Discover Oceans

Perspective

Forethoughtful coral nurseries: alleviating climate change impediments on the reefs of tomorrow

Baruch Rinkevich[1]

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Abstract

As global reef degradation continues, researchers and managers are increasingly adopting active restoration and ecological engineering approaches to mitigate coral loss and support recovery. One of the most widely used coral restoration methods is "coral gardening", which involves collecting small coral fragments, cultivating them in mid-water floating nurseries, and later transplanting them onto degraded reefs. Over time, floating coral nurseries have evolved beyond their original purpose of coral propagation, now serving as innovative tools to mitigate climate change impacts on reefs. This shift has led to the development of "Forethoughtful Coral Nursery" (FCN), each designed with specific objectives beyond coral transplantation. Five distinct FCN types have been identified: (1) Assisted Genetics – transforming traditional mid-water coral nurseries into larval dispersion hubs to seed degraded reefs with propagules; (2) Assisted Connectivity – applying the stepping-stone concept in reef restoration by establishing chain of mid-water nurseries between disconnected reefs; (3) Assisted Biodiversity – using coral nurseries as genetic repositories, preserving coral species and associated biota; (4) Carbon Sequestration Facilitation – adapting mid-water nurseries to function as CO_2 sinks, with the potential for conversion into carbon credits; and (5) Assisted Economy – utilizing nurseries for commercial purposes (e.g., the aquarium trade, bioactive compound extraction, tourism), education, and research. While some of these FCN concepts are still in the proof-of-concept stage, they hold promise as practical tools for reef management. Positioned at the intersection of ecological, societal, and economic challenges, these innovative approaches warrant further scientific exploration and integration into conservation strategies.

Keywords Coral nursery · Reef restoration · Climate change · Reef of tomorrow · Novel ecosystem

1 Introduction

Coral reefs, essential for biodiversity and human well-being, are rapidly declining due to climate change and human activities, with projections indicating enhanced deterioration in the coming decades [1–5]. This degradation of coral reefs worldwide has already advanced to a stage where local conservation efforts and natural recovery mechanisms are no longer sufficient to protect and restore even current biodiversity [5, 6]. Given the challenges of limited natural recovery, low rates of sexual recruitment and poor recruit survivorship, researchers and managers are turning to active reef restoration and ecological engineering approaches as preferred strategies to support the recovery of damaged or depleted coral populations [1, 5, 7]. While active restoration is well-established in terrestrial and some marine ecosystems, coral reef restoration remains in its

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✉ Baruch Rinkevich, buki@ocean.org.il | [1]Israel Oceanographic & Limnological Research, Tel Shikmona, National Institute of Oceanography, PO Box 9753, 3109701 Haifa, Israel.

early stages, highlighting the need for effective, cost-efficient strategies and collaboration among scientists, practitioners, and stakeholders [5, 7, 8].

"Coral gardening" is currently one of the most widely used methods for coral propagation and restoration [5, 9–13]. Inspired by terrestrial silviculture, it involves collecting small coral fragments, from healthy wild populations or corals-of-opportunity, and cultivating them in in situ or ex situ nurseries. These nursery-grown corals provide a sustainable stock for transplantation onto degraded reefs using various attachment techniques [5, 7, 9, 13–15]. Encouraged by successful outcomes, coral nurseries are being increasingly established at reef sites worldwide, ensuring a steady supply of coral colonies for restoration efforts. Originally developed in the Red Sea [9, 13, 15, 16], coral gardening has now expanded significantly across the Indo-Pacific, Africa, eastern tropical Pacific and western Atlantic regions [17–21], and more recently, in the Great Barrier Reef, Australia [22, 23]. Over the past two decades, coral nurseries have demonstrated high survival rates and rapid coral growth, allowing for cultivating genetically diverse nursery stocks. As a result, hundreds of thousands of corals, representing more than 100 species, have already been propagated and transplanted onto degraded reefs, contributing significantly to global coral reef restoration efforts.

