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Seeing the ocean through the eyes of seabirds: A new path for marine conservation?

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ABSTRACT

Seeing the ocean through the eyes of seabirds could help meet the challenges of managing common-pool marine resources both in protected and unprotected areas. First, seabirds are top-predators, exposed to all threats affecting the oceans, and this makes them ideal sentinel organisms for monitoring changes within marine ecosystems. Second, seabirds cross both ecological and political boundaries, and following their movements should help making interdependencies within and between marine ecosystems more visible. Third, seabirds are conspicuous and often charismatic animals, which interact differently with different groups of stakeholders and provide the opportunity to acknowledge and discuss each other's values and interests. In this paper, we present these research avenues using a seabirds' view, for tackling marine conservation and management issues, and we give operational examples of implementation based on our work in the English Channel.

1. Introduction

Humans only very recently admitted to their historical, major impact upon marine ecosystems [35], probably because of their generally remote perception of underwater ecological processes. In parallel to the growing awareness for marine environmental issues, conservation efforts followed the path of terrestrial conservation initiatives, yet with a 100-year time lag [42]. From the industrialization of fisheries in the early 19th century to the late 20th century, marine conservation and marine resource management evolved separately. As in terrestrial systems, the establishment of protected areas has been the main response to environmental degradation. However, in 2010, only 1% of the world's oceans were protected [78], with only a tenth of this surface devoid of exploitation [85], compared to 13% for terrestrial areas [79]. Concomitantly, fisheries management slowly evolved from a state of no restriction supported by government subsidies following World War II to single-species, steady-state management with continued subsidies from the 1960s to the 1990s [33], before finally recognizing the need for an ecosystem-based approach [31,63] in the early 21th century. Today, it is widely acknowledged that ecosystems are complex, dynamic, adaptive systems with nonlinear feedbacks and thresholds [43], and are tightly linked with similarly complex human systems [50]. Protected areas are no longer seen as an exclusionary conservation tool, and conservation policies now emphasize public participation in decision-making [56].

In terms of conservation efficiency and resolution of user conflicts, however, this progressive shift from separated ecological and human systems governed by top–down policies, to more horizontally-governed social–ecological systems [8] has not yet lead to the expected results. We see three main reasons for this: (1) the extreme complexity of social–ecological systems and inherent uncertainties concerning their functioning and dynamics, (2) the incapacity of marine protected areas (MPAs) alone to counter environmental degradation, and (3) the lack of consideration for power and information asymmetries between participants in public participation processes [65]. First, while it is crucial to analyze the social dimension of resource management together with resource and ecosystem dynamics [27], dealing with complex adaptive systems such as social–ecological systems implies addressing complex interactions, feedbacks, and uncertainty

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at multiple scales, a process which requires a huge amount of data [18] which are simply not available for many marine systems. For the ecological system alone, integrating changes in the physical environment and biological responses into operational ecosystem models while dealing with the increased uncertainty induced by climate change and human overuse is an immense challenge. In any marine system, meeting this challenge will take place at a much longer timescale than the one at which resource management commonly operates. Second, while the pace for MPAs designation has increased sharply in recent years to comply with international agreements, they are mostly restricted to the exclusive economic zones of coastal nations and our capacity to manage them efficiently is still lagging [14,59,74]. MPAs are not always ecologically efficient because they are too small or too static compared to the system they are supposed to protect, and/or because of insufficient or insufficiently applied regulations [2,85]. Often, and despite the institutionalization of public participation in decision making, MPAs are socially not well accepted (e.g. [84]). This can lead to user failure to comply with regulations, and ultimately undermine the conservation efficiency of MPAs [14,37,39]. The establishment of MPAs in specific geographical areas may also lead to ecological and social vulnerability transfers to other areas [1,10]. Third, while public participation in decision making is now a regulatory imperative in many countries, its implementation by administrative institutions is often creating more frustrations than shared decisions. Beyond the manipulation of public participatory processes by governance bodies [65,88], asymmetries in perceptions, power, or speaking skills between stakeholders as well as conflicting interests may seriously undermine conservation and conflict resolution [3,14,15,33,49,56], especially when such differences are not made explicit by the participatory process [6].

