing, implementing, and delivering opportunistic collaborative syntheses, based on a strategic alignment of steps pertaining to project leadership, data collection and collation, preparation of deliverables, dissemination of outcomes, and achieving impact (Fig. 2). Whilst not an exhaustive problem-solving list, the framework draws on our combined experiences of leading and managing such projects and aims to provide guidelines that support best practice.

4.1. Design phase

The design phase of a collaborative project involves two stages: ***initiation*** and ***engagement*** (Fig. 2).

4.1.1. Initiation

The ***initiation*** stage includes defining the goals and set up of the project, as well as decisions regarding composition of the project team. In many cases, opportunistic collaborations arise simply through ideas emerging from meetings or a call for people to join forces on funding rounds. Sometimes reviews, perspectives, or horizon scanning exercises can also generate huge interest and serve as starting point for large collaborations. Very often in these cases, there is no a priori allocation of resources.

A key first step of the initiation stage is to clearly define the main goal of the project and who will act as the *Core Team*. This should include identifying the best *Project Champion(s)*, who will lead the project, commit to being the driving force, and be responsible for engaging with all collaborators (who are at this point still to be defined), and should ideally include a *Steering Committee* to help oversee the project and assist with its development. Defining *terms of reference* for the Steering Committee at early stages of the project can assist with outlining commitments and managing expectations. An Advisory Board can also be created to increase representativeness and diversify perspectives, without the members needing to commit to a key role focused on advancing and leading the project. It is important to ensure the Core Team is geographically diverse and multidisciplinary. It is worth noting that developing a values-based *governance* and actively envisioning collaborative work as mutually beneficial (i.e., win-win for all involved) can lead to stronger team relationships.

Together, the Core Team should clearly identify the *research questions and project aims*, with particular focus on the desired impact expected from the project. Setting up an operational team to assist with the daily management and development of the project (including working on the analyses) is also an important step that will prove crucial in moving the project forward. At this point, it is therefore important for the Core Team to *assess resource availability* to ensure that there are sufficient resources allocated to maintain communications within the team and with collaborators, create and maintain essential services (e.g., databases), develop analyses, and sustain project continuity until delivery. This may include identifying potential future applications for funding, which can run in parallel with the initial development of the project. The Core Team assumes the responsibility for financial stability, which represents a key issue throughout the project's lifetime.

Deciding who should be involved as a *contributor* is a key step to complete the initiation stage. This involves defining what the contributor will provide to the project (e.g. data, time, expertise), as well as a clear justification for their selection. The selection of contributors should consider *equality, diversity, and inclusivity (EDI)*, along with potential language or socio-economic barriers and cultural differences. Care should be taken to avoid over-representation of any one group. Considerations on how to reach contributors should be made at this step, as well as, determining upfront if there should be a minimum or maximum number of contributors, or if there is different representation needed for different sections of the project. This is important to ensure balanced teams are forged on ethical and justice principles. When there is a specific focus on reaching a conservation goal, considerations for including contributions from (or consulting with) conservation practitioners and managers should take place at the initiation stage and maintained throughout the project. This can be done through their inclusion as project members or as part of the Advisory Board.

4.1.2. Engagement

In the ***engagement*** stage, the main focus should be on *developing a shared vision*, *clearly defining expectations and commitments*, and *securing buy-in* from contributors. This stage involves reaching out to contributors and directly engaging with them, while clearly defining all steps of the process ahead, the deliverables expected (including planned timelines), how they relate to the main goal, and the *desired project impact*. A *Memorandum of Understanding (MoU)* can be developed as a way to clearly convey the project goals and outline where contributions are needed, including how data are to be collated and stored, how data will be requested, and what recognition is anticipated. Definition of all the criteria that will be needed for contributor inclusion is also essential at this stage. This should include guidance on how any questions or concerns arising during the project will be addressed and what will be the procedure in case any contributor wishes to withdraw themselves or their data from the project at later stages.

