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How to foster scientific knowledge integration in coastal management

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A R T I C L E I N F O

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A B S T R A C T

Development of science-based coastal policies and strategies that effectively cope with coastal change and risk requires transfer of scientific knowledge beyond the scientific community, and its integration in management processes. However, scientists frequently convey their message to non-specialized audiences resourcing to their own empirical experience, often leading to a high effort - low efficiency process.

This paper aims to propose a simple conceptual model to guide scientists in the process of knowledge transfer, focusing on whom and how, and promoting the efficiency of both the science dissemination process and integration of scientific knowledge in management of coastal land and risk. The model proposed herein aims to guide scientists to actively pursue the goal of transferring their knowledge to policymakers and managers besides layman society, and is essentially based upon a review and integration of previous work.

We argue that selection of the most efficient scientific knowledge transfer mechanism (*outreach, crowdsourcing tools, managers-oriented tools or co-production*) should be based following careful consideration of level of engagement with the audience, and take into consideration political and social contexts. The level of engagement also controls the amount of effort involved in message framing, and the nature and robustness of the feedback from the target audience. The model acknowledges that communication strategy must be thought on a case-by-case basis and ranks the proportion of effort distributed between message deliverer (framing) and receiver (engagement) implicit in each transfer mechanism. This helps to select the most adequate mechanism and optimizes knowledge transfer efforts. In addition, it highlights the importance of encouraging scientists to develop message framing skills and to acknowledge the benefits of engaging with others.

1. Introduction

1.1. Challenges in the integration of scientific knowledge in coastal zone management

The coastal zone is the interface where the land meets the sea and comprises a wide range of unique features such as estuarine systems, beaches, coastal dunes and rocky shores. While it is considered to represent one of the major assets of coastal countries, the sustainable management of coastal environments presents significant challenges because they are highly susceptible to human pressure (e.g., Agardy et al., 2005; UNESCO, 2007) and to climate change (e.g., Hinkel et al., 2015).

In the past, the inability to recognize coastal change has led to serious errors in terms of management practice. These errors are particularly obvious at highly populated and vulnerable coasts (e.g., Hsu et al., 1999; de Jonge, 2009; MacFadden, 2007), where unwise occupation and engineering collide with the inherent dynamics of the coast. The present rate of population growth in these areas is still increasing and this trend is expected to continue into the near future (UNESCO, 2007; Brown et al., 2008). Neumann et al. (2015) estimate that the number of people living in low-lying coastal areas will grow from 625 million in 2000 up to 1.4 billion people in 2060. This increase will most likely put additional pressure on the coast and might thus also endanger sustainability (Sekovskiet al., 2012). Adding to this scenario, the expected climate change-related effects may increase the intensity and frequency of risk-prone events throughout the 21st century and beyond (Hinkelet al., 2015; Vousdoukas et al., 2020). Attaining coastal sustainability has been a difficult goal. Considering the existence of additional pressure related with increasing coastal population and the

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impacts of a changing climate an even bigger challenge lays ahead. Timely addressing this challenge in a competent and effective manner implies the integration of scientific knowledge in coastal management. The relevance of scientific knowledge as the rational for coastal sustainability is based in the premise that "we can't [wisely] manage what we don't understand" (Sparrius, 1994).

Integration of scientific knowledge in governance is acknowledged as of utmost importance by major international organizations and highlighted in strategic documents such as the Agenda 21 (UN, 1992), and the Declaration of Science and the Use of Scientific Knowledge (UNESCO, 2000). Even recognizing the existence of limitations in scientific knowledge, the benefits of accessing and adopting the "best available knowledge" will unquestionably facilitate the establishment of sustainable strategies (Cvitanovicet al., 2015). As scientific knowledge takes into consideration the processes that drive coastal dynamics at different spatial and temporal scales, it can support the establishment of scenarios and the development of long-term coastal strategies. Therefore, scientific knowledge is critical to support the goals of sustainable development of the coast in a globally changing environment.