In order to overcome these obstacles and improve the efficiency of marine conservation policies, we advocate using seabirds both as indicators of marine ecosystem health and as ambassadors of less visible, and often less charismatic, marine species, to improve participatory schemes leading to global ocean conservation. While this approach might seem reductive or purely ecology-oriented at first, it is supported by several features that make seabirds a highly pertinent meeting point (or 'boundary object' *sensu* [72]) for marine sciences and stakeholder groups. First, their position at or near the top of most marine food chains results in seabirds being ideal sentinel organisms for monitoring changes within marine ecosystems (e.g. [11,25,30]). Because seabirds are exposed to all threats affecting the marine environment (Fig. 1), conservation strategies based on their ecological requirements deliver broad ecosystem-level benefits [21], as shown for other top predators [70,71]. Second, seabirds cross both ecological and political boundaries on a regular basis [38]. Therefore, following seabird movements throughout their annual cycle should allow overcoming the dichotomy between protected and non-protected areas, and make interdependencies within and between marine ecosystems more visible. Third, seabirds are conspicuous and often charismatic animals (e.g. penguins, albatrosses or gannets) that are part of the culture of coastal communities [51,53] but can be perceived differently by different groups of stakeholders (Fig. 2). Acknowledging and discussing these different perceptions would help build a better understanding of each other's values and interests, which is essential for cooperation. Importantly, seabirds are also big enough to be equipped with electronic devices (e.g. GPS recorders or miniaturized video cameras; [66]) that collect data about their movements and behavior. These data are highly accurate, cheap to acquire compared to vessel-based observations, and can be represented and conveyed to a variety of audiences in a highly visual and intuitively understandable way (e.g. maps of locations and movement, pictures, and video clips) that is likely to facilitate discussions and information transfer among stakeholders.

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Seeing the ocean through the eyes of seabirds therefore implies: (1) identifying, characterizing and quantifying interactions between seabirds and human activities, (2) identifying ecological solidarities and vulnerability transfers among the different habitats used by seabirds, and (3) studying and developing the use of seabirds as a boundary object to foster stakeholder cooperation. Below, we will develop these three research avenues and give operational examples of implementation based on our work in the English Channel.

2. Interactions between seabirds and human activities

2.1. Seabirds as ocean sentinels

Seabirds raise their young on land but feed, and often winter, at sea. Depending on the species considered and on the time of year, they rely on coastal or offshore waters, from the water surface to several hundreds of meters. Seabird behavior (e.g. foraging effort) is especially sensitive to environmental changes (e.g. fish availability)

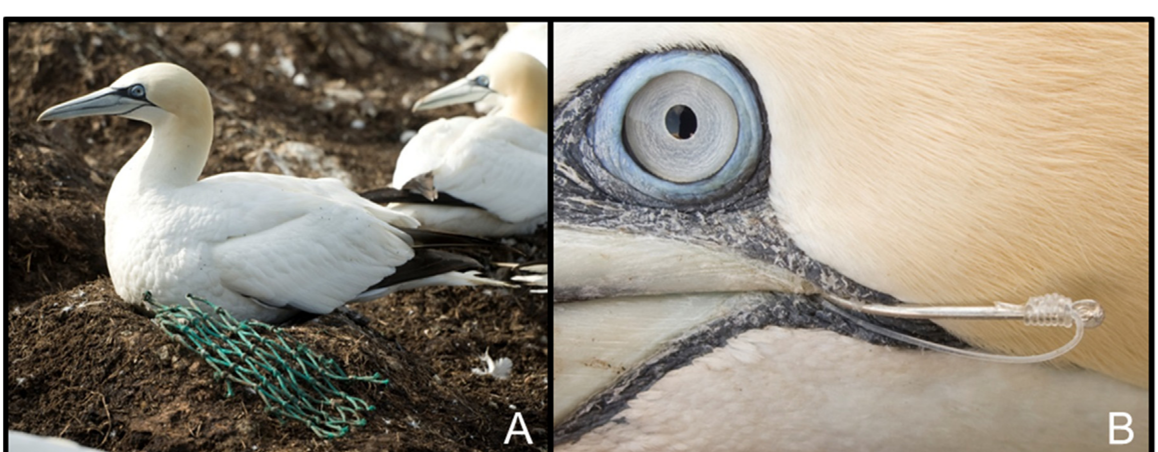

Fig. 1. Seabirds are exposed to all the threats affecting the marine environment: climate warming [34], habitat degradation (organochlorine contaminants and mercury, plastic debris, oil pollution, [80]), direct mortality through bycatch [20] and overexploitation of their prey [64]. On Northern gannet (*Morus bassanus*) colonies, it is common to see plastic debris in nests, often from fishing gear (A), as well as hooked individuals (B). In 2012, 28% of seabird species were classified as threatened (compared to 12% for all bird species; [20]). Pictures by David Grémillet.

