Queen conch aquaculture remains a conservation symbol and is not yet a fisheries solution

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Abstract Conservation aquaculture, defined as cultivating aquatic organisms to manage or replenish natural populations, has been advocated as a strategy to enhance fisheries production and help restore declining populations. Culture is especially compelling for species in steep decline and for which there is established methodology. The queen conch *Aliger gigas* is an example of a species with widely overexploited populations, with attempts to culture the species commercially ongoing for > 40 years. However, hatchery-releases have shown low survival from post-settlement to near maturity, leading to low conservation aquaculture potential. When this is viewed alongside large-scale fishery extractions, it is apparent that it is not commercially feasible to replace wild harvest nor ecologically feasible to replenish queen conch populations using existing aquaculture approaches. An age-based mortality model estimates the magnitude of culture required to replace a single adult of reproductive age. Extrapolations from catch–weight relationships highlight the scale of facilities and costs required to partially offset the harvest in a typical Caribbean fishery. Estimates of reproduction to achieve replacement suggest a greater yield from properly protecting natural breeding aggregations. Queen conch aquaculture is useful for scientific inquiry, community engagement and education, but not for stock enhancement or population restoration without more practical and cost-efficient options. Therefore, protecting breeding aggregations should be prioritized for the ecological viability of the species, as well as for its economic value for the people and industries that rely upon it.

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Introduction

For a long time, humanity's relationship with the ocean has been primarily extractive, and as wild-capture fishing practices have boomed and peaked, the majority of global fish stocks are now fully exploited or overexploited (McCauley et al., 2015; FAO, 2024). This has led to less productive ocean ecosystems, a situation further compounded by habitat degradation and climate change (Pauly et al., 2002; Rogers et al., 2019). Despite these declines, the ocean remains vital for the food security and livelihoods of millions of people. With careful planning, local fisheries management supported by international agreements can reverse the negative trajectories of marine species and ecosystems (Edgar et al., 2014; Duarte et al., 2020). For example, sustainable fishing practices and management can yield economic and ecological benefits in tandem with food security (Costello et al., 2016). Species conservation status assessments and international conventions can help highlight threatened species, protect local populations and control trade in threatened species, and conservation agreements can help nations commit to setting aside areas as marine managed areas focused on replenishing ecosystems (O'Leary et al., 2016). A combination of marine managed areas, local fisheries conservation tools, and controls on trade is needed to maintain livelihoods, food security and biodiversity. Marine aquaculture has also been suggested as an approach to enhance food security given global human population growth (Costello et al., 2020). The idea of a blue revolution reliant on mariculture instead of wild stocks is gaining traction, especially as capture fisheries peaked at the end of the 20th century (Pauly & Zeller, 2016).

Conservation aquaculture

Conservation aquaculture, defined as 'the use of human cultivation of an aquatic organism for the planned management and protection of a natural resource' (Froehlich et al., 2017, p. 1), is a strategy to help replenish natural populations. Here we include two categories of culture that could be considered conservation aquaculture: stock enhancement and restoration aquaculture. We define stock enhancement as releasing cultured individuals to supplement the populations of exploited species that face continued high fishing pressure, and restoration aquaculture as releasing cultured individuals to rebuild historically exploited populations of species that are now protected and face minimal fishing pressure.

The intentional release of cultured organisms into the ocean for stock enhancement dates from the early 1800s, with mixed positive and negative impacts on ecosystems, species and economic systems (reviewed by Kitada, 2018). Increasingly rigorous principles for responsible stock enhancement have been developed (Blankenship & Leber, 1995) and improved (Lorenzen et al., 2010). Guiding principles include grounding practices in basic knowledge of the species and fishery to facilitate realistic enhancement that is evaluated through scientific monitoring and assessment (Lorenzen et al., 2010). However, the global review of Kitada (2018) revealed that stock enhancement remains experimental for the majority of species and ecosystems. Furthermore, empirical assessments are typically missing and when present show a trend towards both ecological and economic failure (Kitada, 2018). For example, integrating stock enhancement with metapopulation modelling to create a self-sustaining reserve network for cultured shellfish, such as oyster, reveals the challenges of rebuilding an ecosystem, even when enhanced sites show clear demographic benefits within their boundaries (Puckett & Eggleston, 2016). Ecosystem condition is typically more important than aquaculture release (Kitada et al., 2019); thus, rebuilding habitats and effective controls on harvest should be in place prior to restoration aquaculture.