Coral gardening has proven to be more successful than direct coral transplantation, because it reduces risks and costs associated with mechanical damage during pruning, predation, and competition for space. By allowing coral colonies to grow in a controlled nursery environment, they reach larger sizes and healthier conditions before being transplanted, increasing their chances of survival [24, 25]. Research has demonstrated that propagating coral fragments on suspended mid-water nurseries can result in increased survival rates (up to 97.5%), enhanced coral growth, and reduced predation [18]. Two main types of coral nurseries have been explored: bottom-attached nurseries and mid-water floating nurseries [9, 12, 13, 16, 19–21, 26–28]. Among the latter floating rope nurseries have gained particular attention [12, 26, 29], as the entire nursery system, including the ropes and corals, is outplanted, reducing the need for individual coral outplanting. While floating nurseries require more maintenance and effort to construct, they offer significant advantages over bottom-attached nurseries, providing a more adaptable and efficient method for coral mariculture in five key aspects [7, 13, 15, 16, 26–28, 30–35]:

1. Water Flow – Mid-water nurseries benefit from stronger water movement, which improves the supply of plankton to the coral colonies, enhances oxygenation, and helps remove mucus from coral tissues.
2. Nursery Movement – Unlike stationary bottom nurseries, floating nurseries move with the water column, promoting better water exchange and reducing debris accumulation on the corals.
3. Sedimentation – Corals in bottom nurseries are exposed to varying levels of sedimentation, which can hinder growth and cause tissue abrasion. In mid-water nurseries, corals are positioned higher in the water column, significantly reducing sediment buildup.
4. Light (PAR) Spectrum – Floating nurseries allow for depth adjustments to optimize light exposure for different coral species, ensuring they are acclimatized to the light conditions of their eventual transplantation site.
5. Reduced Stressors – Placing floating nurseries away from natural reefs minimizes exposure to coral predators, human disturbances, and recreational impacts. Yet, the planktonic recruitment of coralivorous fish, invertebrates (e.g., *Drupella cornus*) and algae remains a challenge.

The gardening approach to reef restoration initially emerged as a targeted restoration tool, with various types of floating nurseries designed primarily for mariculture, providing healthy coral colonies suitable for reef restoration [7, 9, 11–13, 15, 16, 26]. Over time, these floating coral nurseries have evolved to serve additional functions beyond their original role of providing corals for outplanting in degraded reef areas. These innovative floating structures are now designed to address broader objectives and may serve as novel tools to mitigate the impacts of climate change on future reefs (when successfully employed). Below, five such approaches (hereby termed as “Forethoughtful Coral Nurseries”) are outlined, where the novel objectives of these floating devices are strategically defined in advance, differentiating them from the traditional goal of coral transplantation.

2 Assisted genetics

Within-species genetic diversity is primarily maintained through sexual reproduction. In stony corals, this process follows two major reproductive strategies: brooding, where fertilization occurs internally and larvae are directly released, and broadcasting, where fertilization is external, with eggs and sperm released into the water column. In both cases, the resulting planula larvae settle and integrate into the reef community, with all subclones (ramets) derived from a single fertilization event, whether through budding or fragmentation, collectively forming a coral genet.

As coral reef restoration continues to expand globally, integrating population genetics into restoration efforts is becoming increasingly important [36–39]. Most reef restoration initiatives rely on asexually derived coral colonies (created from nubbins or small coral fragments), a practice that, over time, may reduce genetic diversity and limit the adaptive potential of future coral populations. In contrast, sexual reproduction is crucial in maintaining genetic variation, preserving allelic diversity, and enhancing the resilience of restored coral communities [36, 37, 40]. One strategy for managing genetic diversity in restoration involves identifying and culturing genets with rare haplotypes for transplantation. These genets have low average kinship with the population, helping to maintain genetic variation without requiring detailed pedigree information, which is typically unavailable for corals [37]. Yet, although quantifying and monitoring genetic diversity remains resource-intensive, studies suggest that a representative sample of 15–35 different genotypes is sufficient to capture over 90% of a local coral population's genetic diversity (performed on different coral species [40, 41]).

Sexual propagation in corals can generate vast numbers of genetically unique colonies. Coral nurseries have already been employed to enhance sexual reproduction through two primary methods. The first involves growing coral colonies to the larval release stage and collecting larvae on the nursery bed for outplanting through ex situ or in situ rearing [42–45]. The second approach relies on nursery-farmed gravid colonies that release gametes or larvae after being transplanted to restoration sites, thereby maximizing genetic diversity [45–52]. A long-term study demonstrated that nursery-grown transplants exhibited increased larval release, with a higher proportion of gravid colonies over seven years, spanning eight reproductive seasons post-transplantation [51, 52]. This sustained enhancement in larval production suggests a lasting influence of nursery conditions on transplanted corals' fitness and ecological traits.