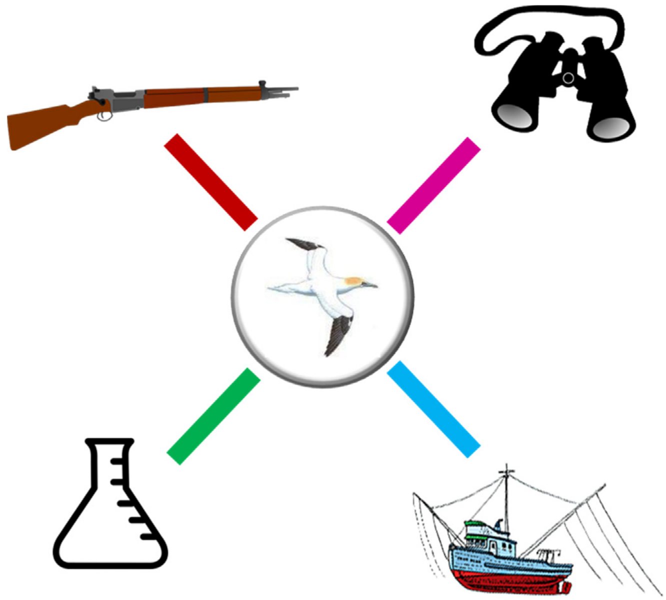

Fig. 2. Seabirds can be used as a meeting point (or 'boundary object', *sensu* [72]) for stakeholder groups. They can be perceived as an ecological component of a complex system by scientists and natural managers, as an economic resource for tour guides and operators, as a competitor for fishermen and shellfish farmers, or as a food resource for hunters.

and can therefore be used as an indicator summarizing large quantities of information into a few relevant signals [25]. By fitting them with electronic devices (such as GPS or satellite tags) when they are on land, it is possible to know precisely what part of the ocean they are visiting, and when (see examples and references in [66]). Seabirds can therefore act as autonomous samplers of the ocean, or'sentinels', and inform us about local to distant environmental degradation. Sentinels are indicators of human-induced alterations of their supporting ecosystems [69]. For example, while concerns are rising about the quantity of plastic debris in the oceans [7,19,36], the level of plastic pollution in a given area can be monitored by examining the debris used by seabirds to build their nests [52,82]. As seabirds often ingest plastic waste [24,68], the level of plastic pollution within the foraging range of a given species can also be assessed by performing necropsies on seabirds stranded on beaches, or accidentally caught by fisheries [16]. Similarly, the concentration of other pollutants, such as heavy metals or organic pollutants, in the environment can be assessed by measuring their concentration in the feathers, blood, muscle or organs of live (for feathers and blood), or dead seabirds (e.g. [28,40]).

2.2. Seabirds as umbrella species and ecological indicators

Top predators usually need large areas for foraging and develop series of functional links to many ecosystem components [69]. They can therefore be used as umbrella species, encompassing the requirements of less demanding species, and as ecological indicators, revealing areas in need of biodiversity protection and/or biodiversity hotspots. In the marine realm, different studies have shown that sites used by top predators for breeding and foraging overlap widely with biodiversity hotspots in the open oceans [86,87]. Therefore, seabirds seem adequate surrogate species for addressing questions about how human activities are conflicting with marine life, what resources are left available for wildlife, and which areas should be protected. One approach to addressing these questions is through biologging technology, i.e. 'the use of miniaturized animal-attached tags for logging and/or relaying data about an animal's movements, behavior, physiology, and/or environment' [67]. Applied to seabirds, biologging allows researchers to produce maps of their location and activities at sea (e.g. [61]) to assess competition for space and food with human activities, such as fishing, aquaculture, extraction of oil and aggregates, production of renewable energy, at a very fine spatial and temporal scale.

2.3. Northern gannets foraging tracks help redefining marine protected areas

For example, in the English Channel, the use of GPS tags on Northern gannets (*Morus bassanus*), the largest seabird species in the North Atlantic, allowed us to identify foraging hotspots that are currently used by government agencies to redefine French marine protected areas and assess the impact of a wind farm project (Fig. 3). In 2013 and 2014, 16 birds were equipped with GPS tags and miniaturized video cameras in order to identify, characterize, and quantify the interactions between gannets and fisheries (Fig. 4). The data collected showed that at least 38% of the tracked gannets fed behind or around trawlers, mainly when the trawl net was hauled but still underwater. Further, there was no evidence of interactions with other types of fishing vessels. This type of assessment (see also [75,83]) is especially important in the context of the new European Common Fisheries Policy, which aims at drastically reducing fishing discards at the horizon of 2019 (REGULATION (EU) No. 1380/2013), and could significantly affect seabirds-fisheries interactions.