Science has always been in a position to play a significant role in detecting and defining local and global environmental problems. In addition, science helped in framing and shaping the public and policy debates around those problems as well as in identifying appropriate solutions (Vogel et al., 2007). However, science should not to be regarded as predictive oracle that defines policy choices. According to Sarewitz (2004) "*Politics helps us decide the direction to step; science helps the eyes to focus.*". The same author highlights the importance of political intervention in dealing with environmental controversies for science to play an effective role in solving environmental problems and risk management. Such approach calls upon science to support, monitor, and assess the implementation of policies that have been selected through the political process (Brunner, 2000; Herrick and Sarewitz, 2000; Lee, 1993 *in* Sarewitz, 2004). In fact, science should inform and not decide because "real world management" is driven by social and political contexts and also by numerous and less tangible cultural dimensions, consisting of human values, ethics and worldviews. This diversity highlights the fact that sustainable coastal development cannot be achieved solely by "reason". It requires effective communication between all coastal actors.

To support effectiveness of knowledge transfer, scientists need to understand their role in the communication process. While for some scientists the communication process is "part of the job", for most of them knowledge transfer is developed without any intentional transfer strategy. Practical guidance to accomplish this task is generally lacking or restricted to social sciences, so physical scientists usually perform knowledge transfer using their own empirical experience. Development of a structured approach to knowledge transfer can help to guide scientists, not only in the selection of the appropriate messages, communication channels and materials (Bayliss-Brown et al., 2015), but also to benefit from end-user feedback, in turn creating synergies with the research process itself.

1.2. Objectives

The ambition of the present work is to foster the integration of scientific knowledge in coastal management through the development of a pragmatic framework that may to guide scientists in the process of knowledge transfer focusing on whom and how to communicate. This was translated in the following specific objectives:

1) to characterize the different types of coastal actors, considering the way in they interact;
2) to propose a conceptual model to guide scientists in maximizing the efficiency of dissemination actions and integration of scientific knowledge in coastal management.

2. Methods

This paper is essentially based upon a review of published work addressing scientific knowledge transfer and integration in coastal management issues (e.g, Armitage et al., 2011; Bayliss-Brown et al., 2015; Bonne et al., 2014; Cvitanovic et al., 2015; Goldsmith et al., 2015; Röckmann et al., 2015). The work also benefited from previous experience of the authors and feedback obtained in scientific, and dissemination forums (e.g., de Jonge, 2007; de Jonge, 2009; Carapuço et al., 2014b; 2014c; Carapuço and Taborda, 2015; de Jonge and Giebels, 2015), besides participation in public discussions following proposal or implementation of specific coastal interventions in Portugal.

3. Coastal actors and their roles

The identification of coastal actors and understanding of the ways in they interact is of paramount importance in the development of a scientific knowledge-transfer framework and a critical factor of success in coastal management (Brown et al., 2002). Coastal actors, other than those directly involved in research, make the non-peer audience that scientists aim to reach, and knowing the audience is vital to ensure that communication is successful.

3.1. Scientists

Scientists are those who pursuit knowledge and the understanding of the natural and social world entailing unbiased observations and systematic experimentation (EEB, 2016; TSC, 2016). Scientists generate knowledge based on the scientific method and aim to transfer it to other coastal actors (Carapuçoet al., 2014a). As scientific knowledge allows for the understanding of the natural world, it gives scientists a unique perspective on the coastal system. The ability to consider the processes driving coastal dynamics at different spatial and time scales makes scientists capable of projecting the functioning of that system under different forcing scenarios and evaluating different short-to long-term coastal management strategies.

The type of research conducted by scientists can be classified into free and driven research (Carapuçoet al., 2014a; de Jonge, 2007; van Koningsveld, 2003). Free research is conducted beyond the constraints of a practical problem and usually without previous identification of target-audiences. Here, knowledge generation is focused on the development and testing of fundamental concepts. Driven research is motivated by both practical and academic interests, which guide the research in some required direction. This type of research generally seeks to solve societal problems. For this reason, scientists must be aware that driven research ambition can only be fulfilled if scientific knowledge is effectively disseminated outside the scientific community.

3.2. Policymakers and managers

"Policymaker" is a broad term that covers all the people responsible for formulating or amending policy as well as providing legal support for sustainable development and utilization of the coastal and marine resources (Zhu et al., 2019). Policy actions, such as increased budgets or the passing of new regulatory instruments at higher levels of government, may help facilitate coastal planning by coastal managers (e.g., Thorne et al., 2017; Bierbaum et al., 2013).

Managers perform functions like planning and establishing strategies towards an end. Both policymakers and managers are strictly linked, and both are responsible for the regulation of coastal zone uses by establishing and implementing the policy framework for the coast.

