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# Reimagining coral reef futures



Ignacio Gianelli[1] ✉, Laura M. Pereira[2,3], Victor Brun[4], Gabby N. Ahmadia[5], Natalie C. Ban[6], Tamatoa Bambridge[7], Emily S. Darling[8], David Gill[9], Georgina G. Gurney[10,11,12], Jean-Baptiste Jouffray[3,13], Stacy D. Jupiter[8], Mohsen Kayal[14,15], Rashid Sumaila[16], Rachel A. Turner[17], Jean Wencélius[7], Rafael Almeida Magris[18], Jessica Blythe[19], Tomas Chaigneau[17], Jordan S. Goetze[20,21], Andrew Merrie[3], Albert V. Norström[3,22], Kim Yip Tong[23] & Joachim Claudet[1]

Coral reefs are vital social-ecological systems, but highly vulnerable to global change and local stressors. While conveying the urgency of existential threats is paramount, bleak outlooks can become self-reinforcing, limiting capacities to act. To counter this, experts working on coral reefs in diverse geographies imagined coral reef futures through a structured visioning process. The resulting visions offer alternatives aspiring to desirability, sustainability, and equity for coral reefs. These broaden the conversation on coral reef futures, enabling discussions beyond siloed conservation, traditional management tools, or pure techno-fixes. Concepts such as earth stewardship, biocultural revitalization, and anticipatory governance emerged as essential to sustaining human well-being and enabling the viability of future coral reef ecosystems before, during, and beyond social-ecological shocks. By fostering forward-thinking dialog, these visions and narratives constitute key stepping stones to reimagining desirable relationships between people and coral reefs and speak to both anticipatory and adaptive pathways toward desired change.

Coral reefs are among the most biodiverse ecosystems on the planet[1,2], supporting livelihoods for over 400 million people[3–5], as well as providing coastal protection[6–8] and other benefits[9] to nearly a billion people. However, they are also among the most vulnerable ecosystems to global change and local anthropogenic stressors[9,10].

By mid-century, projections indicate that coral reefs will be near the brink of biophysical collapse[10,11], placing the species[2] and societies[9,12] that depend on them under existential threats. Yet, some coral reefs show resistance or resilience to repeated climate impacts[13,14], exhibit potential to expand into new suitable habitats enabled by climate change[15,16], and critically, coral reef resilience is largely influenced by local pressures. While global action remains essential to avert the worst effects of climate change, such evidence offers cautious optimism for the future of some coral reef social–ecological systems.

Nonetheless, dystopian narratives often dominate coral reef futures conversations[17]. Over time, these narratives become self-reinforcing[18,19], fueling helplessness without providing actionable solutions[17,20] or overconfidence in technology-based fixes[21]. Even under bleak outlooks, countering such narratives open spaces to reimagine and embrace novel coral reef futures, and to develop anticipatory strategies that maximize coral reefs viability and adaptive capacity in the face of escalating threats[22–24].

Imagining desirable futures (a.k.a. visions[25]) for people and coral reefs is, however, a creative, cognitive, normative, but necessary, challenge. Visioning desirable futures can strengthen both individual and collective agency among those involved in the process, enabling them to (re)discover alternatives and solutions in unexpected spaces and identify and enact actionable pathways to achieve these futures[26,27]. Visions, expressed through stories, narratives, or visual representations grounded in hope, tend to resonate more deeply with society than statistics or facts[28], thereby inspiring transformative change by unlocking new imaginaries and acting as compasses toward transformative futures[19,29].

Here, we envision desirable futures for coral reefs that aim to be sustainable and just, using futures thinking[30] and a combination of methods, including the Seeds of Good Anthropocenes approach[18] and the Nature Futures Framework (NFF)[25]. The former acknowledges that seeds of preferable futures exist in the present and that imaginaries of futures are likely to be influenced by them. The latter enables the visioning and assessment of pluralistic, desirable futures for people and nature, grounded in the intrinsic, instrumental, and relational values of nature. Our focus is on crafting desirable visions that are not confined to a specific place or time, but are instead relatable and applicable to coral reef social-ecological systems across diverse contexts and scales. The aim is not to predict what *will* happen, but to explore what *could* happen, offering multiple potential futures for people and coral reefs.

A full list of affiliations appears at the end of the paper. ✉e-mail: ignacio.gianelli@ephe.sorbonne.fr; ignaciogianelli@gmail.com

## Results

### Desirable futures for coral reefs

We used a structured visioning method involving experts working in coral reef science, conservation, and management across diverse contexts to develop three future visions (see Box 1): *Reeftopia*, *Project Reefoir*, and *The Bay Revolution*. The visions introduce a rich diversity of settings, scales, time horizons, and key events (Table 1). These visions also reflect different combinations of perspectives on human-nature relationships as captured in the NFF; Nature for Nature (NfN), Nature for Society (NfS), and Nature as Culture (NaC), each grounded in intrinsic, instrumental, and relational values of nature, respectively (Table 1). *Reeftopia* embodies a future of Earth stewardship that balances NfN and NfS, underscoring both the intrinsic values of coral reefs and non-material contributions of coral reefs to human wellbeing. *Project Reefoir* embodies a future of biocultural revitalization that merges NaC and NfN, showcasing how cultural heritage and intrinsic values coexist and reinforce one another, while balancing material (e.g., food, habitats) and non-material (e.g., identities) nature contributions to people. *The Bay Revolution* showcases a future of equitable growth that weaves together NfS and NaC, balancing the sustainable use of coral reefs with the pursuit of sovereign futures and the recognition of community tenure rights. It emphasizes context-specific benefits (e.g., sustainable tourism), and material (e.g., food), and regulating (e.g., buffering of extreme weather) nature contributions to people.

Importantly, these futures do not aim to replicate the historical biodiversity of coral reefs, but instead embrace the uncertainties and challenges that coral reefs and dependent communities are facing and are likely to face with greater intensity in the future.

Each vision is introduced with a brief summary, a synopsis of the storyline, and an artwork by Kim Yip Tong (Figs. 1–3; see Supplementary Materials for full storylines or visit https://radicaloceanfutures.earth/coral-reef-futures). The synopses are excerpts from the narratives, highlighting the geographical settings, scope, time horizons, key driving events, symbols,

## Box 1 | Author positionality and reflexivity

We are a group of 23 authors representing 14 countries, including coral reef–hosting nations such as Australia, Barbados, Brazil, Fiji, France, French Polynesia, Mauritius, South Africa, and the United States of America. Collectively, we have experience working across coral reef social–ecological systems in six of the ten regions defined by the Global Coral Reef Monitoring Network, including East Asia (Philippines), Australia (Great Barrier Reef, Ningaloo Coast), Western Indian Ocean (Comores, Tanzania, Mozambique, Mauritius, Mayotte, Reunion Island, South Africa), Pacific (French Polynesia, Hawaii, Fiji, New Caledonia, Papua New Guinea, Solomon Islands, Vanuatu), Caribbean (Barbados, Guadeloupe, Martinique), and Brazil. Our experiences span diverse geographies, with our perspectives being strongly influenced by our training in Western academic traditions. At the same time, our engagement and collaboration with Indigenous Peoples and coastal communities across these regions, and, for some, lived experience in coastal and coral reef areas, have informed our doing and being, fostering reflexivity and critical awareness of positionality.