Restoration aquaculture aims to improve a damaged or diminished ecosystem, and its implementation in marine systems is typically for revitalizing foundational species (e.g. ecosystem engineers) for bottom-up benefits. These efforts are currently being employed on salt marsh, oyster reefs, seagrass, mangrove, kelp forest and coral reef habitats (Duarte et al., 2020). Coral restoration efforts blending culture and outplanting approaches have demonstrated some success; for example, outplanted coral populations in Japan have been observed spawning (Zayasu & Shinzato, 2016).

In some cases, natural populations have been reduced to such a low level that restoration aquaculture may be the only means to prevent extinction (Anders, 1998). Targeted enhancement of endangered species using conservation aquaculture remains problematic in marine ecosystems because of constraints on financial and technical resources, and degraded environments. Therefore, it is typically the action of last resort. For example, following the cessation of fishing in the 1990s, white abalone *Haliotis sorenseni* were expected to go extinct within 10 years without intervention (Hobday et al., 2001; NOAA, 2001). A restoration aquaculture programme took 19 years to rear, release into the wild, and monitor cultured white abalone juveniles (Rogers-Bennett et al., 2016). Likewise, time, money and effort has gone into the culturing of pinto abalone *Haliotis kamtschatkana*, with only 10% survival one-year post release (Carson et al., 2019; Dimond et al., 2022).

Importantly, stock enhancement and restoration aquaculture are typically posited as conservation strategies, but both become necessary because of failed management at local and international levels. Therefore, the industrial application of aquaculture as a fisheries solution has been recognized as a distraction from addressing the proximate causes of decline, typically poor management practices and degraded habitats (Meffe, 1992). Before implementation of new aquaculture outplanting programmes, techniques need to be established based on data from studies of long-term survival, functional equivalency, cost-effectiveness, and estimates of the impact on livelihoods and food security (Lorenzen et al., 2010). The uncertainty of success and cost of conservation aquaculture make the protection and management of wild populations critical, ideally before species approach a point at which further drastic intervention strategies are needed such as closing fisheries or restricting trade. However, conservation aquaculture still receives considerable attention and support as a means of repopulation despite the many well-documented barriers to successful in situ implementation (Glazer & Delgado, 2003).

Queen conch in decline

The queen conch, *Aliger* (formerly *Lobatus*, *Eustrombus* or *Strombus*) *gigas*, is a large herbivorous marine snail that was once common throughout the Caribbean, but populations have been greatly reduced by overharvest (Vaz et al., 2022). Queen conch primarily disperse during a pelagic larval phase and can potentially travel great distances (Vaz et al., 2022; reviewed by Stoner et al., 2023). Conch populations exhibit genetic isolation related to oceanic distance; thus, a careful blend of local and regional management is required to ensure connectivity among stocks (Truelove et al., 2017). After settlement, queen conchs spend c. 1 year buried as infauna during the day to avoid predation until they are big enough at c. 2 years of age (10 cm in length) to avoid fish gape limits (Iversen et al., 1986, 1990). Older individuals inhabit a variety of relatively shallow ecosystems, including seagrass, hardbottom and rubble, from where they are typically harvested by hand, using freediving or compressed air diving. Research on complex reproductive (reviewed by Stoner & Appeldoorn, 2022) and benthic recruitment ecology (reviewed by Stoner, 2003) demonstrates that the species requires minimum densities to maintain population fitness. Maintaining high abundances of a species that is relatively easy to exploit is a challenge for conch fisheries management (Prada et al., 2017). The decline in the queen conch abundance has been well documented as the species plays an important role in the lifestyle, heritage and economy of countries within its range, including The Bahamas where the consensus of fishers is that the population is decreasing (Kough et al., 2019). Despite decades of protection in Florida, USA, populations have been slow to recover from heavy exploitation and are hindered by depensatory breeding effects because low adult density inhibits spawning (Delgado & Glazer, 2020). The metapopulation structure of the queen conch has become fragmented as abundance has diminished (Vaz et al., 2022), which further hinders replenishment because larval sources become scarce and recruitment sporadic or eliminated by high fishing pressure (Kough et al., 2019).