It is important to have a *communication plan* that clearly highlights the appropriate lines of communication between different members of the project and explains the project's communications medium, data storage, and personnel allocated for different tasks. As communications start, a *record-keeping mechanism* (with clear organization and filing systems) needs to be set in place to ensure all contributors are kept informed and datasets are linked to original contributors. This will become increasingly important as a means of keeping track of contributions, comments, and needs from different contributors at the different phases of the project. This is likely to involve the need for a

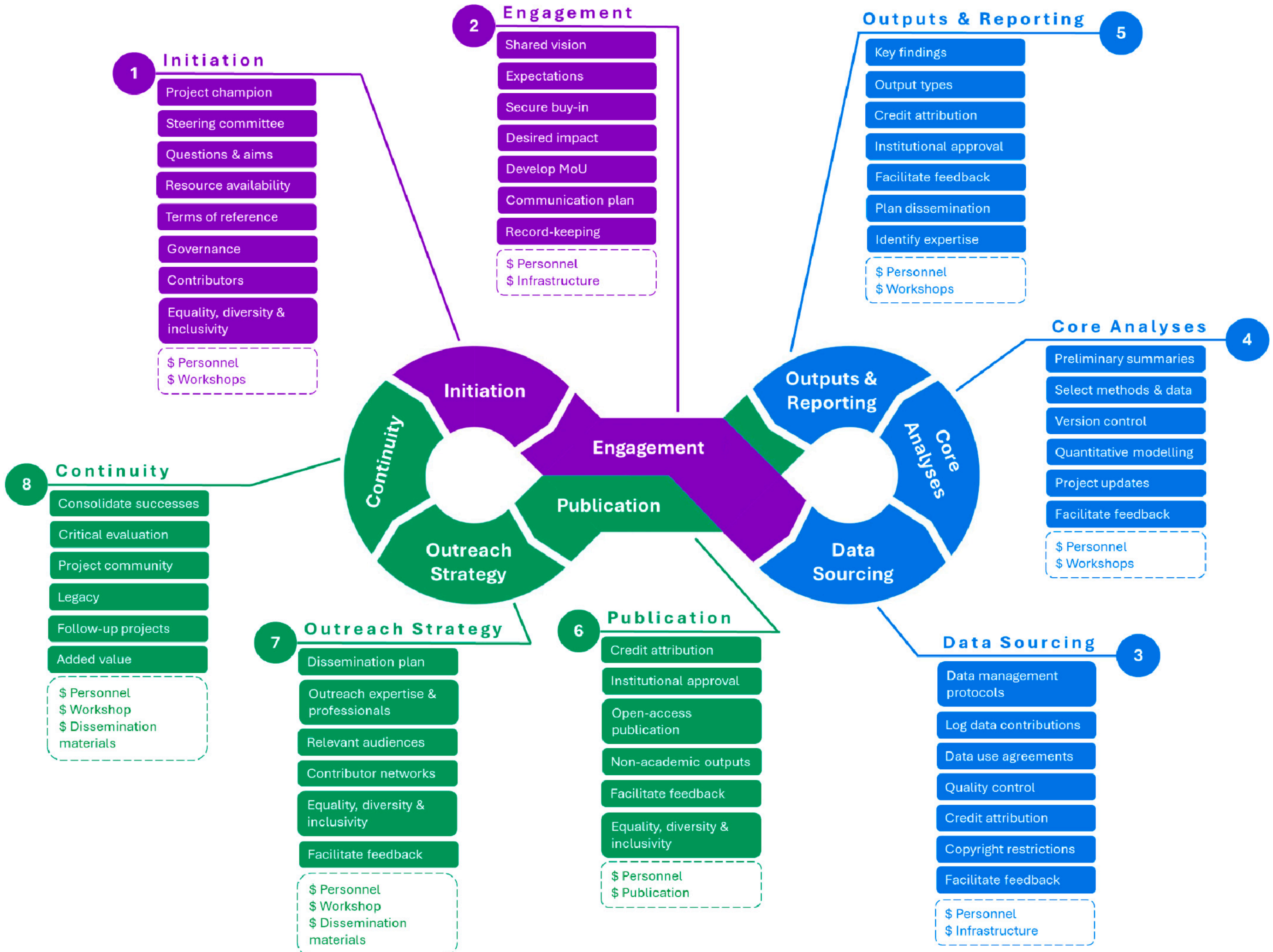

Fig. 2. A framework for bottom-up, opportunistic collaborative projects.
Our framework encompasses the different phases for designing, implementing, and delivering 'big' collaborative syntheses projects The three phases include different stages encompassing project initiation and engagement during the design phase, data sourcing, core analysis and creation of outputs and reporting in the implementation phase, and finally, publication, outreach and considering project continuity in the delivering phase. Each stage faces a series of challenge, and we include a non-exhaustive list of key problem-solving ideas, aiming to provide a strong foundation and guidelines for best practice.

cloud storage system. At the end of the design phase, it is important to consider the development of some web presence (even if just a landing page) and a logo for the project to support communications, group identity, and project longevity. These last two elements (cloud storage and web presence) may involve ongoing financial costs in terms of hosting and/or personnel time, which need to be borne in mind by the Core Team.

4.2. Implementation phase

The implementation phase is when most of the "science action" takes place (Fig. 2). This phase includes at least three stages: ***data sourcing***, ***core analyses***, and ***creation of outputs and reporting***.

4.2.1. Data sourcing

In opportunistic collaborative syntheses, ***data sourcing*** typically involves leveraging existing data and expertise. Thus, data may be quantitative (e.g., counts of species, maps, time-series data), qualitative (e.g., personal perspectives, indigenous knowledge, stakeholder opinions), or a combination of both. Regardless of mechanism or type, it is essential to focus on facilitating data contributions. This process can be streamlined and standardised via thorough *data management protocols*, which are crucial to keep records organised and usable. Potential techniques to consider may involve the creation of data templates, processing pipelines, or databases. It may be beneficial to include an information session or dedicated contact person for data contributors who might need help with the process.