Our disciplinary backgrounds include interdisciplinary or sustainability science ($n = 8$), natural sciences ($n = 6$), social sciences ($n = 6$), and arts ($n = 1$). Our expertise spans marine, coastal, and coral reef conservation and management, social–ecological systems, coral reef ecology, fisheries management, ocean governance, corporate sustainability, anthropology, wellbeing, ocean equity, blue justice, futures thinking and methods, science fiction, storytelling, and arts-based methods. Professionally, we are or have been engaged in research institutions ($n = 20$), civil society organizations ($n = 7$), community-based initiatives or local organizations (n = 6), and governmental institutions ($n = 2$). Approximately half of us have 10–20 years of experience working with coral reef social–ecological systems ($n = 11$), 28% have less than 10 years ($n = 6$), and 19% have more than 20 years ($n = 4$). Around half of us are or have been directly involved in the management or stewardship of specific coral reef social–ecological systems, whether formally through professional roles, technical advice, or collaborative co-production, or informally through local initiatives or communities. In terms of gender identity, the group includes nine women and fourteen men.

As a collective, we acknowledge our privileges, biases, and limitations. These include the predominance of Western academic perspectives, the absence in the visioning process of Indigenous Peoples and local community representatives (those most directly affected by coral reef decline), underrepresentation of certain coral reef regions, and limited expertise in coral reef restoration science and practice. The location of the visioning workshop (Moorea, French Polynesia) may have also influenced the visions, which incorporated many tropical Pacific Island elements and contexts.

We recognize that our positions, disciplines, lived experiences, and biases shaped how we imagine coral reef futures. Accordingly, the visions presented here reflect one perspective among many and should be understood as a valuable but not definitive contribution to broader discussions about desirable, sustainable, and equitable coral reef futures.

**Table 1 | Key characteristics of each envisioned future for coral reefs as social-ecological systems**

| | Reeftopia | Project Reefoir | The Bay Revolution |
|---|---|---|---|
| Setting | Coast of Jigurru (Lizard Island), an actual location off the coast of Queensland, Australia | The Reef and Solastalgia Islands, a fictional island system consisting of both low-lying and high-lying islands | Makani Bay, a fictional small island community in the Pacific |
| Scope | Global | Global to local | Local to global |
| Time horizon | Not specified, but distant in the future | 2100–2199 | 2030–2051 |
| Key events | Eco-harmony council takeover | Climate exodus | The storm, the "revolution" |
| Symbols | Universal Happiness Index | Larvae, Solar-fueled fleet | The wind |
| Human-nature relationship in the NFF | Nature for Nature and Nature for Society | Nature for Nature and Nature as Culture | Nature for Society and Nature as Culture |
| Nature contributions to people | Inspiration and learning, Supporting identities, Experiences | Food, Supporting identities, Habitat creation and maintenance, Maintenance of options | Experiences, Regulation of extreme events, Food |

*NFF* Nature Futures Framework.

**Fig. 1 | Artistic representation of *Reeftopia*, where delegates gather in the *Coralarium* to co-create a new global constitution.** © Kim Yip Tong. Used with permission.

**Fig. 2 | Artistic representation of *Project Reefoir*, a biocultural model for revitalizing coral reefs and local communities in the aftermath of ecological collapse and climate-induced exodus.** © Kim Yip Tong. Used with permission.

**Fig. 3 | Artistic representation of *The Bay Revolution*, where a cluster of *AetherReefs* combine renewable energy generation with the creation of suitable artificial habitats for coral reef settlement and restoration.** © Kim Yip Tong. Used with permission.

human–nature relationships, and the nature contributions to people emphasized in each vision.

**Reeftopia**. Reeftopia is a vision of commitment. It imagines a future where people unite beyond borders and jurisdictions, guided by a deep sense of stewardship for coral reefs and the ocean. Informed by an awareness of past near-apocalyptic impacts, and through sustained investment in nature-centered education and the restructuring of governance to reflect social–ecological processes, future generations are equipped to build the foundations of a global society rooted in care and justice. In this world, progress is no longer measured by growth but by the well-being and happiness of both people and nature.

*Storyline synopsis: Surrounded by a flourishing reef, a floating bioarchitectural structure became the convergence point for global delegates, precisely timed with the annual coral spawning. Among them is Māramāia, a longtime advocate for the Universal Happiness Index, who arrived to represent her people. Tasked with co-creating a global constitution for nature and people, the delegates faced practical challenges related to life above water and the complexities of collaboration across diverse worldviews. Yet, as billions of coral gametes began their synchronized ascent beneath them, the spawning served not only as a biological spectacle but also as a metaphorical guide. Inspired by the beauty of coral reef ecosystems, the delegates shed entrenched positions, finally embracing a collective vision. By the time the last gametes drifted into the current, Reeftopia had been born: an emergent global community oversight by the Ecoharmony Council, a coalition aimed at dismantling the remnants of extractive paradigms and steering people and nature toward ecological restoration and justice.*

The narrative depicts a distant future, far removed from the prevailing logic and dynamics of the present, where humanity has gained awareness of its past near apocalyptic impacts. The vision is set in *Reeftopia*, an emerging global community committed to achieving well-being and ecological sustainability through planetary commons governance. The plot introduces a convention that gathers delegates from all over the world to co-create a novel, global constitution. Delegates do not hold traditional political power, but are rather randomly selected from a pool of eligible candidates who have undergone a comprehensive education, and preparation throughout their lifetimes to represent their communities and the nature that supports them. The story envisions a well-being economy that prioritizes social equity and ecological balance over profit and growth. To operationalize this paradigm shift, the narrative introduces the *Universal Happiness Index* as the guiding measure of prosperity and progress, emphasizing that true happiness encompasses both people, and nature. It replaces outdated metrics like GDP, and monitors the plural values of nature.

**Project Reefoir**. Project Reefoir is a vision of renewal. It imagines a future where coral reefs and coastal cultures rebound in the wake of climate-driven die-offs. Through the foresight and dedication of governments and communities investing today in the protection and stewardship of coral refuges, along with breakthroughs in restoration science, future generations will be able to share knowledge, skills, and biomaterials to restore degraded reefs and revitalize local cultures. In this process, both biodiversity and people are given space to heal, adapt, and flourish together.