The queen conch is included on CITES Appendix II and international trade is regulated (Prada et al., 2017). Although the species has not yet been assessed for the IUCN Red List, it was protected as a threatened species under the US Endangered Species Act in 2024 (NOAA, 2024). In some countries, conch exports have been banned, fisheries have been closed, are no longer viable or are increasingly at risk of failing (Stoner et al., 2019). The long-term ecological consequences of removing a major herbivore such as the queen conch from Caribbean marine ecosystems remain unknown (Tewfik, 2014); thus, strategies that reverse the trajectory of decline are of great interest for both fisheries and conservation.

Queen conch aquaculture reviewed

Since the early 1980s, considerable efforts have been made to raise juveniles from queen conch egg masses in captivity (Davis & Cassar, 2020), leading to many attempts to supply animals for food and for restocking. These aquaculture accomplishments have been reported by the media as a tool for the restoration and rebuilding of declining queen conch populations (Supplementary Table 1).

A majority of the inhabitants of the small island nations where the queen conch is harvested and where aquaculture has been proposed for rebuilding conch populations rely upon local and international media sources for scientific knowledge, rather than peer-reviewed research papers. Media monitoring services are designed for businesses or marketing and public relations professionals to analyse published content from media outlets, including online and print news, broadcasts and podcasts. Meltwater (Meltwater News US Inc., Chicago, USA) is a media monitoring service that scans more than 270,000 sources for user input keywords to aggregate content. For this study, we used Meltwater Services to compile articles that contained the keywords 'queen conch' AND ('aquaculture' OR 'hatchery' OR 'nursery' OR 'farm') and that were published during 1 January 2013–31 May 2024. Reported media coverage was vetted to ensure that each individual story featured queen conch aquaculture and not the keywords dispersed across unrelated content. Travel-centric articles that featured visits to the Turks and Caicos Conch Farm were treated separately (Supplementary Table 2). Each individual article was reviewed for accuracy, and quotes were retained that promoted aquaculture as a viable method to repopulate the queen conch. The resulting database of unique articles is provided in Supplementary Table 1 and summarized in Table 1.

In the majority of unique stories, queen conch aquaculture is reported as a tool to rebuild populations (Table 1). The most common descriptive effect of aquaculture upon queen conch populations was to 'restore' (19 unique articles; Table 1) by 'releasing' (eight unique articles; Table 1) cultured individuals. However, despite decades of experimentation, neither commercial nor conservation aquaculture has proven successful for field repopulation, as comprehensively reviewed by Stoner (2019).

The largest hurdle to conservation aquaculture of the queen conch remains the high natural mortality rate (> 95% annually) in natural juvenile nurseries and outplant areas (Stoner, 2019). Attempts to increase survival rates by raising animals for a longer duration so that they reach larger sizes before release are constrained by the increased costs of specialized feed and decreased viability of the cultured animals as defects accumulate and fitness is reduced (Stoner & Glazer, 1998; Stoner, 2019). Aquacultured animals exhibit physical features that make them more vulnerable once they are outplanted into an unprotected, natural setting, including decreased shell strength, mass and spine growth (Stoner, 2019). Additionally, conch exhibit behavioural deficits, including a decreased propensity to burrow, low anti-predator responses and an inability to identify proper foods (Stoner, 2019). Survival is further modulated by the challenges of locating appropriate outplanting sites, providing available nursery habitat, identifying the proper release time, and controlling density-dependent effects on growth and predation (Stoner, 2019). However, even when the release site and season are optimized, mortality remains high (Stoner, 2019). Despite efforts to maximize their likelihood, high survival rates remain unlikely.