3.3. Society

Society arises as a key coastal actor as it benefits from the services provided by the coastal environment. Society is a very heterogeneous actor encompassing several clusters or groups of people sharing similar goals and activities within each cluster (*e.g.,* surfers, fishermen, tourists). While a common understanding within these groups can ease knowledge transfer, scientists need to be aware that different clusters may have different interests or expectations for the coast. This can favor the emergence of conflicts and constitute a barrier to science communication.

Although society has been and still is frequently regarded as a passive intervenient, the fact is that the role of society in the definition of coastal strategies has been steadily increasing. For policymakers and managers being successful, society must adhere to the solutions proposed (Carapuçoand Taborda, 2015). Specific management strategies will benefit from consensus building and public support. In the past, society was frequently regarded as a passive intervenient that only benefited from the services provided by the coastal environment. But, in fact, it is not. Society is increasingly playing a relevant role and became an indispensable actor in the coastal agenda.

3.4. The Coastal Knowledge Triangle

In summary, three major groups arise as key players in the scientific knowledge-transferring agenda: scientists, policymakers and managers, and society.

However, and as identified by Stocker and Wood (2014) "(… coastal actors do not function alone but in existing networks and in legal, policy, political, social, technological, economic and cultural contexts. Coastal actors share links and can collaborate with each other to share power and available resources, such as knowledge …". Thus, understanding the links among the key coastal actors is also fundamental in moving forward to successful knowledge transfer initiatives as well as in clarifying the different types of knowledge generated by each party.

Scientific knowledge is mainly generated by scientists, which follow a systematic methodology based on evidence (TSC, 2016). Science is not only relevant by itself but also necessary in the integration of "all knowledge types" (Nursey-Bray et al., 2014) including bureaucratic and local, formal (i.e. delivered by academia in a systematic way) and informal (i.e. acquired from experience outside of the formal learning system) knowledge.

Bureaucratic knowledge encompasses knowledge about processes and contexts that are of relevance when identifying viable policy options (Hunt and Shackley, 1999) and is heavily intertwined with administrative and governmental practices (Edelenbosand van Buuren, 2012). Local knowledge is grounded in practical experience and is strongly linked with the day-to-day activities of coastal users. It is derived from the practices in which people (*e.g.,* inhabitants, businesspersons, fishermen, beach users) are involved (Eshuisand Stuiver, 2005).

Benefits in the mobilization and enrolment of bureaucratic and local knowledge were highlighted by Rinaudo and Garin (2005) and include improving the clarity of the issues at stake, the formulation of a generally complex and unstructured problem in an accessible form and the identification of the largest possible panel of alternative solutions.

The *Coastal Knowledge Triangle* (Fig. 1) aims to summarize and illustrate the key coastal actors, their roles and links. This model is based upon the works of Hunt and Shackley (1999) and Röckmann et al. (2015).

The *Coastal Knowledge Triangle* shows that the understanding of links among the different key coastal actors is a fundamental step in fostering knowledge transfer. The existence of weak bounds, or even disconnection, among coastal actors can seriously prejudice knowledge dissemination. It must be stressed, however, that the links among them depend, not only on their willingness, but also on societal organization. This can be put in evidence through the consideration of some basic forms of governance and their implications in knowledge integration where politicians, a subset of policy-makers group, have a critical role in implementation.