A novel assisted genetics approach within the framework of 'Forethoughtful Coral Nursery' may transform the traditional coral colonies maintaining mid-water coral nursery into a 'larval dispersion hub' (Fig. 1a; [53]). In Eilat, Gulf of Eilat, Israel, researchers cultured *Stylophora pistillata* colonies in a floating nursery where after two years, farmed colonies produced approximately 35% more oocytes per polyp than naturally field growing, five-year-old colonies of similar sizes. Additionally, nursery-raised planulae contained more endosimbionte algae, exhibited higher chlorophyll levels per planula, and developed into faster-growing young colonies compared to their reef-grown counterparts [53]. Estimates suggest that a 10 × 10 m mid-water nursery, when strategically positioned upstream of a reef during the reproductive season, could release tens of millions of planula larvae, effectively functioning as a larval dispersion hub. This innovative approach offers a powerful management tool and shifts the focus from traditional coral transplantation to large-scale larval seeding, offering a powerful management tool for enhancing natural coral recruitment (Fig. 1a). By identifying distinct ecological traits between early- and late-season released larvae ([54] *e.g.*, early season *S. pistillata* larvae disperse farther than late-season propagules), reef seeding can be strategically fine-tuned to target either nearby or distant reefs.

3 Assisted connectivity

Most coral reef organisms have a complex life cycle, consisting of site-attached demersal adults and dispersive pelagic larvae. Unlike terrestrial environments, this process in marine ecosystems primarily occurs through the dispersal of planktonic propagules [57, 58]. Consequently, connectivity between reef populations is largely driven by larval dispersal, which can range from a few meters to hundreds of kilometres. Generally, connectivity between subpopulations is expected to increase as the distance between them decreases. Several key factors influence larval dispersal and settlement, including pelagic larval duration, ocean currents, larval behavior (such as vertical migration, swimming ability, and orientation toward reefs or environmental cues), dispersal trajectories, reproductive output, survival rates, and habitat availability [57, 59]. Given that highly connected biological networks improve biological resilience in complex ecosystems [59], interest in biological connectivity in the coral reefs centers on the movement of individuals and/or their genetic material (gonads, larvae) between populations, shaping both, local population dynamics and the broader population networks [60].

Coral reef ecosystems are influenced by various environmental factors, such as temperature, ocean currents, water chemistry, sea level, storms, and abnormal climatic events like El Niño Southern Oscillation (ENSO). Climate change and human activities significantly alter these conditions, disrupting biological connectivity by affecting species distribution, reef community structures, and ecological processes [57, 60, 61]. In recent years, biological connectivity has become a critical component of spatial conservation planning, complementing traditional efforts that focus on species persistence and habitat quality [62]. Connectivity is a dynamic continuum, where populations