Challenges

The low rates of survival from post-settlement to near maturity, when viewed alongside large-scale fishery extraction and low aquaculture production, emphasize that with current techniques it is neither commercially feasible to replace wild harvest nor ecologically feasible to restore queen conch populations using conservation aquaculture. Both stock enhancement and restoration aquaculture remain inviable for the queen conch based on ecological and

Table 1 Queen conch *Aliger gigas* aquaculture featured in the media during 1 January 2013–31 May 2024. Unique articles are media pieces that we located using Meltwater Services (Meltwater News US Inc., Chicago, USA) and total placements are these articles featured in media outlets. The sum of unique articles that suggested that queen conch aquaculture can rebuild conch populations in each year was tabulated using adjectives that describe aquaculture's effect on conch populations. Quotes are from representative articles; Supplementary Table 1 contains sources and quotes from each unique article. Reach was calculated by Meltwater Services and is the estimated number of people exposed to media outlets that placed stories.

Year	Unique articles	Unique articles suggesting aquaculture can rebuild populations	Aquaculture's effect (number of articles)	Quote	Total placements	Reach
2013	1	0		. . .the Caicos Conch Farm has consistently lost investors' money for 29 years & never earned a dime of profit.	1	Unknown
2015	1	0		The team hopes the approach can be incorporated into aquaculture to improve yields of farmed queen conchs, helping to preserve those in the wild.	1	691,361
2016	1	1	Restore (1)	. . .an aquaculture project in the Bahamas with the goal of restoring the natural queen conch population.	1	107,872
2017	1	1	Restore (1)	The hatchery was set up as part of a program to restore queen conch populations in the region.	1	881
2018	1	0		. . .the only conch farm in the world, is now officially closed to the public	1	7,172
2019	4	2	Replenish (1); Restore (1); Release (1)	The intention is that hundreds to thousands of farmed snails will eventually be released into the Curaçao bays with seagrass to restore the [conch] population on the island	6	1,167,470
2021	5	5	Restore (3); Enhance (1); Restock (1); Release (1)	. . .to farm conch for release into the wild & for sustainable seafood production	16	14,441,044
2022	8	4	Restore (2); Rebuild (2)	Aquaculture can take some pressure off wild conchs – & [] its role in building a conservation ethos is significant	28	14,418,918
2023	13	8	Restore (8); Replenish (1); Boost (1); Release (2); Rewild (1); Restock (1); Regenerate (1); Revitalize (1)	This [aquaculture] project is a cornerstone of our program, one that will restore conch populations in The Bahamas while also providing benefits to local communities	875	913,126,270
2024[1]	12	10	Restore (3); Release (4); Strengthen (4); Recover (1); Augment (1)	We are also aware of restoration efforts being carried out to promote population recovery (e.g. . . . Queen Conch Aquaculture program)	18	2,255,036

[1] 1 January–31 May 2024.

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economic constraints. The following examples use estimates of demographic rates from the literature and fisheries data from recent reports to illustrate the formidable challenges faced by queen conch conservation aquaculture.

Juvenile production required to replace a single adult A primary goal of conservation aquaculture for the queen conch, spanning both restoration and stock enhancement, is to release cultured juveniles to produce reproductively viable adult queen conchs. New, pioneering approaches allow juveniles to be grown from egg-masses anywhere in the Caribbean using mobile hatcheries powered by solar energy (Davis & Cassar, 2020). These small-scale hatcheries can be operated in remote areas and can generate 2,000 juveniles per year (Davis & Cassar, 2020), although hatcheries require access to egg masses typically collected from the wild. Laboratory culture of the queen conch has become routine, resulting in increased interest in the idea that it could be used for restoration and stock recovery (Supplementary Table 1). However, small-scale culture does not currently produce an ecologically meaningful quantity of juveniles for outplanting. Using a conservative estimate of 95% annual mortality in juvenile conch, from the compiled results of nine peer-reviewed studies (Stoner, 2019) and from an age-structured mortality model (Appeldoorn, 1993), 4,000–10,000 juveniles need to be released to result in a single animal reaching its earliest possible maturity at 4 years of age (Stoner & Appeldoorn, 2022; Fig. 1).