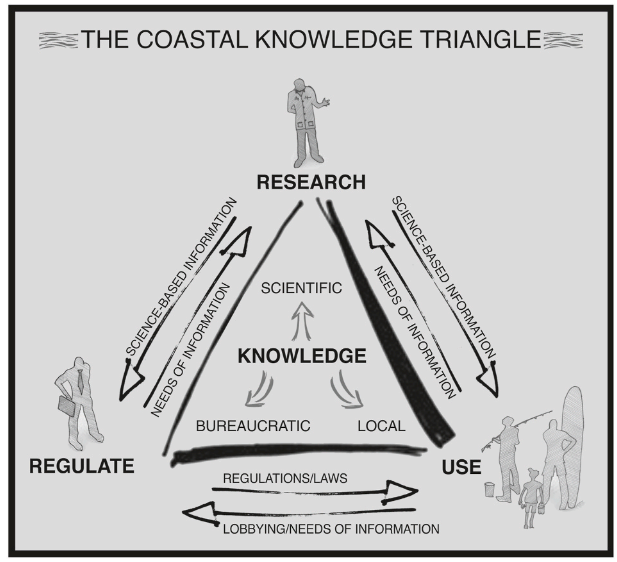

Fig. 1. The *Coastal Knowledge Triangle*: coastal actors, their roles and links. Scientists, who detain scientific knowledge aim to transfer it to policymakers and managers (bottom left) and society (bottom right). Policymakers and managers, who detain bureaucratic knowledge, regulate the use of the coastal zone affecting the way society benefits from coastal services and convey policymakers and managers' needs for information to scientists. Society, who detain local knowledge acquired in relation to day-to-day activities (e.g. fisheries, surfing, beach activities), benefits from the services provided by the coastal environment; it influences the decisions taken by policy-makers and managers via lobbying, and conveys their needs of information to both policymakers and managers, and scientists.

In participatory governance schemes where decision-making disregards scientific knowledge, management strategies emerge from the interaction between regulators (government, administrative bodies, authorities) and society (users). This scheme ensures that immediate societal expectations are integrated within the spirit of regulations and management decisions. However, disregarding scientific knowledge results in a disproportionally large influence of lobbying in the decision-making process that can threaten sustainability. In fact, the demands of society frequently do not encompass an adequate perception of coastal dynamics and risk, especially at medium-to long-term time scales. For example, the uninformed occupation of a seafront, which may not be perceived as problematic in the short-term, may disregard or even lead to severe coastal erosion and flooding on a longer time scale, and compromise future management options. In contrast, a governance system exclusively driven by scientific and bureaucratic knowledge, generally fails to consider the different points of view and needs of society. Such a technocratic system has well-known limitations in the ability to manage conflicts inherent to the different interests of coastal users (for example, nuclear power plant siting on the coast zone). Finally, under centralized governance schemes, policymakers and managers (regulators) are decoupled from every other actor. In the case of centralized schemes, not only there is no independent control of management decisions, but also there are no countervailing mechanisms to assure coastal sustainability and the incorporation of society's expectations.

The above highlights the importance of the political environment (herein taken in its broadest sense) in providing the adequate settings to foster scientific knowledge transfer. In this context, the influence of politicians goes beyond policymaking and knowledge implementation, as they can also have a fundamental role in strengthening the links among key coastal actors. Scientists, however, should always seek an active role in fostering knowledge transfer, even in an adequate political environment that favors incorporation of scientific knowledge in decision-making.

4. Scientific knowledge transfer

To foster scientific knowledge integration, the coastal message has to reach the target audience. Usually, scientific knowledge transfer is regarded as a synonym of outreach. However, scientists must be aware that other mechanisms to connect with the audience are available: crowdsourcing tools, manager-oriented tools and co-production. These mechanisms, if adequately used, can foster engagement, minimize framing effort and optimize audiences' feedback. Feedback is considered the essence of two-way communication, as it indicates if and to what extent the message has been successfully transferred (Hattie and Timperley, 2007).

4.1. Outreach

Coastal science outreach aims to raise coastal literacy and awareness. These are important political and societal goals characterizing a knowledge-based society engaged with science. As defined by Ray (1999) outreach is a "*meaningful and mutually beneficial collaboration with partners in education, business, public and social service. It represents that aspect of teaching that enables learning beyond the campus walls, that aspect of research that makes what we discover useful beyond the academic community, and that aspect of service that directly benefits the public*". Poliakoff and Webb (2007) defined outreach in a broader sense as "*any scientific communication that engages an audience outside of academia*". Varner (2014) stated that "*although objectives and envisioned outcomes will inevitably vary widely among scientists and institutions, effective outreach should be about building capacity, fostering mutual trust, and achieving a shared understanding of the relevant science*". Burns et al. (2003) highlight that it aims at fostering public awareness and understanding of science and knowledge thus developing comprehension of both their meaning and implications. In outreach, the message to be conveyed can be framed within a wide range of options, including tutoring, giving presentations, supporting teachers, developing resources, exhibitions and so forth (Andrews et al., 2005). In their description of an outreach project targeting to raise public awareness on coastal evolution, Carapuço et al. (2017) emphasized that science outreach efforts can be highly valuable in fostering public engagement in coastal issues and in developing a knowledge-based society.