*Storyline synopsis: Maya returns to Reef Island, her ancestral homeland, once devastated by climate change and environmental collapse. Most of her people were forced to migrate in an exodus due to rising seas and ocean warming, while others stayed and adapted, developing new subsistence livelihoods and cultural adaptations such as fishaliser, a fertilizer made from fish discards, and chem tu, grilled fish eyeballs that have become a gastronomic delicacy in times of scarcity. Now that climate change stressors have receded, Maya is determined to restore the reef, drawing on her ancestors' knowledge, breakthroughs in restoration science, and the availability of renewable energy and technology. She eagerly awaits the Daramak fleet, who arrive with precious coral and fish larvae from climate-resilient refuges, transported by solar-fueled vessels. The biomaterial and knowledge transfer between the two communities is the cornerstone of Project Reefoir, a plan for biocultural revitalization of the reef and its people and culture. Maya's community is confident that Project Reefoir will enable coral reefs to rebound and revitalize local communities in the wake of social-ecological collapse. As the Daramak fleet is about to arrive, Maya believes this marks a hopeful new beginning, one where people will truly honor and regenerate coral reefs.*

The narrative unfolds sometime in the 22nd century on an island system composed of both a low-lying and a high-lying island in a post-tipping-point world where localized cultures and coral reefs are gradually rebounding together. The narrative centres the interaction between a fourth-generation climate migrant, recently returned to her homeland (i.e., a low-lying island), and a futuristic fleet from a community who herds coral and fish larvae from climate-resilient refuges to replenish damaged or decimated coral reefs. The story references a period of climate overshoot (ca. 2050–2070), where tipping points were surpassed, leading to coral reef die-offs and the migration and relocation of ocean-dependent communities in high-lying islands. A low-cost, renewable energy system and cultural adaptations enabled some individuals to survive in isolation throughout that time. Now, with gradual ocean cooling and signs of ecological recovery, exiled communities are returning and revitalizing their homelands and traditions, and laying the groundwork for restoration based on climate-resilient refuges, culture, and a set of technologies that support and enhance these efforts. Blending traditional practices with futuristic adaptation, the story introduces *Project Reefoir*, a biocultural model merging traditional reef management with sustainable gastronomy and food culture, highlighting the distinctiveness of local coral reefs in a manner akin to terroir in gastronomy. The story uses larvae as symbols of renewal and hope of ecological recovery, representing life's resilience and the potential for degraded reefs to rebound. The solar-fueled fleet symbolize a forward-thinking mindset grounded in renewable energy and technological innovation.

**The Bay Revolution**. The Bay Revolution is a vision of collective action. It imagines a future where communities draw inspiration from nature, reclaim agency, and shape their own sovereignty. Born from the challenges of resource dependence and coral reef decline, this future embraces situated technologies to power renewable energy, restore coral habitats, and buffer ocean conditions. In this world, people and nature thrive together, renewing reefs and empowering local communities for generations to come.

*Storyline synopsis: The Bay Revolution follows Jomari, a young student, as he meets Professor Aria, to uncover the story behind the revolutionary AetherReef, biomimicry structures that generate renewable energy while serving as an artificial, coral-friendly environment. After being severely affected by storms and power outages, the professor recounts how The Bay's community discovered that wind power could help restore coral reefs, and free them from dependence on fossil fuels and a monopolizing oil company. Led by friends Tuane and Sefina, The Bay's community fought government and corporate influence, eventually securing tenure rights to create a AetherReef prototype. Their success sparked a regional movement where AetherReef spanned first across the island and then across the ocean, empowering local communities with energy independence, job creation, and sustainable tourism. Their legacy, cemented in The Makani Bay Memorandum, stands as a lasting blueprint for climate resilience and community empowerment.*

The narrative is set within a small island community, spanning the years 2030–2051. It begins amidst intensified tropical storms fueled by climate change, exacerbating inequalities and power imbalances between citizens and corporations. Recognizing the potential to harness wind power for energy independence, the local community transforms the wind, initially portrayed as a disruptive force, into a source of empowerment that drives their "revolution." From that point, the story follows the bottom-up journey of three characters as they design, and implement an innovative, community-owned prototype. This not only produces renewable energy, but also creates suitable habitats and adaptable local environmental conditions for coral reef conservation and restoration. As private interests resist their efforts, the narrative shifts into one of collective action, where local communities challenge their government and the lobbying power. The success and widespread adoption of the prototype lead to energy sovereignty, community-based coral reef restoration, slow tourism and rising local incomes, shaping a future where communities reclaim control over their resources and break free from monopolistic power structures. Ultimately, the vision highlights the importance of perseverance, and collective action to secure tenure rights over coral reefs and energy sources.

## Coral reef futures, uncovered

To characterize the backbones of our coral reef futures, we analyzed the visions across key dimensions frequently used to either develop or characterise scenarios[31–34] (Table 2 and Fig. 4). This approach helps to reveal how

**Table 2 | Coral reef futures illustratively positioned along a continuum, ranging from a more status quo perspective to more transformative futures, across various dimensions**

| Dimension | Reeftopia | Project Reefoir | The Bay Revolution |
|---|---|---|---|
| *Cosmovision*<br>Worldviews that shape how people relate to, and exist within, nature, from human-centered (anthropocentric) to nature-centered (ecocentric). | Mostly ecocentric, prioritizing ecological balance, social equity, and the interconnectedness of all life while centering the well-being of nature and people | Leaning towards ecocentric, emphasizing ecological recovery and sustainable practices while incorporating human-centered elements such as food security | Leaning towards anthropocentric, prioritizing growth while recognizing environmental co-benefits |
| *Connectedness*<br>Degree of integration within and between social-ecological systems, from fragmented to fully connected. | Fully connected, emphasizing global cooperation and social-ecological interconnectedness | Loosely connected, transitioning from fragmented communities and ecosystems to more integrated networks | Connected, fostering strong intra-community bonds and collaboration with other actors, ultimately leading to international coalitions and agreements |
| Ecological<br>State of nature and resource availability, from degraded and scarce to healthy and abundant. | Fully sustained, envisioning a society where harmonious coexistence between people and nature is central | Gradual recovery from collapsed social-ecological systems, marked by assisted restoration of coral reefs and communities, with continued reliance on inputs | Moderately sustained, with coral reef resilience to climate change dependent on human-made structures and interventions |
| *Social structure*<br>Power and wealth distribution, from centralized and hierarchical to inclusive and equitable. | Equitable, ensuring fair resource distribution and shared responsibility toward nature and people on a global scale | Transitional, with communities establishing new rules and fostering cultural innovations on a local scale | Transitional, shifting toward a community-led model after dismantling a monopolistic system dominated by corporations and enabled by the government |
| *Governance*<br>Systems of control and decision-making, from centralized state authority to multilevel, community-led arrangements. | Planetary commons governance, prioritizing global stewardship beyond traditional state structures | Community-led, where communities independently govern their resources and manage reefs, bypassing traditional state-centric models | Transitional, as communities acquire tenure rights and shift toward a more community-based governance approach, while state-based elements persist |
| *Economy*<br>Economic model, from growth-driven capitalism to post-growth approaches prioritizing equity and wellbeing. | Post-growth, actively rejecting capitalism in favor of a well-being economy that prioritizes happiness, ecological health, and equitable resource distribution | Biocultural model, moving away from capitalism and embracing sustainability and cultural continuity as core values | Modified capitalism, shifting away from corporate-driven capitalism while still maintaining growth and economic prosperity as central measures of success |