3. Ecological solidarities and vulnerability transfers

3.1. Seabirds help thinking the world's interconnections

Seabirds cross ecological boundaries because they breed on land but feed at sea, or travel in the air but often dive underwater for catching prey. Seabirds also cross political boundaries on a regular basis, moving from coastal to international waters or from one management unit to another. By connecting habitats and ecosystems in space and time, they play an important role as 'mobile links' [44] in ecosystem dynamics. Seabirds also connect protected areas and non-protected areas, as well as different nations and local communities. These multiple connections provide a great opportunity to 'think large' and understand the 'ecological solidarities' that exist in the marine realm. The concept of 'ecological solidarity (ES)' is a core notion of the 2006 law reforming National Park policy in France [47,76] and the umbrella concept of the new French national law on biodiversity conservation presently in preparation (last reading by the parliament). ES is defined as the interdependence of living organisms and integrates ecological, social–ecological, and social–political interdependences. Shifting from the concept of 'interdependence' to ES in viewing this plurality of ties underlines the community of fate between humans, their societies, and the rest of nature [48]. Respect and care for ecological solidarities becomes the contract by which we define our duties and the limits of our action on nature. It differs drastically from the traditional design for protected areas, i.e. an 'island' of strict regulatory protection, by highlighting the importance of the connections between a protected area and its geographical and social surroundings. Indeed, the outcome of conservation strategies implemented in a protected area can be significantly affected by the social and economic situation of non-protected areas to which it is connected.

A good example of such connections is the link between bushmeat hunting, wildlife declines, and fish supply in West Africa [10]. In Ghana, the decline in fish supply from heavily exploited coastal waters led to a shortage of proteins for the local population, which had to rely increasingly on bushmeat hunting, both for

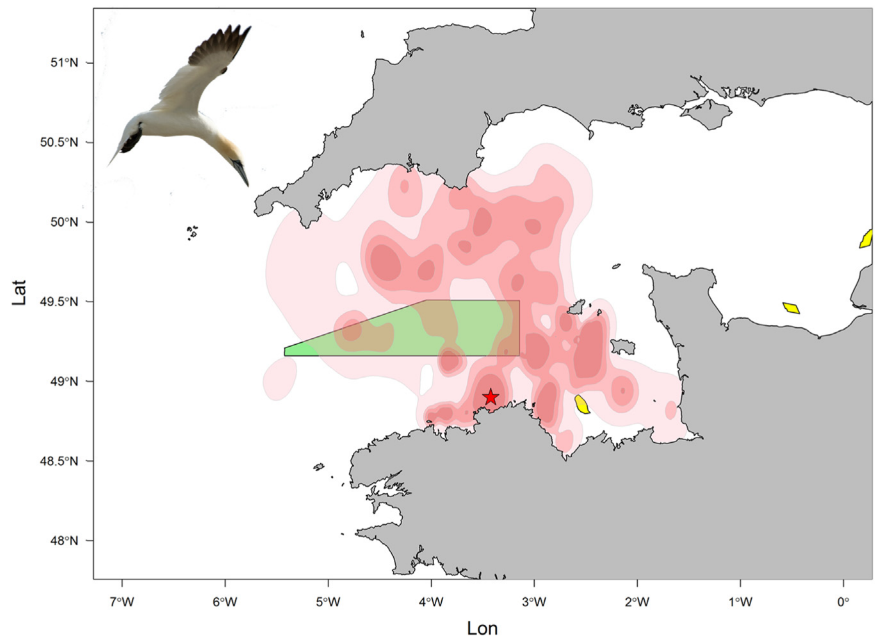

Fig. 3. (Color online) Contours of foraging habitat utilization of 91 Northern gannets tracked from Rouzic Island (red star) with GPS tags during the chick-rearing period (2005–2013). Kernel utilization density (UD) contours correspond to the spatial extent of gannet foraging range (90% and 70% UD), focal areas (50% UD) and core areas (25% UD) from light to dark gray (dark pink). Black (yellow) polygons represent areas selected for wind farm projects. The polygon with a dashed outline (green polygon) represents the area of interest for the conservation of seabirds and marine mammals in the English Channel, as first proposed by the French MPA Agency. The location of this area is being redefined, partially based on this tracking data.

income and subsistence. This in turn led to increased poaching in terrestrial protected areas, and coincided with sharp declines in the biomass of mammal species in these areas. Our own work on the at-sea distribution of Northern gannets and Scopoli's shearwaters (*Calonectris diomedea*), whose breeding sites are strictly protected in Europe, suggests that industrial fishing in West African waters by foreign fleets (including from the EU) could also significantly affect the population dynamics and conservation status of these populations in Europe, through seabird bycatch and fish stock depletion at their West African wintering grounds ([32]; Fig. 5).