Stock enhancement to replace commercial landings Despite steep declines in queen conch stocks, there are still active queen conch fisheries, ranging from small-scale to those supporting large exports. In other species, conservation aquaculture to enhance wild stocks has been applied to improve fisheries while allowing natural populations to rebound by offsetting part or all of the wild catch with aquaculture-sourced individuals (Free et al., 2022). In 2019, some of the largest fisheries for the queen conch were in Nicaragua and Honduras (Horn et al., 2022), with export quotas of 419 and 638 t of 100% clean queen conch meat, respectively. Such quotas involved retrieval of an estimated 6,972,210 individuals from the Nicaraguan Rise, a relatively shallow bank stretching north-east from the Central American coast towards Jamaica. If an aquaculture programme is designed to enhance wild stocks by annually supplementing the Nicaraguan Rise population with just 10% of the exported adult catch, it would require an approximate production of 2,788,884,000 juveniles, as a conservative estimate. This estimate uses the assumption that 4,000 outplants generate one adult in 4 years, and a conservative average of seven adults generating 1 kg of meat (Fig. 1). The yield of meat is based on fishery reports that 6.6 adults generate 1 kg of 100% clean meat on the Nicaraguan Rise (Ehrhardt & Galo, 2005) and that 8.14 adults generate 1 kg of 50% clean meat on the Pedro Bank (Ehrhardt et al., 2023). There remains a lack of documented success in small-scale or industrial population restoration, and scaling up production to commercial levels remains unlikely, with an unknown, yet high, economic cost (Fig. 2).

Potential production from protecting wild populations There are still actively breeding populations of the queen conch that support small and large populations and fisheries throughout their natural range that, if protected, have the potential to generate a vast quantity of eggs and larvae (Fig. 3). Importantly, the queen conch exhibits density-dependent breeding (reviewed by Stoner & Appeldoorn, 2022), so fishery managers and scientists have recommended a minimum spawning density of 100 individuals per ha (FAO, 2020). To succeed, stock enhancement and restoration aquaculture must sustain localized population densities at that level while accounting for fishery extraction and/or natural mortality. The average individual age in a breeding population of the queen conch, including disproportionately important large, mature and highly fecund individuals (Froese, 2004), is significantly greater than 4 years old (Boman et al., 2018; Tewfik et al., 2019; Stoner & Appeldoorn, 2022). Therefore, our estimate of juvenile outplants required to replace an adult in a breeding aggregation is an underestimate.

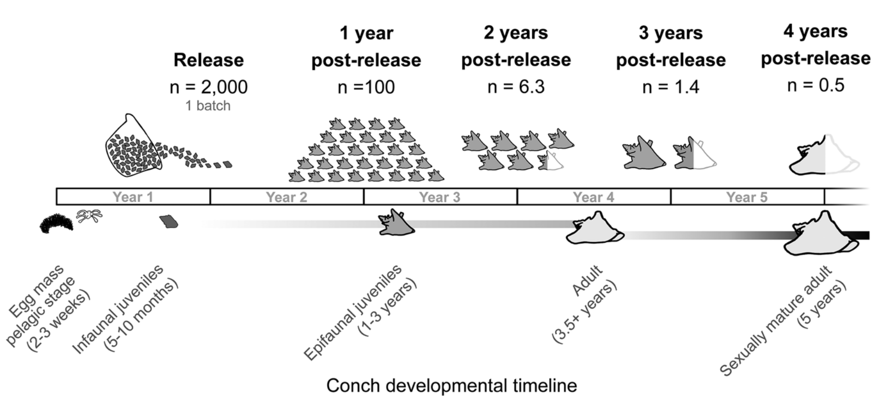

Fig. 1 Estimating survivorship to maturity from releasing cultured queen conch *Aliger gigas*. Conservative estimates of natural mortality from in situ experimentation (Stoner, 2019) and a stage-based model (Appeldoorn, 1993) demonstrate the time and number of young, in cultured batches (Davis & Cassar, 2020), required to replace a single, sexually mature queen conch.