4.2. Crowdsourcing

Crowdsourcing benefits from the involvement of high numbers of people willing to support and contribute to the generation of large sets of data. In the context of scientific knowledge transfer, these tools can have a profound positive impact on the participants. Besides enhancing coastal awareness, involvement in crowdsourcing creates a feeling of "ownership" of the coastal environment (Wagner, 2004). Some initiatives under the citizen science framework (SCU, 2013) have already been developed within crowdsourcing namely in the context of public participatory monitoring (e.g., Stojanovic and Ballingerv, 2009; Tulloch et al., 2013). For example, the development of specific web applications allowed for crowdsource mapping in the scope of volunteered geographical information projects (e.g., Leidig et al., 2015; Harley et al., 2019; Lira et al., 2019).

4.3. Management-oriented tools

Coastal management community has specific needs of information that is required to address particular management issues (e.g., Goldsmith et al., 2015; van Koningsveld et al., 2005). This principle drives the development of management-oriented tools. More than providing access to coastal data, management-oriented tools aim to turn scientific data into helpful information for non-experts, thus fosters knowledge transfer.

The work by Carapuço et al. (2014b) makes a good example of the above. These authors developed the "wave transformation matrice" (WTM) tool, aiming at timely and easily delivering nearshore wave data of use for coastal authorities and managers. WTM are also suitable to address information needs of sub-groups of society with varied interests in the coastal zone (*e.g.*, surfers, fishermen). Lessons learned showed that WTM allow for rapid computation of reliable and timely information on parameters of nearshore waves that inform on probability of coastal overtopping, for example. Moreover, WTM also allow users to acknowledge the physical processes governing wave transformation from deep coastal waters in an intuitive manner, besides informing on uncertainty, thus upstreaming their understanding of the coastal system.

The largest compilation of coastal management-oriented tools is "The Digital Coast" (NOAA, 2021) a web platform "*developed to meet the unique needs of the coastal management community*". This platform provides access to a very significant number of science-based GIS (Geographic Information System) tools capable of generating spatial information targeting different coastal issues. Available tools include web applications to compute rates of shoreline change, and to create maps of potential ecological, social, and economic impacts from rising seas and changing climate.

4.4. Co-production

Co-production emerged in social sciences in the 1970's. The idea was first articulated by Elinor Ostrom (2009 Nobel prize winner for economics) (Boyle and Michael, 2009) who, in 1996, defined co-production "*as process through which inputs from individuals who are not in the same organization are transformed into goods and services*" (Ostrom, 1996). The concept has been evolving and more recently Armitage et al. (2011) have (re)defined co-production "*as the collaborative process among [coastal] actors bringing a plurality of knowledge types together to address a specific problem, aiming at building an integrated solution for that problem*".

The theory of co-production was originally developed to conceptualize a particular type of relations between knowledge generators and knowledge users (Heaton et al., 2016). However, in recent years, it has also been used to describe the growing engagement of policymakers and managers in driven research, motivated to solve societal problems (Martin, 2010; Nutley, 2010).

Despite some problems persist in agreement on a worldwide-accepted definition of co-production, the intrinsic benefits of the concept are generally acknowledged and consensual (Boyle and Harris, 2009; Edelenbos et al., 2011). Co-production creates the possibility for coastal actors to share their knowledge and motivations and to shape consensual or best-compromise solutions around their needs. Co-production fosters mutual trust and communication. It generates reciprocal and mutual benefits, and alters attitudes, as those involved become active asset-holders rather than passive spectators (LARCI, 2010). The work of Thorne et al. (2017) clearly highlights effectiveness of co-production in narrowing the communication gap between policymakers and managers, and scientists, by achieving tighter partnerships that translate into facilitation of information transfer among all coastal actors. In the work of Carapuço (2016), the design and outcomes of the "Coastal Information System for the municipality of Cascais" (CIS) project, which ran under the co-production approach, are discussed. Results highlight the benefits of co-production in addressing information needs of all participants, regardless of their specific interests, education or training, besides maximizing the impacts of project resources namely in what concerns increasing the changes of projects' implementation and longevity beyond the contract time schedule. The trigger for the development of the CIS project was the positive experience resulting from the outreach initiative "The Beaches of Cascais: past and present" (see Carapuço et al., 2017). This highlights the importance of outreach in enabling conditions for fostering closer collaboration between coastal actors in a particular context requiring high levels of engagement.