3.2. Following seabirds through their lives, and identifying management deficiencies

Identifying the areas and habitats used by seabirds throughout their annual cycle (breeding vs. non-breeding season) and their life stages (juvenile, immature and adult phases), as well as interactions between seabirds and human activities within these areas, will help with understanding the ecological, social, and economic dimensions of marine ecological solidarities, and reaching a more integrative view of conservation issues. Indeed, while most seabird breeding colonies of the Northern hemisphere are protected, this is rarely the case for the marine habitats they rely upon during the breeding season, their migration corridors or their wintering areas, especially when the latter are located in the Southern hemisphere or in international waters. From an ecological perspective, identifying connectivity between seabird habitats, threats to ecosystems, and management deficiencies in these habitats would allow proposing meaningful protected area networks and/or ocean zoning schemes.

3.3. Understanding the influence of socio-economic contexts and power relationships

Unfortunately, ecologically sound does not always mean practically efficient, and conservation strategies which ignore socio-economic contexts are likely to fail. The collapse of many fish stocks in the North Atlantic [12,22,29,54] and increasing environmental regulatory requirements within the EU incited the industrial players of marine resource exploitation to transfer their activities and related environmental impact to waters belonging to states which do not have the necessary legislation to protect their marine resources [4]. Understanding how social and economic interdependencies between seabird habitats may be fueling such vulnerability transfers, from strong institutional, social or economic actors to weaker ones, should help greatly in building more efficient conservation strategies.

4. Seabirds as a boundary object for stakeholder cooperation

4.1. From flagship species to boundary object

As other top-predators, seabirds (e.g. puffins and albatrosses) have been widely used by conservation organizations as flagship species to raise funds and/or communicate about conservation issues [69]. This approach has been criticized for indirectly giving prominence to public preferences over scientific criteria in setting conservation priorities [26] and also for generating conflict with local communities, for instance when top predators are competing with human activities (e.g. [55,89]).

Here we propose to go beyond the concept of flagship species and to use seabirds as a boundary object for the different marine stakeholder groups. According to [72] '*boundary objects are objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use. They may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is key in developing and maintaining coherence*