It is crucial to carefully *log data contributions*. Depending on the size of the data and project, it may be appropriate to consider purchasing and maintaining a dedicated portal and online system for data depositing (and/or for communications). However, there are also various free resources for smaller datasets and analyses. For this stage, it is also important to consider financial constraints of hiring personnel (as part of the operational team or outsourced) to assist with data standardisation, metadata creation, and general data management, as often the dimension of the data to be dealt with is only known after the engagement starts.

Considerations on data security and evidence of appropriate ethics or permits should be taken at this stage too. *Data use agreements* are likely to be needed and it is helpful if a draft is circulated early on across all involved parties. Part of the agreement should include specificities about the data, protocols, or any other particular terms of reference that will be needed for data analyses or for outputs of the project. Such agreements may seem like an unnecessary burden in the early, enthusiastic project initiation stage, but can prevent considerable challenges in its later stages (e.g., avoid conflict of interest when releasing results obtained).

We advise the inclusion of a *quality-control* step to confirm that datasets provided correspond to expectations (e.g., bias removed or identifying specific life-stage of animals). Timely and direct communication with contributors to clarify information is encouraged, potentially including approvals from their organisations and decisions on protocols to ensure data are not at risk of being withdrawn at a later stage of project development. *Confirmation of credit attribution* is also necessary to ensure that all personnel involved in the original data collection are known from the start of the project and are appropriately acknowledged. Any *copyright restrictions* associated with data release, publication, media communications, intellectual property, or monetisation as part of project outputs or beyond the project lifetime should be discussed at this step to ensure smooth project development.

Clear communication is important throughout all phases, but particularly crucial at this stage, where it is advised to *facilitate feedback* for any potential conflict resolution needed. For example, to address any concerns contributors have regarding data submission and/or use. Despite careful initial planning, it is still common for such questions to only arise once data sourcing is underway.

4.2.2. Core analyses

The ***core analyses*** stage needs to be managed to ensure all data can be used together and treated or analysed equally. It is highly recommended to first create *preliminary data summaries* to be cross-checked by contributors, which can feed back into the quality control stage. This will also help ensure that *appropriate analytical methods are chosen* for the final analyses. To facilitate implementation of analyses, it is important to consider digital access of data to the operational team members working on the analyses and *version-controlled code and documentation* (e.g., a cloud-platform, such as GitHub).