4.5. A conceptual model for successful scientific knowledge transfer

It is widely acknowledged that to promote the integration of science in the decision-making process a "one size fits all" approach will not work (Bonne et al., 2014). In this work, four main mechanisms for transferring scientific knowledge were identified: outreach, crowdsourcing, management-oriented tools and co-production. Selection, by scientists, of the more adequate knowledge transfer mechanism will depend on the audience's engagement level, on the feedback aspired and on framing commitment (the amount of effort the scientist is willing to invest in translating the scientific message). It is worth noting that these mechanisms are not mutually exclusive. For example, when the audience is more engaged with the topic addressed, the framing effort is lower and the expectable feedback is higher. This reasoning lead to the development of the conceptual model depicted Fig. 2, that aims to guide scientists in the selection of the best mechanism to transfer scientific knowledge to other key coastal actors.

The conceptual "meeting line" (depicted in Fig. 2 by the solid oblique line) illustrates that communication is only effective if both scientific and non-scientific actors are willing to converge and take the necessary steps to meet at some point of the communication process. This bridging effort can (and should) be approached from both sides in a proportion that will depend on the communication mechanism adopted. When the communication process is successful it not only increases scientific understanding on the coastal system but also fosters engagement and generates feedback. Feedback depends on the adopted mechanism and contains complexity and richness that increase from awareness (in response to outreach) to knowledge (in response to co-production). The conceptual model shows that, in order to adopt higher-level communication mechanisms (such as co-production), it is necessary to assure high levels of engagement. Whenever these conditions are not met the effectiveness of communication is at risk, making it necessary to previously implement lower level mechanisms (such as outreach) fostering engagement. When the objective of scientists is to raise awareness of an audience that is scarcely engaged into coastal science, *outreach* arises as the most adequate mechanism for scientific knowledge transfer (bottom of Fig. 2). As the audience may not be tuned to scientific language and contents, outreach is the mechanism involving the highest framing effort by scientists. The feedback of a well-succeeded outreach initiative is raising awareness on coastal issues, thus contributing to trigger involvement of the audience. In addition, this helps to change receivers' attitude from passive to active, increasing their level of engagement. When society is engaged with science, it is no longer a mere spectator of coastal policies and development and is more capable and willing to influence both policymakers and managers towards coastal sustainability.

In *crowdsourcing* the audience plays an active role. Thus, the adoption of this mechanism requires some level of engagement of the audience. This mechanism has the advantage of contributing to the development of a participatory society, which is an important step towards coastal sustainability. Furthermore, the data generated by crowdsourcing also create a positive feedback to the knowledge generation process.

In *management-oriented tools*, it is expected that coastal actors become more autonomous in generating information according to their specific needs. This mechanism needs lower framing effort because coastal