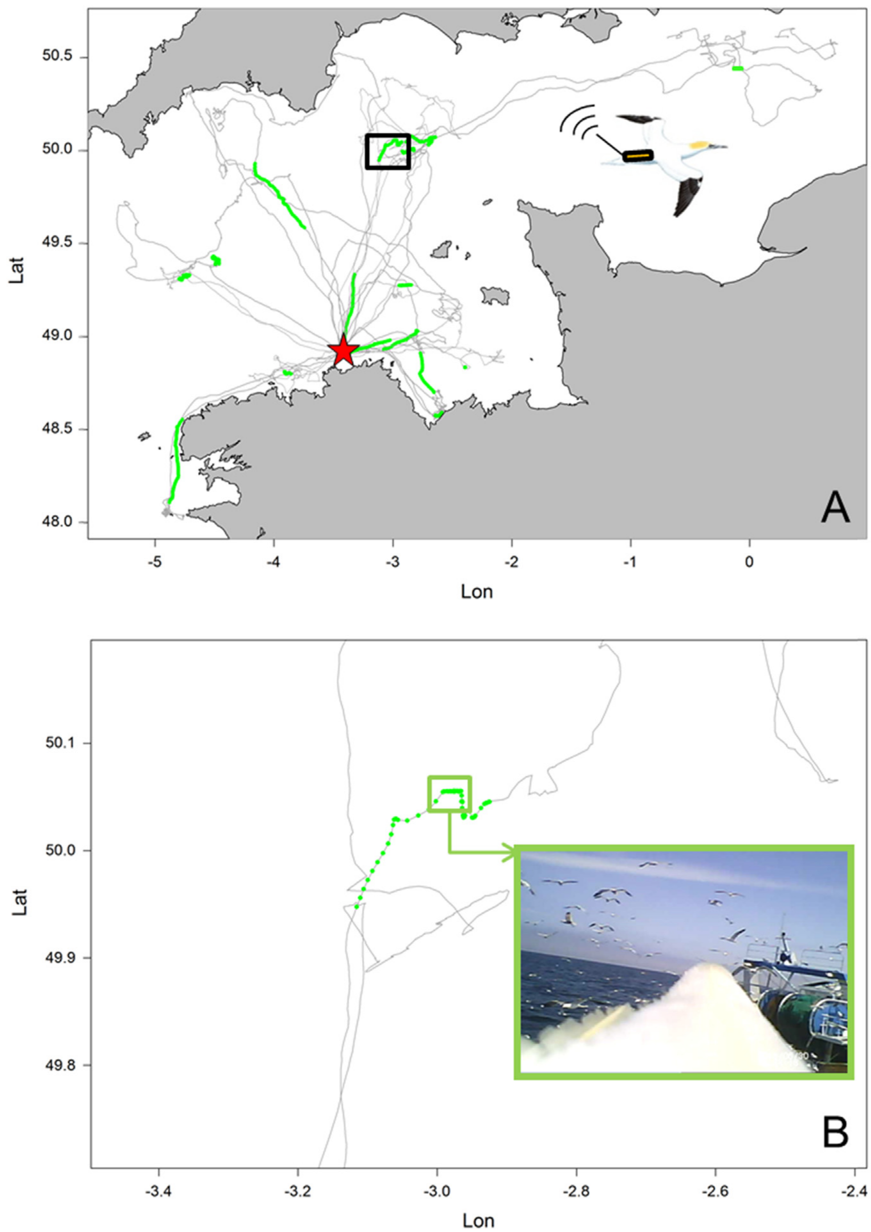

Fig. 4. (Color online) (A) GPS tracks (gray lines) collected from adult gannets breeding on Rouzic Island (red star) in 2013 (7 individuals) and 2014 (9 individuals). For each of these tracks, miniaturized video cameras attached on the gannet's lower back continuously recorded the bird's environment on its fishing grounds over 1.3 h (thicker black/green sections). (B) Close-up of a filmed section for an individual track. From these recordings, we determined that 38% of the tracked gannets fed behind or around trawlers. Two short video sequences of "natural" foraging and foraging behind trawlers are provided as electronic supplementary material.

across intersecting social world'. We suggest that seabirds could be used to promote discussion and develop cooperation between stakeholder groups such as fishermen, shellfish farmers, NGO representatives, environmental managers and scientists. Seabirds interact with all these groups, therefore materializing an intersection between them, but they are perceived differently by each individual group (Fig. 2). Recognizing and discussing these differences could be a way to reach a reciprocal understanding of everyone's norms, interests, and values, creating the basis for effective cooperation. Due to the transboundary nature of seabird ecology, discussions about the interactions between seabirds and human activities would allow raising most global marine-specific conservation issues (e.g. overfishing), in a less conflicting way than if they were directly addressed.

4.2. *Using visual data as a springboard for stakeholder cooperation*

Beyond the image of seabirds as used in a classical 'flagship species' approach, we suggest that visual data collected on and by seabirds (e.g. maps of GPS tracks, pictures, and video clips) provide a major opportunity to convey knowledge to a heterogeneous public, and to generate immediate interest. As the saying goes, 'a picture is worth a thousand words' and it is especially true in the marine realm since most people do not have direct experience with what is happening under the ocean surface and/or off the coast. This led a few researchers to develop dynamic visualizations of marine ecosystems, based on different management scenarios, to better enable government officials, environmental groups, and commercial fishers to make informed policy decisions (e.g. [13]).