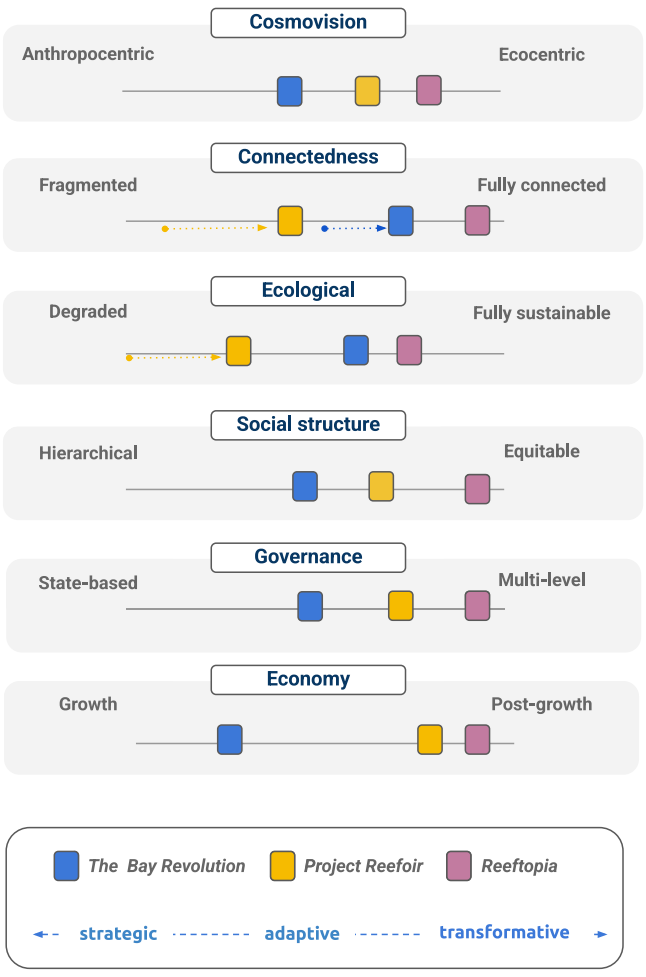


**Fig. 4 | Vision dimensions.** Each future is illustratively positioned along a continuum across various dimensions. This representation is not intended to quantify or measure but to depict a conceptual spectrum of possibilities that *Reeftopia*, *Project Reefoir* and *The Bay Revolution* offer.

our visions diverge from the present, while also highlighting differences and alignments.

*Reeftopia* envisions a transformative future grounded in an ecocentric worldview and a post-growth paradigm, where ecological balance and social equity underpin a global well-being economy that prioritizes the interconnectedness of all life and the harmonious coexistence of people and nature (Table 2 and Fig. 4). *Project Reefoir* blends ecocentric values with human well-being within an adaptive future. Ongoing processes of ecological and cultural recovery reflects how people and nature are transitioning from post-collapse restoration towards a community-led future where local governance and cultural innovation drive the restoration of coral reefs and food systems (Table 2 and Fig. 4). *The Bay Revolution* envisions a strategic, anthropocentric future where growth remains central but is reoriented through strong community collaboration, international coalitions, and modified capitalism. It prioritizes economic prosperity alongside environmental co-benefits, with coral reef resilience sustained through human-made interventions, and devolution of tenure rights (Table 2 and Fig. 4).

Following the plausibility–desirability continuum proposed by Iwaniec et al.[35], these dimensions position *Reeftopia* as a transformative future where desirable outcomes break free from the status quo, *Project Reefoir* as an adaptive future shaped by extreme events and the limitations of adaptive responses, and *The Bay Revolution* as a strategic future aligned with existing strategies and goals (Fig. 4).

## Pathways toward coral reef futures

The unfolding of desirable futures depends on rapid, broad, long-lasting systemic change to both enable the foundational building blocks for the visions and prevent undesirable scenarios, such as global die-offs that could tip low-latitude warm coral reefs into irreversible states[11,23]. The storylines describe how humanity can tackle key distal drivers negatively affecting coral reefs (e.g., GHG emissions) and build resilience in the face of climate change and biodiversity loss through anticipatory strategies (e.g., identification and conservation of climate-resilient refuges, culturally attuned sustainability approaches that integrate local ecological knowledge, traditional management systems, and community priorities).

The visions, and their accompanying stories, do not overlook potential, looming social-ecological shocks; rather, they integrate these into the

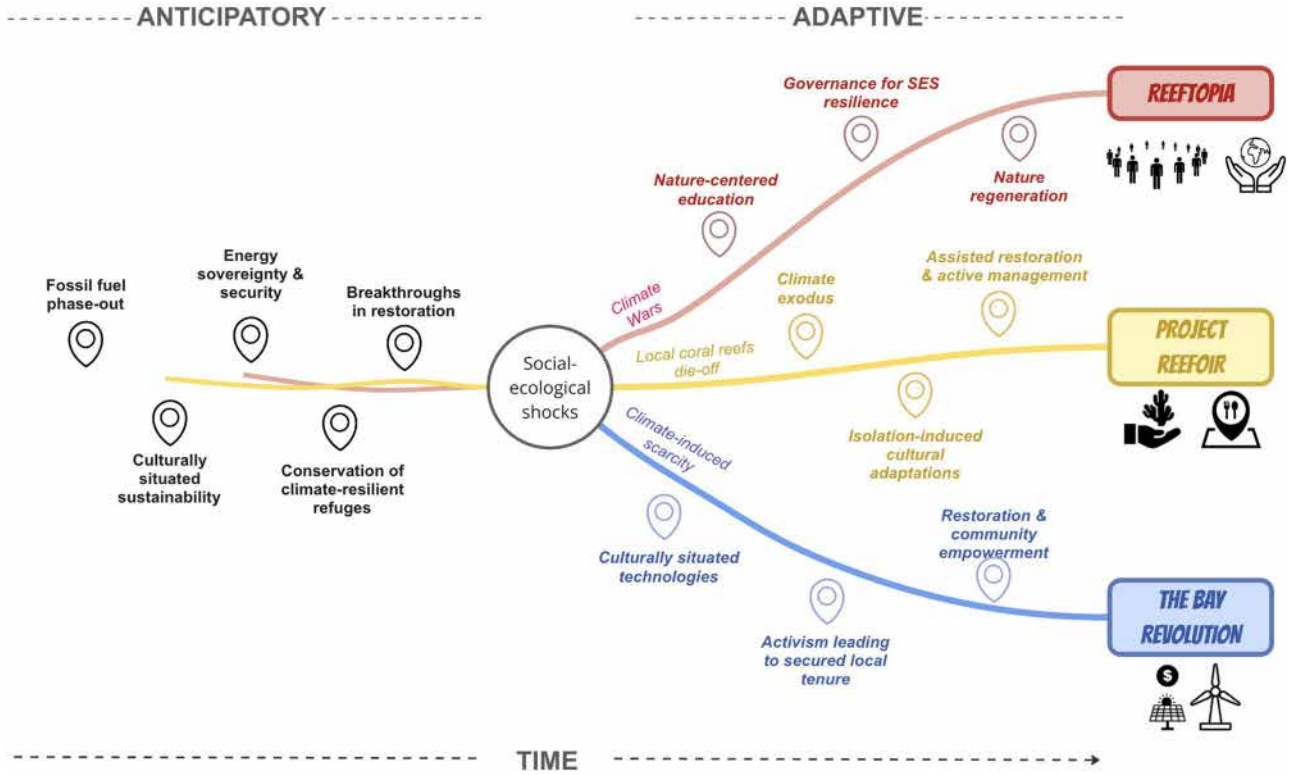


**Fig. 5 | Pathways towards desirable futures for coral reefs social-ecological systems.** While *Reeftopia* (red line) and *Project Reefoir* (yellow line) combine anticipatory and adaptive actions, *The Bay Revolution* only include adaptive responses to a social-ecological shock. Icons were downloaded and modified from https://uxwing.com/.