Having a plan for frequent project communications and *project updates* will facilitate progress and alleviate tension during analyses (which can sometimes be long and leave collaborators wondering if the project is still moving ahead). It is helpful if key steps of this stage are identified a priori, including when and how contributors will be invited to provide *feedback*. This will serve to remind contributors to remain engaged and provide ample opportunity to implement needed changes before the analyses are completed. Sufficient time should be planned to re-run analyses based on feedback received from contributors. During this phase, having multiple workshops involving the Core and operational teams is essential to facilitate dedicated discussion of results and needed analyses as the project progresses, to address any conflict resolution arising at different stages, and to problem solve any issues surrounding the final analyses and results to be released.

4.2.3. Outputs and reporting

After analyses are completed, the creation of ***outputs and reporting*** begins. The key aim of this stage is to work towards *agreement on the key findings* and conclusions, and to clearly define the relevant *type of outputs* that will be generated. This stage is also important to confirm rightful *attribution of credit* for each contributor. It is also a good point to remind contributors who may need *institutional approvals* prior to publication to start moving that process ahead so further delays in delivering the outputs of the project can be avoided. A period of *facilitated feedback* should be included at this stage to address unexpected concerns that arise and ensure all contributors have opportunity to raise them and agree with outputs being prepared for the deliverables phase.

4.3. Deliverables phase

The deliverables phase of the project may include the submission and dissemination of different outputs, and potentially the creation of follow-up projects (Fig. 2). As the project prepares for the deliverables phase, the Core Team has the additional role of increasing project visibility, including identifying relevant academic conferences, conservation decision-making meetings, and/or funders at which it might be beneficial to begin the release of results. Such visibility will be critical to influence conservation practice and uptake of project recommendations. The deliverables phase will generally include three stages: ***publication***, ***outreach strategy***, and ***continuity***.

4.3.1. Publication

Particularly important for the ***publication*** stage is to carefully recap *credit attribution* and *institutional approval* to any acknowledgements, restrictions, or permissions that might have been indicated at the start of the project or highlighted through project communications at different stages. Additionally, selection of the best venue for publication and the associated expenses should be considered based on the results obtained and expected impact. Peer-reviewed publications are the currency for scientific projects, and so it is important to consider financial support to cover journal fees, ideally for *open-access publications*. However, this stage also includes *non-academic outputs*, such as reports, presentations, policy briefs, or infographics. This is essential if the project is of direct interest for statutory entities, non-government organisations, or businesses (e.g., environmental ministries, conservation departments, voluntary organisations, consultancies). Allowing for contributor *feedback* and support at this stage can be beneficial. This can also help ensure that *EDI* principles are incorporated into publications, by consulting diverse perspectives, languages, and cultures.

4.3.2. Outreach strategy

For greater impact, the second stage of the deliverables phase benefits from an effective ***outreach strategy***, where a *dissemination plan* is devised to best promote the project outcomes in a collaborative way. This plan should state the strategy for dissemination and expectations for communications from the project's leadership team and collaborating organisations. Such forward planning is essential for achieving targeted interactions with key decision-making stakeholders, such as contribution to critical international policy-making bodies.

This stage also offers an opportunity for new type of engagement with contributors, who may have useful *dissemination expertise* in crafting engaging narratives or visuals or may have information on relevant campaigns, meetings or negotiations taking place in their region that could benefit from the results of the project. However, it is strongly encouraged that financing support is available to engage with *outreach and communications professionals* for the production of *dissemination materials*, with a particular focus on identifying and connecting with the most *relevant audience(s)*, including other scientists, governments and policy makers, media producers, schools, or local and indigenous communities.