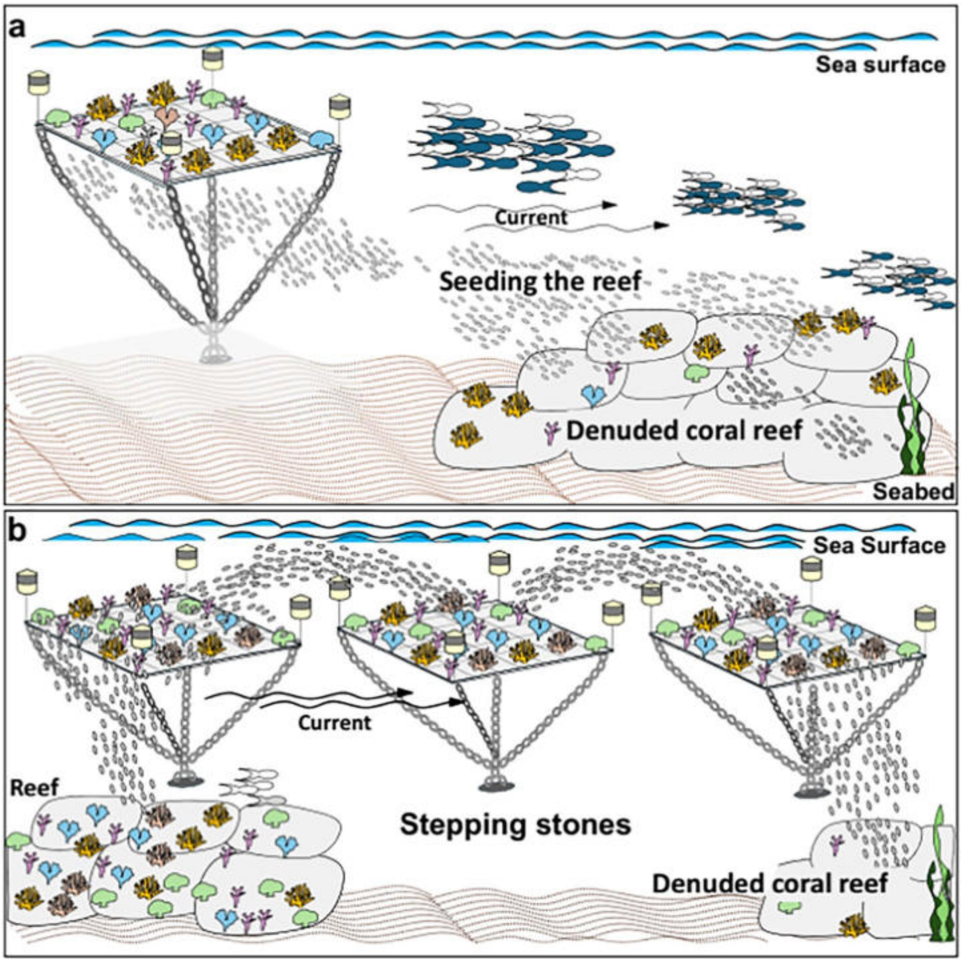

Fig. 1 A schematic illustration for two "Forethoughtful Coral Nurseries" types depicting non-traditional functions. (**A**) Seeding the reef (assisted genetics) approach; (**B**) Stepping stone (assisted connectivity) approach (following [55, 56])

are intermittently linked through temporally limited events [60]. Consequently, restoring lost ecological connectivity, or creating new pathways between fragmented and deteriorating habitats, has become a priority for resource managers and conservation decision-makers [57, 61].

One approach to restoring marine connectivity involves establishing "stepping-stones," as discrete habitat patches that facilitate the movement and dispersal of marine organisms across otherwise isolated areas. These stepping-stones serve as crucial corridors for migrating larvae of sedentary species and juvenile fish, enabling them to traverse between larger habitat areas over multiple generations [63, 64]. Such structures provide temporary refuge, feeding grounds, and breeding sites, particularly benefiting species with limited dispersal capabilities, allowing species to migrate between disconnected areas over multiple generations [64]. Networks of hard-bottom reef sites, including natural reefs, artificial reefs, shipwrecks, offshore infrastructure, energy platforms, and intentionally scuttled structures, act as long-term homogenizers of coastal biota by promoting connectivity across various depths and distances [59, 63–65]. These structures function as vital links within a chain of stepping-stones, supporting settlement and subsequent larval production, ultimately facilitating species dispersal between fragmented habitats [63, 64]. By maintaining gene flow, sustaining biodiversity, and enhancing ecosystem resilience, stepping-stones are essential in conservation and restoration strategies, helping to reconnect disrupted marine environments [59, 63–65]. Yet, robust hydrodynamic models and a thorough understanding of local water flow patterns are essential for coral nurseries to effectively serve the purpose of facilitating assisted connectivity. These benefits can be further amplified by integrating detailed knowledge of coral reproductive strategies [66, 67], along with the reproductive patterns of other reef-dwelling organisms.

The concept of using stepping-stones for reef restoration was initially proposed as a tool for rehabilitating degraded reefs in the Red Sea, via the protocol of coral transplantation in clusters to create stepping-stones nuclei of reef restoration for future 'spontaneous colonization' (also termed as 'protoreefs') [68, 69]. This approach was later adapted in Florida, USA, as part of an assisted migration project [70]. This study transplanted 50 coral fragments from five nursery-raised genets of the threatened elkhorn coral (*Acropora palmata*), across five sites spanning 350 km offshore reef, to enhance sexual reproduction and improve reef connectivity [70].

Combining coral gardening with reef restoration ecosystem engineering tools, a concept paper [55] has suggested a novel management approach (Fig. 1b) that utilizes a chain of nurseries as stepping stone links, replacing the traditional method of raising colonies for transplantation. It aims to create functional stepping stones between isolated reefs by strategically positioning floating mid-water nurseries in a series, facilitating the reconstruction or establishment of biological connectivity and new biological corridors. This assisted connectivity (Fig. 1b), thus, addresses the emerging needs to repair reduced connectivity, limited dispersal, and decreased larval replenishment, all resulting from the increasing fragmentation of reef habitats due to global reef degradation. A real-world example of this concept can be seen in the northern Gulf of Mexico, where offshore oil and gas platforms serve as stepping-stones, facilitating coral expansion and bridging connectivity gaps between distant reef systems [71]. A similar approach has also been applied to degraded coastal wetlands in the Baltic Sea, where the construction of floating wetlands has successfully enhanced habitat connectivity for transient aquatic species [72]. These examples highlight the potential for innovative ecological engineering solutions to mitigate habitat fragmentation and promote biodiversity conservation in marine environments.