narratives, offering pathways to overcome or prepare for them (Fig. 5). For example, *Reeftopia* envisions a period of "climate wars"—global societal shocks induced by a changing climate—that catalyzes a fundamental shift in people's values, and education. This transformation leads to a reconfiguration of governance aligned with social-ecological system boundaries, ultimately contributing to a regenerating planet. *Project Reefoir* acknowledges that certain tipping points, particularly those occurring locally, may be unavoidable, even if GHG emissions were to cease soon[36]. This vision emphasizes building resilience to adapt to a post-tipping world, and overshoot scenarios through anticipatory strategies (e.g., accelerating the transition to renewable and locally sourced energy, conserving climate-resilient refuges) and adaptive strategies (e.g., diversifying livelihoods for coral-dependent communities). The narrative also supports the development of restoration science, including coral husbandry[37], assisted migration[38], larval enhancement[38], AI-assisted monitoring and assessments. Finally, *The Bay Revolution* illustrates a future in which climate-induced scarcity triggers the development of culturally situated technologies that enable both people and nature to thrive. The scaling of local innovations leads to regional reconfigurations in nature's contributions to people, alongside intensified efforts to restore coral reefs.

The combination of anticipatory and adaptive actions embedded in diverse pathways illustrate how coral reef social-ecological systems can become more resilient to shocks, reorganize in their aftermath, and ultimately re-emerge in a transformed world.

### Coral reef futures inspire

Beyond the value of visions and narratives as outputs, we also collected participant reflections using a survey to gain understanding of the wider implications of this future visioning exercise (Table S3 and Figs. S5 and S6). Participants highlighted that the visioning process was instrumental in inspiring hope, freeing them from entrenched thoughts, and offering a safe space to explore alternative solution spaces. The process prompted participants to reflect on their initial standpoints on coral reefs' futures, which were predominantly described as "*mostly doom and gloom*", "*quite bleak and pessimistic*", "*bleak*" or, at best, "*cautiously optimistic*". As the workshop progressed, the participants expressed individual, and collective challenges related to "*…the difficulty of moving beyond already established thought processes*", "*…divorcing* [themselves] *from the present reality*", "*setting aside negativity*", or "*…navigating instances where people have quite different ideas about what a positive future would look like*".

Towards the end of the workshop, participants recognized the potential, and benefits of visioning desirable futures for coral reefs, stating that "*…providing a space for creative thinking and letting go of the constraints of practicalities can be really liberating, fun, and eye-opening*" and emphasizing the value of "*…constructing a desirable future without constraints*". Furthermore, participants shared that "*Envisioning elicits hope, which actually could be more important than the outcomes themselves*", and fosters "*…big picture thinking, new ways to talk about coral reef futures, inspiration, commitment to the cause*", all of which helped overcome barriers and reshaped participants' initial thoughts on possible futures for coral reefs. The experience was summarized as a "*state of suspended reality*," capturing both the creative freedom and the challenge of staying grounded, a sentiment echoed by most participants.

Workshop participants reported feeling satisfied to very satisfied with both the workshop, and its outputs, indicating that these outputs were perceived as relatable to their own contexts and experiences (Fig. S5). Overall, most participants expressed feeling comfortable with the proposed visions and narratives, suggesting a high degree of alignment and applicability with their professional perspectives, and practices (Fig. S5). Two concrete examples of the above were the incorporation of futures thinking approach in the Wildlife Conservation Society Coral Reef Strategy and the featuring of the visioning outputs at the Blue Zone of the United Nations Ocean Conference 3 (UNOC 3) in Nice, France.

## Discussion

Once symbols of nature's diversity, coral reefs now embody the struggle between survival and extinction in the Anthropocene[39]. To encourage actions that tip the scale towards survival, here we have reimagined coral reef

futures, and explored some needed actions to face upcoming shocks. By surfacing aspirational visions, we broaden the conversation around futures for coral reefs across scales (local, regional, global), to encompass interventions beyond siloed conservation measures, conventional management tools[40], or pure techno-fixes[41–43]. More importantly, we expand the temporal horizon to explore desirable futures beyond the potentially inevitable, regional and global social-ecological shocks. Rather than aiming to reinstate some reference, or "pristine" conditions of the past, the visions here balance maintaining ecological functions[22,40] with preserving some, though not necessarily all, contributions to people that coral reefs provide (i.e., food, recreation, cultural heritage, inspiration)[22,44]. As such, the visions mirror tensions and the diversity of values embedded in distinct perspectives on present and future human-nature relationships, captured in the NFF that we used in this visioning process.

By incorporating creative elements into coral reef science, we aim to captivate and inspire audiences beyond academia (e.g., decision-makers, practitioners, NGOs, funders, citizens), using artwork and stories that are often more engaging and memorable than traditional scientific outputs[45]. By fostering this kind of forward-thinking dialog, we take an essential step toward reimagining a sustainable and just relationship between people and coral reefs in the Anthropocene[22,24].

All three visions pinpoint that no desirable futures exist without efforts to tackle human-induced climate change in the present. Regardless of actions to curb global warming however, the pathways also highlight the importance of protecting present-day coral reefs from local stressors as invaluable foundations for future recovery efforts, especially those with resilience to climate impacts[13,46]. The visions thus underscore the need for sustained investment in protecting climate-resilient refuges over the coming decades, as well as situated conservation practices elsewhere, regardless of how pessimistic the immediate future outlook may be. However, the visions also acknowledge that while conventional management (e.g., restricting harmful activities) is necessary in the short term, it can be insufficient in an increasingly uncertain and highly volatile world. Therefore, designing and implementing proactive, situated interventions such as creating infrastructure or seeding corals as exemplified by the visions may be the pillars of future conservation and restorative efforts portfolios. The feasibility, cost-efficiency, scalability, and, in some cases, the ethics of these local restorative interventions remain topics of ongoing debate[38,42,47–50]. Yet, these visions openly explore their potential benefits, contributing to the redefinition of conservation paradigms, and management goals[22], and highlighting where there may be tensions in responses based on different value systems.

In this context, visions can therefore serve as valuable compasses for shaping coral reef conservation and restoration programs and strategies, offering desirable futures to guide strategic planning and short- to medium-term actions.

The visions presented here add to the growing body of aspirational futures for the ocean[19,31,51]. By adopting a system-specific rather than a site-specific approach, our visions aim to strike a balance between specificity and relatability, making them well-suited to inform ongoing high-level efforts toward ocean sustainability across various scales. Furthermore, a striking aspect of the discussions showed that despite focusing on coral reef ecosystems, getting onto a more sustainable trajectory requires accounting for the socio-economic, political and cultural factors that reinforce status quo dynamics. This means that the coral reef visions discussed here, which deal with questions of post-growth dynamics[52,53] or regenerative social-ecological systems[54], are relevant for the futures of other ecosystems and places. The outcomes of this study are intended to contribute to the Earth Commission 2.0 efforts to define safe and just ocean boundaries, and to develop transformative pathways. In turn, these can support and inform the development of sustainability transformation processes that align with maintaining safe and just boundaries for the Earth system[55,56].