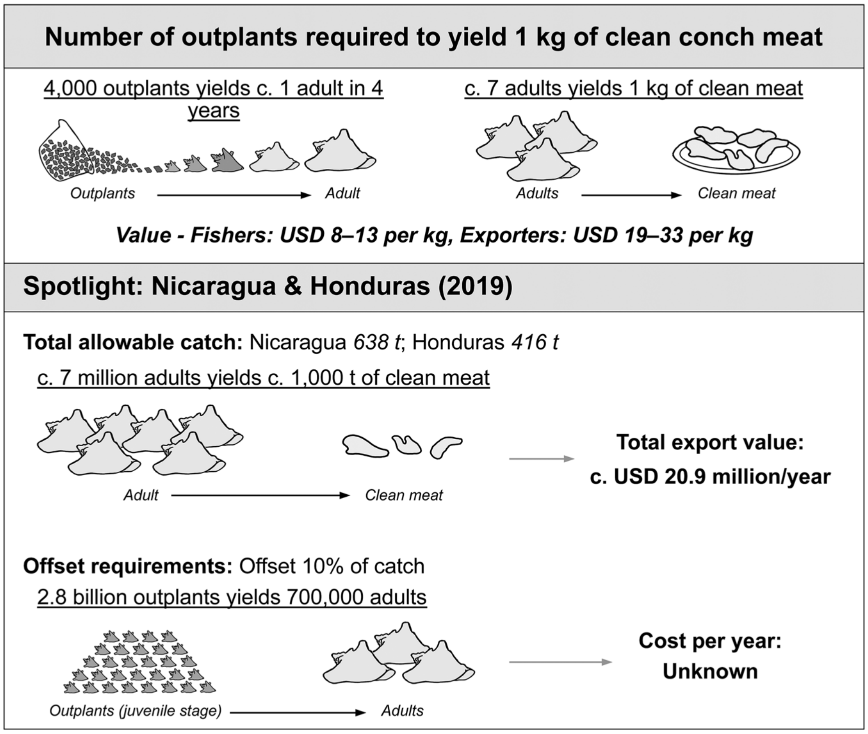

Fig. 2 Fishery value and the aquaculture production to partially offset landings in one region. Nicaragua and Honduras have lucrative queen conch fisheries on the Nicaraguan Rise, with values estimated in USD. Converting cultured animals into a fishery product, clean meat, requires time and a considerable outplanting effort. Based on an estimate of required sexually mature adults to generate the catch in 2019, replacing just 10% of the legally allowed harvest would require approximately 2.8 billion outplanted individuals from aquaculture. The costs to create and maintain the infrastructure to generate this level of culture are unknown, but probably vastly exceed the value of the fishery from both countries.

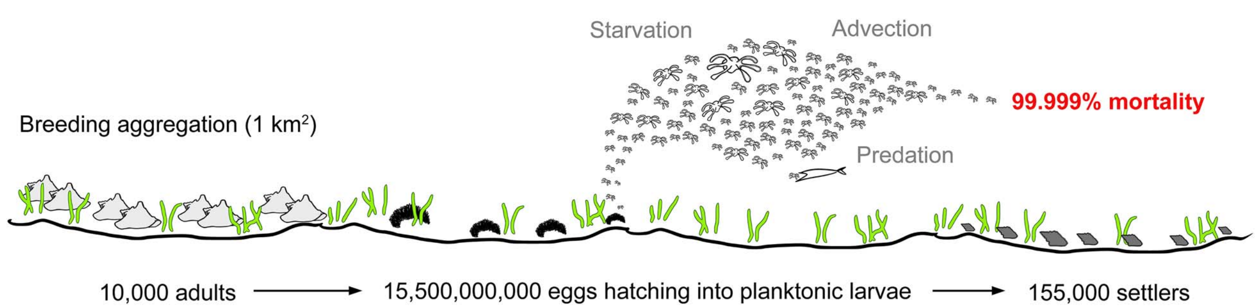

Fig. 3 Natural yield of the queen conch from protecting wild breeding populations. An area of 1 km² could support 10,000 adults at the recommended minimum density for reproduction. The minimum observed annual reproductive output of 5,000 females is 15.5 billion eggs (Stoner & Appeldoorn, 2022) which leads to an estimated 155,000 settled conch after accounting for planktonic mortality to achieve life-time replacement. Rates were estimated for a population at full capacity and without the added mortality of harvest, making them conservative.