4 Assisted biodiversity

Active coral restoration, including the establishment of coral nurseries, is a widely implemented strategy for rehabilitating degraded reef areas and enhancing the resilience and adaptability of coral reef ecosystems in response to increasing anthropogenic pressures and climate change [1, 8, 11, 17, 18, 20, 23, 25, 29, 39, 55, 57]. While current reef restoration initiatives and traditional conservation measures, such as marine protected areas, can mitigate some human-induced and climate-related stressors, their effectiveness in halting reef decline remains limited. The escalating and widespread impacts of environmental change continue to drive biodiversity losses, leading to the extinction of rare, endangered, and cryptic species, and ultimately reducing population genetic diversity [73]. Alternative conservation strategies, such as zoos and public aquariums, have been proposed for long-term marine biodiversity management. These institutions can play a crucial role in ex situ breed-for-release programs and serve as instrumental contributors to the establishment of wildlife biobanks [74, 75]. Biobanks involve the collection of cryopreserved living cells, while advancements in reproductive technologies offer promising avenues for wildlife conservation [76]. In this context, the cryopreservation of gametes, coral tissues, or individual cells has been explored as a potential method for preserving the genetic diversity of reef organisms [73, 76–79]. Properly stored cryopreserved coral cells and gametes are believed to remain viable for years or even centuries without experiencing DNA degradation. However, despite its promise, this approach is still in the early stages of development, with current research lacking evidence of its long-term efficacy beyond two years [78].

This novel 'Forethoughtful Coral Nursery' approach suggests that coral nurseries may serve as repositories for genetic material (either for species or genotypes within a species; Fig. 2a, b) [16, 55, 56, 80], that would have otherwise been lost from reef sites. This concept was introduced over a decade ago [81] in response to an unexpected cold-water event along the Florida Reef Tract. Following this event, sites that had suffered complete mortality of *Acropora cervicornis* populations still contained surviving coral fragments within in situ coral nurseries. In this case, the strategic placement of coral nurseries in deeper habitats, away from shallow nearshore areas that experienced extreme temperature fluctuations, provided a buffer against the cold-water event. As a result, crucial local genotypes were preserved, offering a valuable genetic reservoir for future restoration efforts [81].

Coral nurseries have the potential to serve as extensive living biodiversity repositories, surpassing the genetic stock preserved in captive breeding programs, parks, and zoos. Unlike terrestrial tree nurseries, which remain isolated from their surroundings, floating coral nurseries are fully immersed in the open marine environment, initially devoid of reef-associated organisms but soon attracting larvae from a wide range of fish and invertebrate species [84, 85]. These include cnidarians, sponges, tunicates, mollusks, echinoderms, crustaceans, polychaetes, and many more, both sessile and mobile organisms (Fig. 3a–d) [13, 16, 80, 81, 84, 85]. Once settled, these organisms undergo metamorphosis and maturation within the nursery, gradually transforming into a thriving, self-sustaining floating reef—an oasis amid nutrient-poor tropical waters [83]. This novel 'Forethoughtful Coral Nursery' concept has also been explored as a tool for assisted evolution in coral adaptation [39] resulting in an innovative approach for constructing future reefs populated by local reef-dwelling species [55]. As such, mid-water coral nurseries present a unique opportunity for biodiversity management, playing a dual role in the rehabilitation of degraded reefs while simultaneously acting as genetic reservoirs, functions that terrestrial nurseries are not designed to fulfill [55].