Given that the visions were developed by coral reef experts (albeit with expertise in diverse disciplines across academia, governments, or NGOs), the envisioned futures represent only a small fraction of the pluriverse of aspirational imaginaries for coral reefs, and thus do not attempt to capture the full diversity of perspectives (Box 1). Consequently, we neither assume nor expect consensus around these visions; rather, our goal is to contribute system-specific visions to the broader space of ocean aspirational visions. To enrich the tapestry of transformative futures for coral reefs, it is essential to incorporate site-specific futures, whether individually gathered[57] or collectively created[58], particularly those that embrace and reflect the aspirations of Indigenous Peoples, local communities, on-ground practitioners, and other coral reefs end-users and rights holders. The next steps include outlining pathways toward the envisioned futures, emphasizing short-, mid-, and long-term actions, along with the intended outcomes, and the mobilization of the diverse actors required to ensure a safe and just space for coral reefs.

## Conclusions

Ongoing trends and future projections may lead people, governments, and funders to conclude that it is too late to save coral reefs, diverting their efforts and resources to other causes. To counter this and inspire action, we developed three aspirational visions for coral reefs, offering renewed perspective about their futures. For the participants involved, the process of visioning desirable futures challenged entrenched beliefs and provided a safe, collaborative space to explore innovative solutions beyond the silos and constraints of the present. These visions aim to alleviate feelings of helplessness, facilitate inter-sectoral dialog between diverse coral reef actors, and hopefully mobilize the diverse range of capacities essential to imagining, and enacting transformative change for safe and just coral reef futures.

## Methods

### The people in the room

The visioning process (i.e., Step 1–3 in Fig. 6) involved 24 participants, 16 of whom attended the visioning workshop in person.

At the start of each engagement process, we obtained either verbal or written consent from all participants, allowing session outputs to be used in research publications while ensuring that no personal data would be shared. Due to the global scale of the visioning processes and as well as with any participatory process, representation was constrained by available resources, the availability of invitees, and other factors. Box 1 details these limitations and fully unpack the positionality of participants.

### Preparatory workshop (Step 1)

Identifying seeds: Building on the premise that visions of the future will need to leverage what exists in the present, we began by identifying "seeds" that could contribute to more desirable futures for coral reefs. According to Bennett et al.[18], seeds are "*initiatives (social, technological, economic, or social-ecological ways of thinking or doing) that exist, at least in prototype form, and that represent a diversity of worldviews, values, and regions, but are not currently dominant or prominent in the world.*" These seeds experiment with novel social-ecological configurations, generating practical and contextualized solutions and providing innovative, bottom-up visions to redirect unsustainable trajectories.

Before the workshop, we invited all participants to submit seeds they believed were important starting points for building desirable coral reef futures. A total of 31 submissions were received and analyzed by the facilitation team to ensure thematic diversity and eliminate overlap. Each seed was categorized by geographic region and according to social, technological, economic, environmental, political, and values dimensions (i.e., STEEP-V framework). As there was overlap in some seeds, some were combined, which resulted in a refined list of 23 seeds.

To ensure seeds balance distinct nature futures perspectives, we used the NFF (https://www.naturefuturesframework.org/). The NFF is a flexible tool that captures diverse, positive values for human-nature relationships in the form of a triangle where corners represent distinct ways of valuing nature: Nature for Nature (NfN), Nature for Society (NfS), and Nature as Culture (NaC)[25]. The NfN perspective recognizes nature's inherent value, emphasizing species diversity, ecosystems, habitats, natural processes, as well as nature's ability to function autonomously. The NfS perspective highlights the practical benefits nature provides to humans, focusing on its

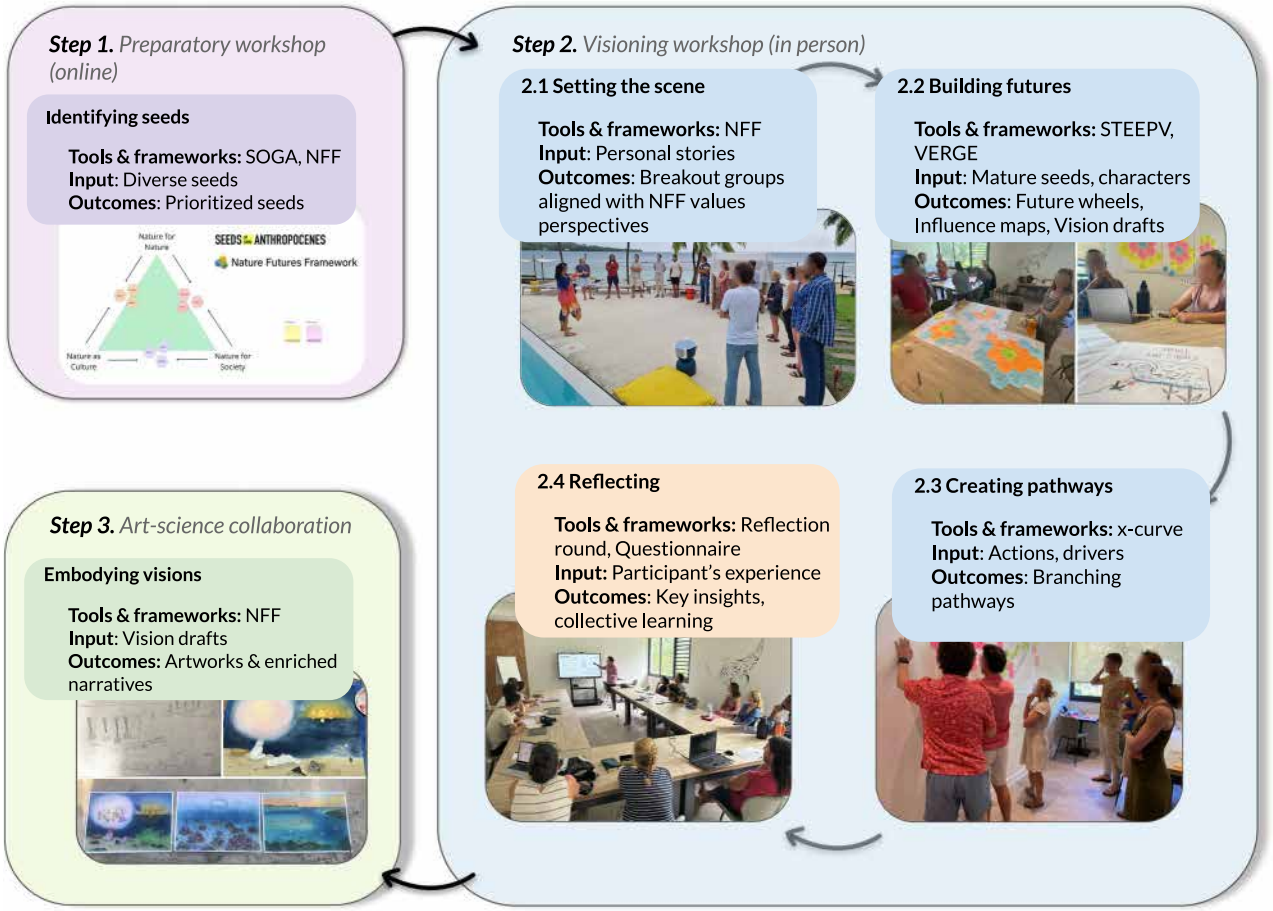


**Fig. 6 | Flow of the visioning process.** It includes the online preparatory activities, the in-person visioning workshop, and the art-science collaboration. FWs Frameworks, SOGA Seeds of Good Anthropocenes, NFF Nature Futures Framework, STEEPV Social, Technological, Economic, Environmental, Political, and Values, and VERGE Vision, Experience, Relationships, Governance, and Economy.

instrumental value to people and societies. The NaC perspective underscores the deep connections between nature and human cultures, traditions, and beliefs, illustrating the relational values shaping biocultural landscapes. Based on seed characteristics, the facilitating team positioned the 23 seeds within the NFF triangle, distributing them across the space defined by these three value perspectives.