Aquaculture decreases planktonic mortality yet even with planktonic mortality estimates accounted for, natural reproduction outstrips foreseeable aquaculture production levels (Fig. 3). Mortality rates during larval dispersal are unknown for the queen conch and for most other marine species with a bipartite lifecycle and planktonic larval phase (Houde & Bartsch, 2008), but they far exceed those of settled juveniles. Statistical models to estimate larval mortality require extensive field sampling and typically focus on quantifying either predation or growth rates but can use size-structured approaches that combine the two (Hinchliffe et al., 2021). Here, natural mortality is estimated from hatching to settlement based on the lifetime fecundity calculated by Stoner & Appeldoorn (2022) and the assumption that mortality rates enable replacement. Our examples (Figs. 1–3) are conservative with regards to natural mortality, harvest estimates and potential industry growth. An added benefit of protecting swathes of mature, reproductively active gastropods is increased population resilience and faster recovery when confronted with climate change or other events that cause mass mortality (Micheli et al., 2012).

Discussion

Queen conch conservation aquaculture, designed to restore natural populations or partially offset harvest, faces substantial hurdles that science, non-profit entities and industry have yet to overcome. Furthermore, a changing environment with increased frequency of extreme storms causing negative effects on infrastructure is another barrier to broadscale aquaculture that has impacted past commercial operations (Wida, 2018). However, queen conch aquaculture remains a critical tool in education and tourism and has contributed to understanding queen conch biology and ecology. Queen conch aquaculture should be encouraged as a means of furthering scientific knowledge and increasing community support while simultaneously and transparently communicating its current limitations for repopulation efforts.

Conservation benefits of aquaculture

Queen conch aquaculture is widely perceived as a positive and successful scientific practice (Table 1). People who enjoy consuming or celebrating the conch throughout the Caribbean benefit from understanding the lifecycle and the staggering mortality experienced as they grow towards maturity. Small-scale aquaculture facilities and mobile labs make larval transport and slow growth tangible concepts for educators, students and the general public. For example, the Turks and Caicos Queen Conch Farm, a commercial enterprise, was an effective educational attraction for tourists (Supplementary Table 2). Small-scale farms and hatcheries also provide an opportunity for community involvement and could partially incentivize a decrease in fishing pressure by paying fishers to participate in conservation programmes rather than in harvesting. Aquaculture has also answered important questions about larval hatching, development, metamorphosis, swimming capacities and food consumption (Stoner et al., 2023). The spatial management and conservation of the queen conch has also been shaped by contributions from aquaculture that facilitate connectivity and demographic modelling across their range (Vaz et al., 2022; Stoner et al., 2023). Future research on the impact of stressors such as climate change and disease could use cultured individuals so as not to impact wild stock.

There are many longstanding research needs before aquaculture can contribute effectively to in situ restoration and conservation. Overall, evaluating the plausibility of restoration aquaculture for the queen conch requires a large-scale experiment across multiple locations that tracks free-ranging individuals from release through to maturity, to gauge mortality, realized population enhancement and the potential benefits across the ecosystem. It is imperative that an interdisciplinary team of aquaculture practitioners, ecologists and local stakeholders, including fishers, design and conduct these experiments to fully evaluate and substantiate success prior to proposing aquaculture as a realistic and scalable avenue for population recovery.

Fisheries management

Policy changes have been successfully used to rebuild queen conch populations across many spatial and temporal scales. Over small spatial scales, no-take protected areas can harbour breeding populations (Stoner et al., 2012; Kough et al., 2017; Tewfik et al., 2019) that replenish unprotected areas, as predicted by biophysical models (Kough et al., 2019) and confirmed empirically (Kough, 2024). At the country scale, in Jamaica, scientific surveys and genomic connectivity studies (Blythe-Mallett et al., 2021) coupled with adaptive fishery management over the course of several decades (Ehrhardt et al., 2023) led to a sustainable seafood certification by the Marine Stewardship Council in 2024. For severely overexploited populations, the management strategy of last resort is a full fishery closure coupled with protection. In Florida, USA, these measures resulted in a protracted recovery from < 30,000 adult queen conch in 1986, to 200,000 in 1990 (Berg & Glazer, 1995), and an estimated 700,000 in 2017 (Florida Fish and Wildlife Conservation Commission, unpubl. data).