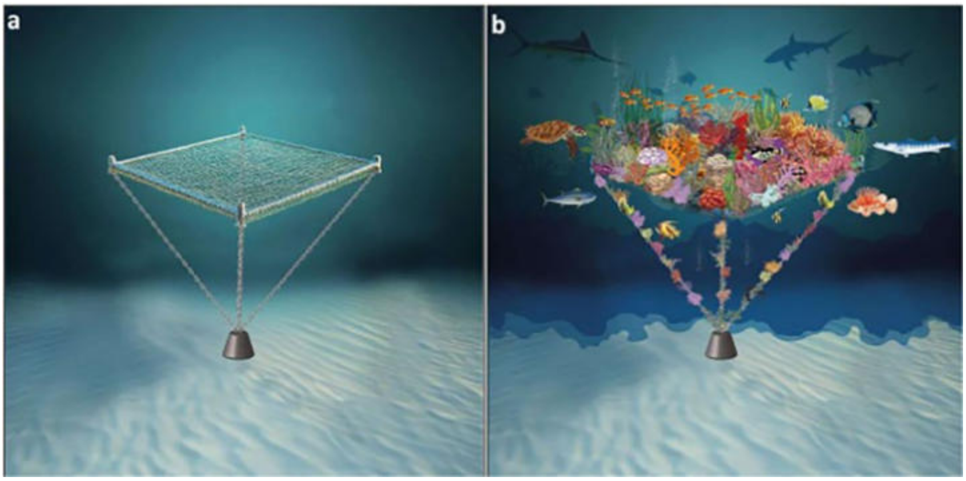

Fig. 2 An AI illustration for two 'Forethoughtful Coral Nursery' approaches that present (1) the establishment of biodiversity repository, and (2) an innovative marine animal forest apparatus that facilitates carbon sequestration and biodiversity enhancement. (**a**) an empty floating coral nursery before being populated by coral nubbins; (**b**) an established, presenting a floating, highly diverse reef situated in blue water (following [82, 83])

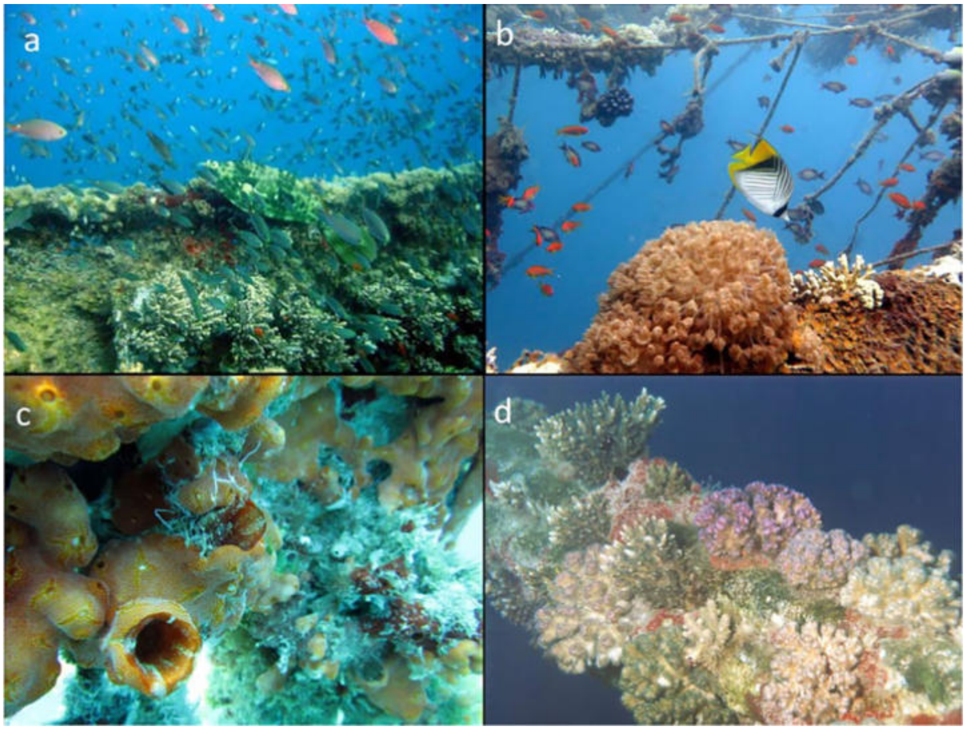

Fig. 3 The floating coral nursery in Eilat, Israel, is developing into an oasis reef in blue waters. **a**, **b**, **c** fish and invertebrate species recruited from the plankton; (**d**) coral colonies recruited from the plankton and settled on the nursey's construction

5 Facilitation of carbon sequestration

Recent studies [82, 83] have introduced the concept of carbon sequestration within mid-water nurseries that are situated in oligotrophic tropical waters, further referred to as Floating Reef Devices (FRDs). These structures support coral propagation and function as measurable blue carbon sinks (Fig. 2), effectively transforming traditional coral nursery practices into carbon-sequestering FRDs. This approach is based on two fundamental principles: (a) oligotrophic tropical waters are nutrient-poor, resembling marine deserts, and (b) the photosynthetic activity of coral symbiotic algae sustains the entire FRD system.