In an online workshop held before the in-person workshop (8th of July, 2024), participants who were keen to contribute to the process but who could not attend the in-person workshop reviewed the list of seeds, reflecting on two key questions: (1) Do you agree with the placement of each seed on the NFF triangle? and (2) Are there additional seeds that should be considered to address any identified gaps? The panel prioritized seeds by voting and selecting three seeds for each side of the NFF triangle (i.e., NfN-NaC, NfS-NaC, NfS-NfN). The facilitation team then envisioned what each seed could become in its fully developed form and shared these refined versions with the online group for further feedback. The outcome was a subset of nine seeds, developed by prioritizing, combining, or enhancing seeds with missing elements that address broader systemic issues (Supplementary Material and Table S1).

### Visioning workshop (Step 2)

The visioning workshop was held in-person in Moorea, French Polynesia (July 29–August 2, 2024).

Step 2.1 (Setting the scene): As an icebreaker activity, the three corners of the NFF were mapped out on the floor and then each participant was asked to think of an instance where they value coral reefs and then to find a place somewhere in the NFF triangle that best represented the value perspective of this memory. They then shared this experience with nearby participants thereby unpacking the various value perspectives. This exercise facilitated an initial exchange of perspectives and, by clustering participants into nearby groups, formed three smaller groups alongside the NFF triangle for the remainder of the workshop. Each group represented a unique combination of nature perspectives, supporting the development of pluralistic visions for coral reef futures.

Step 2.2 (Building futures): The visioning method followed the Seeds of Good Anthropocenes Manoa Mash-up method[59]. Each group created Future Wheels with their mature seeds as the starting point. Future Wheels, akin to a collaboratively brainstormed mind map, allowed participants to identify primary, secondary, and tertiary impacts of specific changes or developments that could arise from that future condition. To generate ideas that could help nurture desirable futures, participants were encouraged to focus exclusively on positive impacts. When concerns about potential negative impacts arose, one of two strategies was applied. Whenever possible, these concerns were reframed into positive or mixed outcomes. When reframing was not feasible, the negative impacts were documented and revisited in subsequent stages of the process. Participants considered various dimensions based on the STEEP-V framework, ensuring a comprehensive mapping of potential impacts (Fig. S1). Once the consequences of the three seeds were mapped separately, the groups "clashed" their three Future Wheels together to start combining the different elements examining synergies and trade-offs (Figs. S2–S4). Participants identified reinforcements, contradictions, surprising possibilities, and counterintuitive

outcomes, embodying these insights using strings to create connections across three wheels, resulting in an influence map. Following the exercise, participants reflected on the results to trace implications into the distant future, developing emerging narratives and storylines. They then generated news headlines and/or statistics to encapsulate their findings, as well as preliminary working group names that started to forge a group identity.

Each group then started to draft vision skeletons focused on desirable futures. They employed the Ethnographic Future framework (a.k.a. VERGE) as a guide[60], using sticky notes to address key guiding questions and thus outlining a vision for these futures. The framework encompasses six domains of human experience: Define, Relate, Connect, Create, Consume, and Destroy. Facilitators translated these domains into guiding questions to help participants explore how people experience the world being co-created in situ. For example, questions included: What do people value? What does it mean to have a good life? (a full list of guiding questions is available in the Supplementary Material and Table S2). Although not all VERGE questions were explored, every domain was addressed. To further enrich the aspirational visions and stimulate creativity, each working group was assigned three distinct characters from previous ocean-related visioning projects[19] to weave into their storylines. Participants were encouraged to use elements such as a "day in the life" of a character, relevant news events, dates, and significant occurrences to develop these narratives. Working groups focused on drafting first-generation storylines that incorporated up to two of the assigned characters, integrating them with the key elements identified in their aspirational visions. By the end of the session, each working group shared their stories. By this stage each group had started on their creative process, some made use of Chat GPT to help with their creativity while others began sketching ideas and timelines to visualize or add to the stories. Later, each group presented their visions in plenary, using different resources to complement the narrative. For example, one group used a Haiku (a seventeen-syllable Japanese poem, often about natural wonders) as a preamble to their performance, while another group complemented their story with a booklet of handmade drawings that embodied each scene depicted in the story.

Step 2.3 (Creating pathways): Pathways towards desired futures were first mapped using the x-curve[61], a simple graphical tool used to map the transition from the current state to desired futures. To do this, we used a large white sheet with an x-curve drawn on it and colored sticky notes to distinguish between elements that need to fade out and those that need to emerge. Firstly, the potential actions and solutions that could foster more sustainable practices, behaviors, and mindsets - retrieved from the breakout group work and brainstormed in plenary - were added as green sticky notes, contributing to the emerging patterns and building up the x-curve (Fig. S5). Next, the challenges, drivers, and threats facing coral reefs were collectively identified, clustered, and added as red sticky notes into the x-curve, representing patterns that needs to break down. Lastly, participants matched red and green sticky notes thematically to graphically illustrate how elements in the x-curve can be linked (Fig. S5).

Using this as a foundation, key anticipatory actions that would help maintain trajectories aligned with the visions were identified, along with critical branching points (i.e., moments of opportunity, major societal decisions, major shocks within the narratives). These were marked with different types of sticky notes on the x-curve. Through this process, multiple branching pathways began to emerge, reflecting variations among the envisioned futures. The method of constructing branching pathways to link the three narratives together with interventions over time drew on the process outlined in Pereira et al.[62]. However, it introduced a novel contribution by identifying key interventions that needed to be made not just to orient towards a particular endpoint, but also to avoid tipping points that could lead to worse states.

The final step in building the pathways involved deliberating on specific actions that diverse actors could take over the next 5–10 years that would be needed irrespective of the pathway to strengthen governance systems that could enable more just and sustainable outcomes. The branching pathways presented in Fig. 5 provide a conceptual synthesis of the process described above and further illustrated in Fig. S5.

Step 2.4 (Reflecting): To close the workshop, participants engaged in a collective reflection round, sharing how they experienced the process, what surprised them, and what they learned. This was also an opportunity to consider the outcomes in relation to their individual initial expectations. Additionally, participants were encouraged to reflect on how elements of the process and its outcomes could be incorporated into their daily activities and professional practice. The session concluded with a collective brainstorming exercise to identify concrete ways to move forward together.

A voluntary and anonymous survey was circulated among participants to gather feedback on the process and outcomes, including the narratives and visions (Table S3). It included a mix of closed and open-ended questions aimed at capturing participants' initial thoughts, their learning experiences during the workshop (e.g., revelations and challenges), and their perceptions of the relatability and applicability to their roles as researchers, their organizations, or ongoing efforts, as well as their comfort level with the methods and outcomes (Figs. S6 and S7).