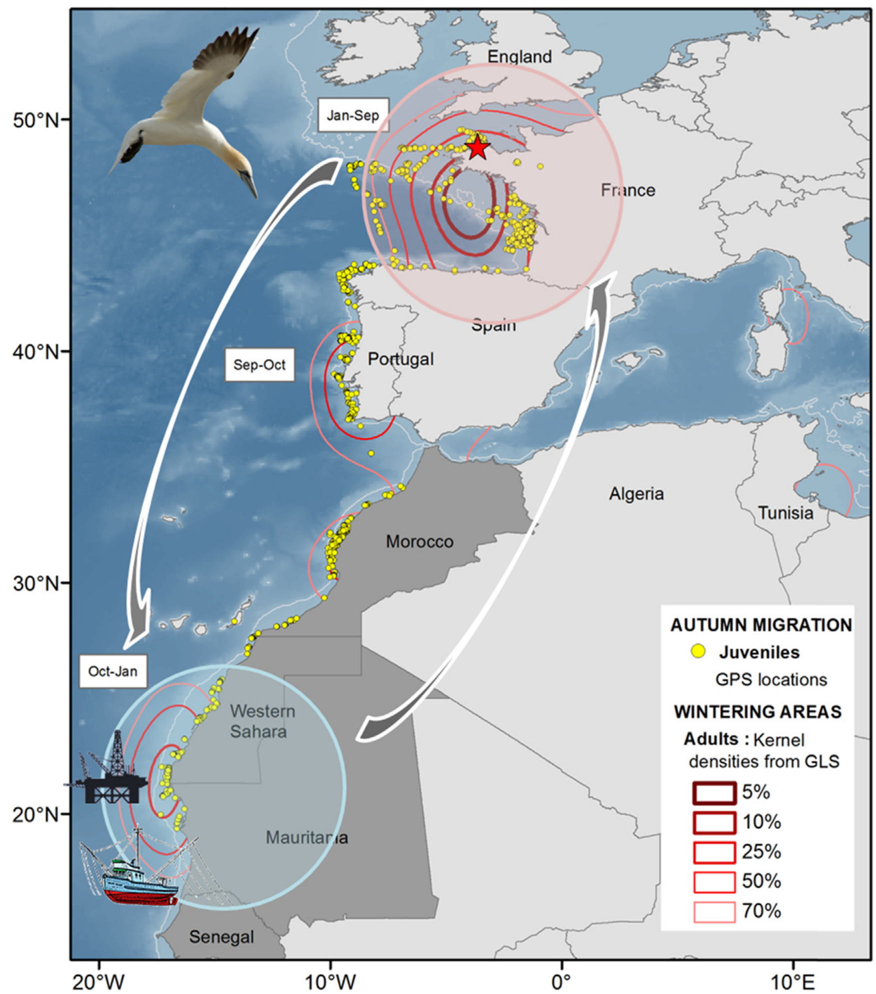

Fig. 5. Migratory movements of juvenile and adult Northern gannets between their breeding (black circle, short dash contour) and wintering (black circle, long dash contour) areas, illustrating the connectivity (arrows) between European protected areas and West African coastal waters. The location of the breeding colony (Rouzic Island) is indicated by the star. While European breeding sites are strictly protected, birds wintering off West Africa are at risk from oil spills, competition with fisheries, as well as intentional and incidental mortality by fishing gear. Adapted from Grémillet et al. [32].

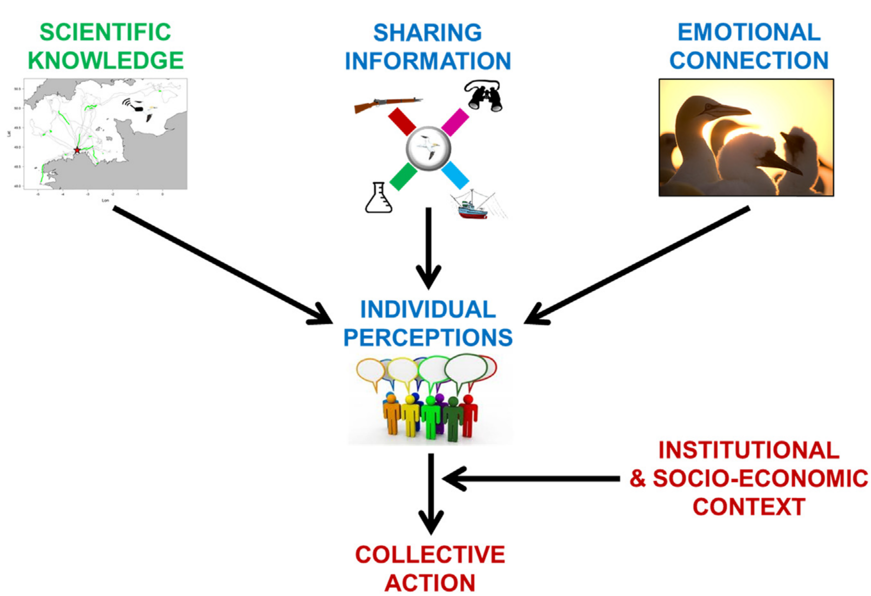

Fig. 6. Sharing seabird-related visual data within multi-sectoral working groups can nourish and modify both the cognitive dimension of individual perceptions by providing scientific knowledge on the interactions within a marine social–ecological system, and the affective dimension of these perceptions by reinforcing the emotional connection to marine biodiversity. Scientific knowledge, shared information between stakeholder groups, and reinforced emotional connection to nature should enhance the ability of stakeholders to coordinate for changing regulation frameworks. Photo credit: David Grémillet.

Additionally, studies have shown that affective factors can play a greater role than scientific considerations in the willingness of individuals to pay for biodiversity conservation, e.g. people would rather pay for conserving species which they like and are familiar with, often part of the charismatic megafauna, than for endangered but more cryptic species [46]. In the context of participatory management processes, we hypothesize that seabird-related visual data can nourish and modify (1) the cognitive dimension of individual perceptions by providing easily understandable information on seabird ecology and the interactions between seabirds and other components of the social–ecological system, and (2) the affective dimension of these perceptions, by conveying a sense of awe and closeness for marine biodiversity (Fig. 6).