The formation of the FRD follows the coral gardening principle [5, 7, 39], where small coral fragments, initially containing minimal carbon, are cultivated in floating nurseries until they grow into large colonies. As discussed in Sect. 4, these floating nurseries function as open systems, attracting larvae from hundreds of fish and invertebrate species, which then develop into adults (Fig. 3). Over time, the nurseries transform into complex floating reefs, serving as thriving oases within the nutrient-poor tropical waters. Rather than being harvested for coral outplanting, these flourishing nurseries remain intact, gradually evolving into FRDs. Sustained primarily by the photosynthetic activity of symbiotic algae [82, 83], FRDs accumulate carbon in multiple reservoirs, including the skeletons of corals and other calcifying organisms, skeletal organic matrices, coral and algal tissues, the biomass of recruited fish and invertebrates, as well as the daily surplus of fixed carbon discharged as mucus and dissolved organic carbon.

A comprehensive overview of coral reef biogeochemical processes, including community metabolism, organic production, calcium carbonate precipitation, and long-term recalcitrant dissolved organic carbon export [82, 83], reveals that well-managed FRDs have the potential to function as CO_2 sinks, and that their metrics may be translated to carbon credits, reflecting the market value on CO_2 reductions [83].

6 Assisted economy

Coral reef organisms are invaluable sources of novel compounds and metabolites with applications in the pharmaceutical, agrichemical, cosmetics, antifoulant, and fine chemical industries [86, 87]. Additionally, corals and their associated species play a significant role in the ornamental trade [88]. However, searching for new marine natural products from these organisms largely depends on harvesting wild specimens, which presents sustainability and replicability challenges. Sustainability concerns stem from the substantial biomass required for drug discovery, which has historically led to negative impacts on reef ecosystems [89]. Replicability issues arise due to environmental variability, as the chemical composition of target organisms can fluctuate across locations and seasons, potentially resulting in the loss of viable sources [89].

Though not yet widely adopted, several studies [88, 90] have explored the potential use of coral nurseries for aquaculture in the ornamental trade and other commercial applications. These include (Fig. 4) innovative ecotourism concepts, such as using nurseries as tourist attractions, creating floating artificial reefs for divers [91], or placing them near resorts for vacationers. Additionally, coral nurseries could generate revenue through educational and research initiatives, such as cultivating coral fragments for scientific studies or academic research programs at various levels.

The economic valuation of traditional coral reef ecosystem services, such as fisheries, aquaculture, tourism, coastal protection, and cultural significance, is well-documented in the literature (e.g., [92, 93]). However, assigning economic value to emerging coral reef services remains challenging, as most efforts focus on restoring reef health rather than addressing evolving economic opportunities. Introducing economic and tradable rights specifically for the nursery phase, rather than solely for reef restoration, could help develop mechanisms that enhance environmental value while mitigating ecological