Open-ended responses were deductively analysed by the first author to identify: (i) participants' baseline perspectives on coral reef futures prior to the visioning process; (ii) ontological and epistemological challenges encountered during the exercise; and (iii) the potential of the visioning experience to catalyze individual and collective shifts such as increased motivation, inspiration, new perspectives, enhanced agency, or the shedding of entrenched beliefs about the future.

### Art-science collaboration (Step 3)

The vision skeletons developed during the workshop were analysed to identify key elements shaping overall the narrative, including structure, point of view, tone, and characters within the plot. Subsequently, the analysis examined specific settings, scope, time horizon, and key events or shocks that drive the narrative forward. Building on these vision skeletons and identified elements, a subset of co-authors—including experts in science-fiction prototyping—iteratively refined the visions to make them more textured, holistic, compelling, and engaging[31], resulting in the foundation for the art-science collaboration (i.e., first-generation storylines).

Embodying visions: To identify a suitable artist collaborator, we conducted a global search for creators whose work is closely connected to the ocean, who reside in a coral reef country, and who have demonstrated experience in storytelling. From this process, twelve artists were shortlisted. A subset of the authors then ranked these artists based on their portfolios and perceived fit with the project. Six artists were subsequently contacted, and four of them were available and agreed to participate in online interviews. The final selection was based on prior experience with art–science collaborations, willingness to engage in a horizontal collaboration rather than a commissioned arrangement, and the overall level of interest and engagement expressed during the interviews. Kim Yip Tong (https://kimyiptong.com/), a multidisciplinary creator from Mauritius who works across both analog and digital media, was selected for embodying the visions.

A 5-month collaboration was planned between the artist, the first author, and the subset of co-authors engaged with the first-generation storylines. Importantly, everyone agreed that the art-science collaboration should ensure creative freedom while maintaining internal coherence with the vision skeletons. To do so, the collaboration included multiple meetings to share project goals and align expectations, and research on the artist's side to familiarize with the process and first-generation storylines. Before the sketches were drafted, the first-generation storylines were critically reviewed by the artist and the first author to challenge assumptions and stereotypes, test the internal coherence of the narratives, and enhance their depth and consistency. Throughout this iterative process, two visions (*Project Reefoir* and *The Bay Revolution*) were moderately refined and adjusted, while for *Reeftopia*, a complementary storyline was developed to precede and introduce the narrative element created during the visioning workshop (the constitution of *Reeftopia*). The final storylines were

circulated among all co-authors for feedback and approval (Supplementary Material).

During the artwork production phase, which involved exchanging ideas and developing pencil sketches, particular attention was given to incorporating the artist's lived experience as an islander from Mauritius. This perspective also informed reflections on aspects such as how materials might be sourced within the envisioned futures. The visions were embodied in three watercolor paintings (42.0 × 59.4 cm), which were digitized in several formats. Motion was added to the digital versions to highlight key elements of each vision: coral spawning in *Reeftopia*, sailing communities in *Project Reefoir*, and wind in *The Bay Revolution*.

Although logistical constraints required implementing the art–science collaboration as an art commission, in practice, it evolved into a genuinely horizontal partnership (reflected in the co-authorship) in which the artist was deeply involved in rewriting narratives, integrating lived experiences, and embodying the envisioned futures. Importantly, both the final narratives and artworks remained faithful to the outcomes of the visioning workshop while allowing the artist to fully stand behind the creative expression.

### Analysis of visions and narratives

To unravel visions, we used various dimensions (framed as polarized axes) contrasting current dominant economic, governance, and cultural structures, or undesirable outcomes like collapsed ecosystems and dystopian societies, on one end, with radically different, transformative states on the other. These dimensions, along with their contrasting extremes, are grounded in existing approaches used to build[34] and/or categorize scenarios[31–33]. Disentangling the stories through these dimensions helped to (i) identify commonalities and tensions, thus providing an overall sense of how similar or dissimilar the visions are, and (ii) to situate stories along a continuum, from a conformist stance that maintains existing social-ecological systems to a reformist outlook that envisions futures markedly distinct from the present.

## Data availability

Data is provided within the manuscript or Supplementary Material files.

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## Author contributions

I.G., J.C., and L.P. conceptualized and designed the study. I.G., J.C., V.B., and L.P. facilitated workshops and developed the first draft of the manuscript. G.N.A., N.C.B., T.B., E.S.D., D.G., G.G.G., J-B.J., S.D.J., M.K., R.S., R.A.T., J.W., R.A.M., J.B., T.C., J.S.G., A.M., and A.V.N. contributed to writing and reviewing the manuscript. I.G., K.Y.T., A.M., and L.P. developed the full storylines with input from all authors. K.Y.T. created the artworks displayed in Figs. 1, 2, and 3. J.C. and L.P. funded the study. All authors participated in in-person and online workshops, reviewed, and approved the submitted version.

## Competing interests

R.S. is an editor-in-chief (co) and J.B. is an associate editor.

## Additional information

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**Correspondence** and requests for materials should be addressed to Ignacio Gianelli.

[1]CNRS, PSL-EPHE-UPVD, CRIOBE, Maison de l'Océan, Paris, France. [2]Global Change Institute, University of the Witwatersrand, Johannesburg, South Africa. [3]Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden. [4]Ocean & Climate Platform, Paris, France. [5]Ocean Conservation, World Wildlife Fund, Washington, DC, USA. [6]School of Environmental Studies, University of Victoria, Victoria, Canada. [7]CNRS, PSL-EPHE-UPVD, CRIOBE, Papetoai, Moorea, French Polynesia. [8] Global Marine Program, Wildlife Conservation Society, Bronx, NY, USA. [9]Duke Marine Laboratory, Nicholas School of the Environment, Duke University, Beaufort, NC, USA. [10]College of Arts, Society and Education, James Cook University, Townsville, QLD, Australia. [11]Centre for Marine Socioecology, Institute of Marine Science, University of Tasmania, Hobart, TAS, Australia. [12]School of Geography, Planning, and Spatial Sciences, University of Tasmania, Hobart, TAS, Australia. [13]Center for Ocean Solutions, Stanford University, Stanford, CA, USA. [14]ENTROPIE, IRD, IFREMER, CNRS, University of Reunion, University of New Caledonia, Nouméa, New Caledonia. [15]Station Marine d'Endoume, Marseille, France. [16]Fisheries Economics Research Unit, Institute for the Oceans and Fisheries and the School of Public Policy and Global Affairs, University of British Columbia, Vancouver, BC, Canada. [17]Environment and Sustainability Institute, Penryn Campus, University of Exeter, Cornwall, UK. [18]Chico Mendes Institute for Biodiversity Conservation, Brazilian Ministry of the Environment and Climate Change, Brasilia, Brazil. [19]Environmental Sustainability Research Centre, Brock University, St. Catharines, ON, Canada. [20]Department of Biodiversity, Conservation and Attractions, Kensington, WA, Australia. [21]School of Molecular and Life Sciences, Curtin University, Perth, WA, Australia. [22]Future Earth, c/o Royal Swedish Academy of Sciences, Stockholm, Sweden. [23]Visual Artist, Tamarin, Mauritius. ✉e-mail: ignacio.gianelli@ephe.sorbonne.fr; ignaciogianelli@gmail.com