To make the most of the dissemination potential, it is essential to provide good guidance for what to disseminate, and preferably to offer *dissemination materials*, such as pre-prepared flyers, social media content, or brief reports (where appropriate). Discussing how results can be translated into solutions and preparing region-specific results or other summaries that can be easily used by different stakeholders or are relevant across the project's institutional and multinational range can further create engagement opportunities and support knowledge translation. Due to the dimensions of the project, it is wise to take advantage of the large number of co-authors and utilise *contributor networks* to assist with promoting and disseminating the outcomes, which should also be made relevant for different regions.

One of the biggest benefits of opportunistic collaborative syntheses is that the opportunity to achieve impact is greatly assisted by the great size and diversity of the contributors. This provides considerable capacity to reach more *diverse and broader audiences* (including, for example, documents translated into different languages and reaching governments in multiple countries). A period of *facilitated feedback* may be needed early during this stage to address any unexpected concerns that arise due to differences in expectations between the communications teams associated with collaborating organisations, and the project's leadership team. Strong dissemination will help with consolidating the success of the collaboration.

4.3.3. Continuity

The final stage, ***considering continuity***, is essential for long-term impact of opportunistic collaborative syntheses. *Consolidating the successes* of the project can include evidence from each stage, such as effectiveness of recruiting and securing contributors, the range of data sourced, scientific discoveries revealed during analysis, effectiveness of dissemination, and uptake of project recommendations. At the same time, it is also important to *critically evaluate* the challenges encountered, so that lessons can be learned and utilised going forwards.

An important aspect of the project delivery is the solidification of the sense of *community* associated with the synthesis project created. It is important to pay particular attention to the project's *legacy* and how the data assembled will be managed after completion. A period of formative evaluation or feedback from contributors might be beneficial at this stage. Additionally, considering how *follow-up projects* could take place and ensuring contributors are willing to continue collaborating will result in the most *added value* to the assembled datasets and expertise. Such follow-up projects can be extremely powerful to further advance science while identifying the needs for which securing funding is urgent to address global challenges.

5. Funding to meet the challenges of the 21st century

Opportunistic collaborative syntheses have the potential to better contribute to world-changing solutions with strategic planning and implementation. However, despite the obvious benefits of these projects, there are limited opportunities for developing and maintaining such big collaborative efforts in ecology. In fact, a lack of appropriate (and outdated) funding systems have been identified as key deterrents for the type of global collaborations needed to address current global environmental challenges (e.g., Crewe et al., 2020). Some current large collaborative initiatives are made possible by specific funding schemes that allow collaborations between international groups, such as the Scientific Committee on Oceanic Research (SCOR). Some research councils also have programmes that encompass international and multidisciplinary teams, for example, the European Research Council Synergy programme funds projects with teams across European countries and from outside Europe (https://erc.europa.eu/apply-grant/synergy-grant). However, funding schemes that allow for costs of international collaborations are relatively rare, and mostly focused on the design or deliverables phases (e.g., funding a workshop that brings an initial team together or attending conferences and meetings). Here, we highlight the need for funding that can be used for such opportunistic or rapidly emerging projects that address pressing global challenges across boundaries, particularly those that cross jurisdictional boundaries and focus on global scale studies. Although the start of these projects relies on voluntary contributions from the science community, sustained collaborator engagement and project implementation still requires long-term resources. However, most current funding bodies focus on supporting projects to solve issues within jurisdictional geographical boundaries and there is not a mechanism to support globally-focused projects despite most current challenges applying at global scale.

Although we are focusing on syntheses projects that can leverage existing data and expertise, funding for specific personnel to advance such projects is still essential at every stage (Fig. 2). This includes salary for project leaders (particularly early- and mid-career researchers who are often not in permanent positions but are the ones with the impetus to drive such projects) and operational team members. Funding will also be required for specialised personnel (e.g., data scientists, programme developers, outreach professionals, or graphic designers) and costs of software and cloud storage (e.g., record keeping, data collation and storage, analysis, and outcome dissemination), as well as for workshops at key project stages that require collaborative input (particularly given that online meetings are not effective for large numbers of attendees). Securing funding and resources for the entire lifespan of an opportunistic collaborative synthesis project is particularly challenging, and difficulties associated with supporting project personnel based in different institutions and countries adds a level of legal and financial complexity.