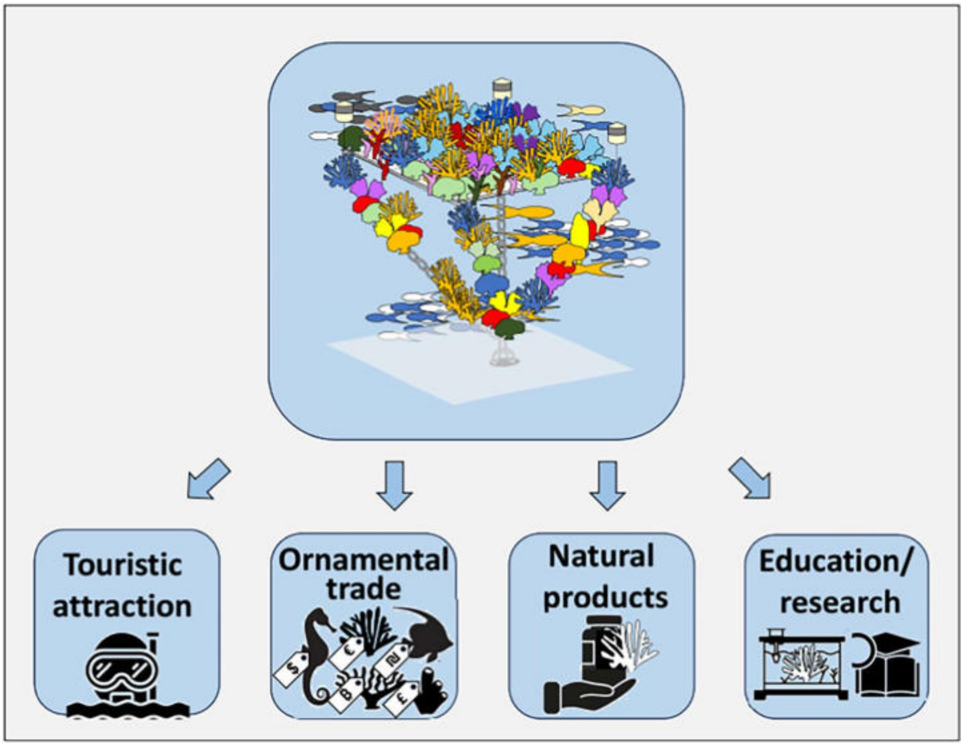

Fig. 4 A schematic illustration for the four major assisted economy sectors assigned to the FRD

and human-induced impacts [90]. Increasing recognition of the economic potential of environmental goods and services will drive greater efforts to capitalize on these assets and expand the utilization of coral nurseries' ecological benefits.

7 Epilogue

The gardening approach to reef restoration and in situ coral propagation methods [5, 9–13] are still in their early stages, with ongoing advancements aimed at producing large quantities of coral fragments more cost-effectively. While current propagation efforts cannot yet fully replace natural recovery or ensure complete reef recruitment, targeted propagation and restoration initiatives can still play a vital role in localized coral reef recovery. Within this approach, in situ nurseries are essential for coral propagation, as they accelerate coral growth and enhance the cost-effectiveness of restoration efforts [5, 9–15, 25, 27, 30, 56, 94], including enhanced sexual reproduction [51, 52]. The concept of "Forethoughtful Coral Nurseries", when successfully employed, expands beyond the traditional role of coral nurseries in coral propagation for reef transplantation. Instead, it encompasses innovatively designed nurseries with strategic, forward-looking objectives to address broader environmental and economic challenges.

Leveraging market- and environment-based incentive mechanisms through initiatives that utilize floating reef nurseries presents an innovative approach to reef restoration. This overview highlights five distinct types of "Forethoughtful Coral Nurseries," each serving a novel function: (1) assisted genetics, which repurposes traditional mid-water coral nurseries into 'larval dispersion hubs' (Fig. 1a [53]), (2) assisted connectivity, which applies the stepping-stone concept by linking mid-water nurseries in a strategic chain to restore reef connectivity (Fig. 1b [55]), (3) assisted biodiversity (the use of coral nurseries as repositories for genetic material (Figs. 2, 3 [16, 55, 56, 80]), (4) carbon sequestration, where mid-water nurseries function as CO_2 sinks with measurable carbon metrics that can be translated into carbon credits (Fig. 2 [82, 83]), and (5) assisted economy, where nurseries contribute material to the aquarium trade, facilitate the extraction of bioactive compounds from farmed organisms, serve as tourist attractions, and support educational and research initiatives (Fig. 4 [88, 90, 91]). These expanded roles of floating coral nurseries go beyond cultivating resilient corals for transplantation, addressing pressing ecological, societal, and economic challenges while opening pathways for broader applications.

Beyond their direct benefits, "Forethoughtful Coral Nurseries" may play a crucial role in shaping the Reefs of Tomorrow by enhancing the effectiveness of reef restoration methodologies and by providing additional potential economic sources. While additional types of "Forethoughtful Coral Nurseries" remain to be explored, and some of the five identified models are still in the proof-of-concept stage, their potential to influence reef management strategies is significant. However, as the costs of climate adaptation and mitigation continue to rise, it is essential to incorporate cost analyses of "Forethoughtful Coral Nurseries" into planning and decision-making processes. Similar to ecological engineering approaches [7, 25], these innovative nurseries contribute to reef functionality and resilience. As such, "Forethoughtful Coral Nurseries" are poised to become indispensable tools for addressing current and future environmental, societal, and economic challenges, warranting further scientific exploration.

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Data availability No datasets were generated or analysed during the current study.

Declarations

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Consent for publication Not applicable.

Competing interests The author declares no competing interests.

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