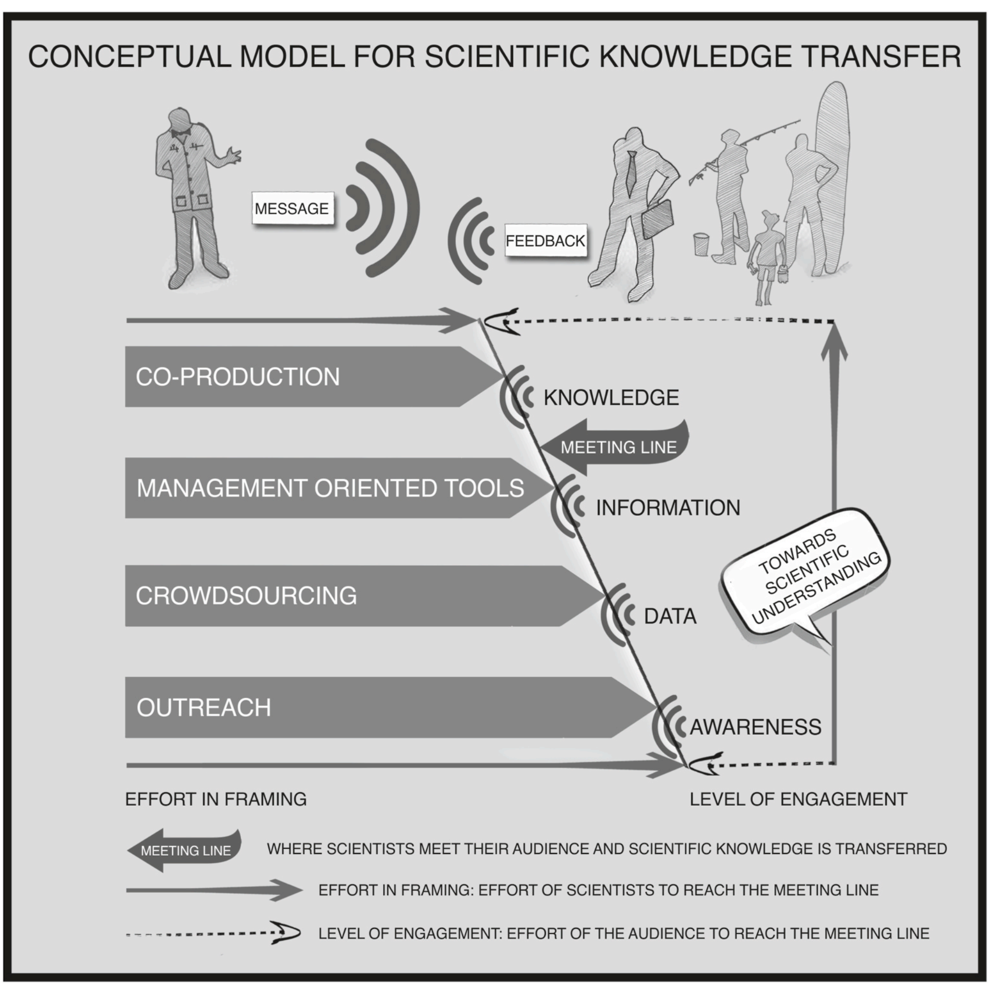

Fig. 2. A conceptual model to guide scientists (on the left) in the selection of the best mechanism to transfer scientific knowledge to other key coastal actors (on the right). Four mechanisms for transferring scientific knowledge can be adopted: co-production, management-oriented tools, crowdsourcing and outreach. Different mechanisms generate different types of feedback (e.g., outreach generates awareness). Each mechanism requires a different effort in framing by scientists, and its adoption is constrained by the engagement level of the audience. This is depicted by horizontal arrows: framing effort by scientists (solid arrows), and engagement level of non-scientists (dashed narrow arrows).

actors involved are, in general, more engaged and aware of the challenges of coastal sustainability. Information generated by using management-oriented tools also increases in relevance, as it refers to contextualized data, helping scientists to further understand the coastal system.

Co-production can be regarded as the highest-level mechanism in scientific knowledge transfer, as the audience is closer to scientific language and issues, thus involving the lowest framing effort by scientists (top of Fig. 2). The adoption of this mechanism benefits from knowledge (*i.e.*, combined information leading to understanding) generated (also) by the audience. This mechanism stimulates the integration of different types of knowledge, thus promoting optimal conditions for implementation.

The conceptual model for scientific knowledge transfer aims to contribute towards a society where all key coastal actors are active assetholders. The mechanisms portrayed in the model proposed herein can be linked with their typical audiences and expected feedbacks: the lower-level mechanisms usually target society, and the higher-level mechanisms target policymakers and managers. Notwithstanding, they can be used to reach all types of audiences with a level of success that mainly depends on the initial levels of engagement of the different parties.

5. Conclusions and outlook

Effective integration of scientific knowledge in the decision-making process is fundamental in achieving coastal sustainability. To foster scientific knowledge integration, scientists need to be willing and be able to transfer knowledge beyond the boundaries of scientific community and effectively convey their message to policymakers and managers, and the layman society. In this process, scientists should properly acknowledge the political context, and also the less tangible cultural dimensions, consisting of human values, ethics and worldviews.

In scientific knowledge transfer, scientists can adopt different mechanisms to reach their audience and convey their message: *outreach, crowdsourcing, management-oriented tools* or *co-production*. A pragmatic conceptual approach is presented to support the selection of the most efficient mechanism. In this selection, scientists must weigh the level of engagement of the audience and the expected feedback. Each mechanism delivers the message in a different manner leading to differences in feedback. However, all mechanisms share a common goal: to foster knowledge transfer and increase the participation level of key coastal actors in decision-making, shortening the leap to implementation.

In our view, a knowledge-based society is needed to meet the objective of coastal sustainability. This objective has been further challenged by global environmental changes and cumulative threats imposed by human activities. Scientists should actively pursue this goal by transferring their knowledge outside of the scientific community, developing their message, increasing their framing skills and acknowledging the benefits of engaging with others.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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