To achieve equity, diversity and inclusion goals, as well as interdisciplinary and global impact, funding is required across boundaries (e.g., jurisdictions and existing funding schemes). In conservation, philanthropic foundations play a key funding role, and the financing of opportunistic collaborative syntheses provides a true opportunity for catalytic development and impact. Indeed, philanthropy is likely to have a key role in starting the funding mechanisms that will support the expansion of ‘big opportunistic collaborative syntheses’ and may assist with leading the way in showing that appropriate funding mechanisms need to be created for such projects to be sustained. Additionally, cross-jurisdiction collaboration among agencies could provide a solution for funding the international and interdisciplinary research needed to address current global challenges in ecology.

6. Conclusion

We provide a general framework to propel the development of future opportunistic collaborative syntheses by considering the failures and successes experienced across many diverse global synthesis projects spearheaded by our co-author team. Our framework can be used to increase transparency of each phase throughout the development of collaborative projects. Important aspects to keep in mind include valuing different contributions, understanding (and creating space for) different goals of collaborators, communicating clearly, focusing on equitable benefit sharing among partners and collaborators, and securing adequate funding. The complex, multi-dimensional, and geographically wide-ranging challenges currently facing the environment call for funders who will take leadership roles in supporting the innovative opportunistic collaborations that are needed to tackle those wicked problems. Our insights will provide both researchers and funders with a coherent conceptual guide to visualise and tackle the steps necessary for big collaborations so they can fulfil their potential and achieve positive societal impacts in rapidly advancing global conservation.

CRediT authorship contribution statement

Ana M.M. Sequeira: Writing – original draft, Visualization, Project administration, Methodology, Investigation, Conceptualization. **Amanda E. Bates:** Writing – original draft, Project administration, Methodology, Investigation. **Graeme Hays:** Writing – review & editing, Investigation. **David W. Sims:** Writing – review & editing, Investigation. **Samantha Andrzejaczek:** Writing – review & editing, Investigation. **Asta Audzijonyte:** Writing – review & editing, Methodology, Investigation. **Julia K. Baum:** Writing – review & editing, Methodology, Investigation. **Martin Beal:** Writing – review & editing, Investigation. **Barbara Block:** Writing – review & editing, Methodology, Investigation. **Joshua Cinner:** Writing – review & editing, Methodology, Investigation. **Kaitlyn Cowley:** Writing – review & editing, Methodology, Investigation. **Eric Gilman:** Writing – review & editing, Methodology, Investigation. **Arthur Gleason:** Writing – review & editing, Methodology, Investigation. **Autumn-Lynn Harrison:** Writing – review & editing, Methodology, Investigation. **Charlotte Hudson:** Writing – review & editing, Methodology, Investigation. **Gakushi Ishimura:** Writing – review & editing, Methodology, Investigation. **Rima W. Jabado:** Writing – review & editing, Methodology, Investigation. **Jason P. Landrum:** Writing – review & editing, Methodology, Investigation. **Sangeeta Mangubhai:** Writing – review & editing, Methodology, Investigation. **Loren McClenachan:** Writing – review & editing, Methodology, Investigation. **Laura Meagher:** Writing – review & editing, Methodology, Investigation. **Cynthia Riginos:** Writing – review & editing, Methodology, Investigation. **Ester A. Serrão:** Writing – review & editing, Methodology, Investigation. **Richard B. Sherley:** Writing – review & editing, Methodology, Investigation. **Rick D. Stuart-Smith:** Writing – review & editing, Methodology, Investigation. **Nina Wambiji:** Writing – review & editing, Methodology, Investigation. **Sarah A. Marley:** Writing – original draft, Visualization, Project administration, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Ana M. M. Sequeira reports financial support, administrative support, and travel were provided by PEW Charitable Trusts. Charlotte Hudson reports a relationship with PEW Charitable Trusts that includes: employment. Jason Landrum reports a relationship with PEW Charitable Trusts that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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