4.3. From gannet/trawler interactions to global marine conservation issues

Although these hypotheses need further exploration and testing, our preliminary work in the English Channel yields promising results. Indeed, maps of GPS tracks and videos of gannet/trawler interactions were successfully used to address global marine conservation issues with fishermen, shellfish farmers, NGO representatives, environmental managers and scientists at a workshop held in Dinard (France) in November 2014. These stakeholders had been invited to work collectively on the interactions between seabirds and human activities. The discussion about these interactions and the visual data shared during the workshop addressed a large range of global marine conservation issues, including wildlife disturbance by recreational activities, fisheries management, degradation of benthic habitats, water pollution (caused by plastic debris, microbial contamination and chemicals), competition for food between marine top predators and fishermen, invasive species, impact of marine renewable energy facilities, and fisheries bycatch. These open discussions did indicate that seabirds can be used as a boundary object to facilitate dialog and knowledge transfers among stakeholders. In great contrast to conventional public participation processes, this workshop was not oriented towards consensus and decisions-taking, something which was greatly appreciated by all stakeholders who often feel they are being talked into pseudo-participation.

This first experiment created an arena of discussion and coproduction of knowledge related to social and ecological interactions. Such an arena is key to the governance of biodiversity by allowing social learning and creating the necessary conditions for a deliberative process geared towards integrated institutional and technical innovations to deal with global change and market liberalization. Indeed, by making stakeholders acknowledge the existence of interdependencies among humans and non-human components of the marine social–ecological system, we also lead them to be aware of their dependence on each other to solve conservation and natural resource management issues. In turn, this will increase their willingness to engage in collective action as an alternative or complementary approach to public policy or market forces [41,57,58].

5. Limits

5.1. Suitability of seabirds as surrogate species for marine biodiversity

Part of the approach advocated here involves using seabirds as surrogate species for marine biodiversity. Specifically, we suggest using seabirds as umbrella species and ecological indicators. While there is a consensus around the efficiency of top predators in general as sentinel species, their pertinence as biodiversity indicators seems highly species- and context-dependent. There has been little quantitative investigation of their effectiveness as umbrella species, though their use in marine systems is promising (see studies reviewed in [69]) and should be tested in different contexts.

Using seabirds as a boundary object for stakeholder cooperation also requires formal testing, which we are currently undergoing. As underlined by Sergio et al. [69], '*the context-dependence and species-dependence* […] *indicate the importance of locally tailored, cautious choices of top predatory species appropriate to the conservation task to be achieved*'. Seabirds are better suited to promote discussion and develop cooperation between stakeholder groups than other marine top predators, such as seals or toothed whales, whose depredation in fisheries is a source of conflicts and polarization of viewpoints among stakeholders (e.g. [17,62]). However, even among seabirds, special care should be taken to select the species in line with the social–ecological context and objectives. In the European context of coastal fisheries, for example, herring gulls (*Larus argentatus*), which are perceived by the general public as thriving on our garbage, or great cormorants (*Phalacrocorax carbo*), seen as gluttons of the sea by many people, should probably be avoided, at least during the first discussion phase.

5.2. Conflicts arising from large-scale economic and/or political power asymmetries

While using seabirds as a boundary object for stakeholder cooperation will help with recognizing and discussing differences of perceptions and interests among stakeholders, it will not rule out conflicts arising from large-scale economic and/or political power asymmetries. For example, public participation processes and concerted action schemes often take place at a local scale with community stakeholders, but the most powerful drivers of a system may actually act at a much larger scale (such as the industrial fish meal fishery). Nonetheless, understanding the ecological solidarities that exist between marine social–ecological systems will help shed light on these drivers, and provide key knowledge that could be used by the most vulnerable stakeholders to push for changes in regulation frameworks [58].

5.3. Participating in multi-sectoral workshops is time-consuming

Lastly, 'seeing the ocean through the eyes of seabirds' and ultimately getting involved in discussions with stakeholders is probably more time-consuming for researchers than just providing their data to government agencies and/or conservation organizations. However, creating such an arena of discussion for fishermen, shellfish farmers, NGO representatives, environmental managers and scientists can lead to multi-way transfers of knowledge, increase mutual trust and the establishment of new collaborations, and ultimately open new research avenues for scientists.

6. Conclusion

Seeing the ocean through the eyes of seabirds is a new, synthetic approach to the complex interactions between the ecological and social components of marine systems, and for addressing global marine conservation issues with a wide array of stakeholders. While there is no single, ideal solution to the marine social–ecological crisis, creating arenas of social learning and coproduction of knowledge based on a shared understanding using seabirds can promote collective action and help meet the challenges of managing common-pool marine resources by enhancing ecosystem stewardship both in protected and unprotected areas.

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