Community action, such as starting a queen conch nursery or citizen scientist surveys, may instil conservation ethos. Should active intervention beyond policy be deemed necessary, translocations to increase adult densities above minimum thresholds for reproduction have been posited as an alternative to aquaculture (Delgado et al., 2004; Delgado & Glazer, 2007). Translocating queen conchs from larval sinks to larval sources to boost reproductive output can provide an inexpensive, genetically sound alternative to aquaculture as hatchery production costs are eliminated. Translocations maintain the genetic integrity of the stock because of the use of wild animals as opposed to releasing hatchery-reared juveniles potentially derived from few parents (i.e. there is no outbreeding depression). Lastly, translocations will have a more immediate impact on reproductive output because there is no need to wait for juveniles to survive to reproductive maturity. Experimental-scale translocations have shown that translocated queen conchs engage in reproductive activities at their new location (Delgado et al., 2004) and do not displace native individuals within the aggregation (Delgado & Glazer, 2007). However, a cautious approach must be taken to ensure that the carrying capacity of the habitat is not exceeded and that larval sinks and sources are correctly identified.

The way forward

Queen conch aquaculture has been practiced with success in laboratories and hatcheries around the Caribbean, yet there is so far no scientifically quantified or documented example of successful repopulation of wild stocks with cultured conchs. A well-documented example of an ecologically viable, self-replenishing population that supplements or replaces traditional wild capture would promote its practicality for responsible stock enhancement. Furthermore, such an example would increase confidence in restoration aquaculture as a solution to prevent extinction should the conch population plummet and fisheries close. This has been recognized, and for as long as conchs have been cultured, attempts have been made to replenish wild populations. Overcoming natural mortality rates remains a challenge. Four decades ago in Puerto Rico, Appeldoorn & Ballantine (1983) suggested that fisheries enhancement through aquaculture was untenable without reducing juvenile mortality rates. In 1998, after more than a decade of experimental hatchery releases in the Florida Keys and The Bahamas, Stoner & Glazer (1998) came to the same conclusion. The Florida Keys hatchery was the only well-documented attempt to assess the feasibility of using hatchery-raised juveniles to replenish wild stocks. When the Florida hatchery closed, a cost–benefit analysis showed that it was not economically feasible to replenish wild stocks with hatchery-raised juveniles because of high mortality rates and the exorbitant monetary costs of compensating for mortality (Glazer & Delgado, 2003). The largest and most well-funded aquaculture facility for the queen conch was the Caicos Conch Farm. This commercial endeavour closed because of poor profitability (Trade Wind Industries, 2018) compounded by a hurricane strike (Wida, 2018), highlighting the financial challenge of stock enhancement. Although progress continues, poor conch survival (Figs. 1–3) and the history of past attempts (reviewed by Stoner, 2019) suggest a cautionary approach for presenting culture as a viable tool for queen conch repopulation without further advances. The creation and implementation of agreements for species management and restoration can be fraught with challenges, as illustrated by those for migratory fish (Cullis-Suzuki & Pauly, 2010), yet the best hope for species recovery remains better management of remaining wild stocks at national and international levels, informed by fisheries science and emphasizing protected area management and sustainable fishing approaches (Froese, 2004).

The idea that the conservation aquaculture of the queen conch is an option to replenish populations provides an appealing excuse to avoid the difficult tasks of managing local capture fisheries and addressing the causes of degraded ecosystems. An inclusive and interdisciplinary approach to restoration is needed to ensure the conservation of healthy habitats. Depending on repopulation through aquaculture in lieu of the robust management of natural resources is not in the best interest of the future of the species nor the people and industries that rely upon it.

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Data availability This study combines previously published data from reviews and industry.

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