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Perspective

Conservation aquaculture: Shifting the narrative and paradigm of aquaculture's role in resource management

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ABSTRACT

In the 21st century, aquaculture is generally characterized as a foe to conservation efforts. Yet, much has changed in the two seemingly disparate practices over the last two decades, motivating an updated evaluation of the scientific evidence for how aquaculture currently impacts conservation, as well as prospects for further alignment and research. Here we present a new perspective on *conservation aquaculture*, which we redefine as "the use of human cultivation of an aquatic organism for the planned management and protection of a natural resource." Looking across scales of conservation aquaculture that include single species to ecosystem level benefits (and limitations), we highlight ways aquaculture has historically, and is currently being integrated into conservation (e.g., habitat restoration of oyster beds) and areas that could be improved for the protection of critical species and habitats (e.g., aquarium trade of coral reef species). With a more strategic focus, there appears to be notable conservation aquaculture potential via the cultivation of species for harvest that could provide wild harvest alleviation through replacement or supplement – particularly for over-exploited species – and/or ecosystem services, such as improved water quality and reduction in greenhouse gas emissions. Given that aquaculture is the fastest growing food industry on the planet, aligning farming practices with conservation objectives is particularly pressing to ensure that growth happens in the service of conservation in the most effective and sustainable way possible. The sheer potential of conservation aquaculture suggests a tale of redemption for aquaculture and opportunity for conservationists to bring in a new age of collaborative practices to address global issues.

1. Introduction

For most modern-day conservationists, aquaculture is something to avoid. Shrimp farms destroy coastal mangrove habitats (Silva, 2012), salmon farms can release genetic anomalies into local populations (Naylor et al., 2005, 2001), farms of high-value (often higher-trophic level) species tax wild-caught forage fish stocks for feed inputs (Naylor and Burke, 2005; Naylor et al., 2009), and farms of fed species can pollute local waters (Islam, 2005; Sarà, 2007), among other impacts on native species and natural ecosystems. While some of this reputation is understandably deserved, much has changed in the last 20 years and needs to be revisited in a systematic way. Advances in the technology, practices, and siting of aquaculture have allowed significant mitigation of these environmental risks and harms (Bostock et al., 2010; Edwards, 2015), and expanding uses of aquaculture in resource management have changed the role that aquaculture can, and does, play in conservation. In this paper, we argue that aquaculture has the potential to play a significant, global role in achieving conservation objectives; realizing that potential requires a shift in the way we think about aquaculture, and scaling the way aquaculture is used to be part of the solution, instead of the problem.

Conservation aquaculture is not a hypothetical idea. Nearly all possible ways aquaculture can be used to improve the status and condition of species and ecosystems is already in practice somewhere on the planet, generally at a local level, but occasionally at larger scales (e.g., hatcheries supplying wild salmon stocks). Drawing attention to such approaches helps highlight aquaculture's potential to aid conservation, guide how to appropriately scale the practices, and ultimately offer conservationists a new tool. Changing the narrative around what aquaculture is (and is not) will enable and clarify efforts to use

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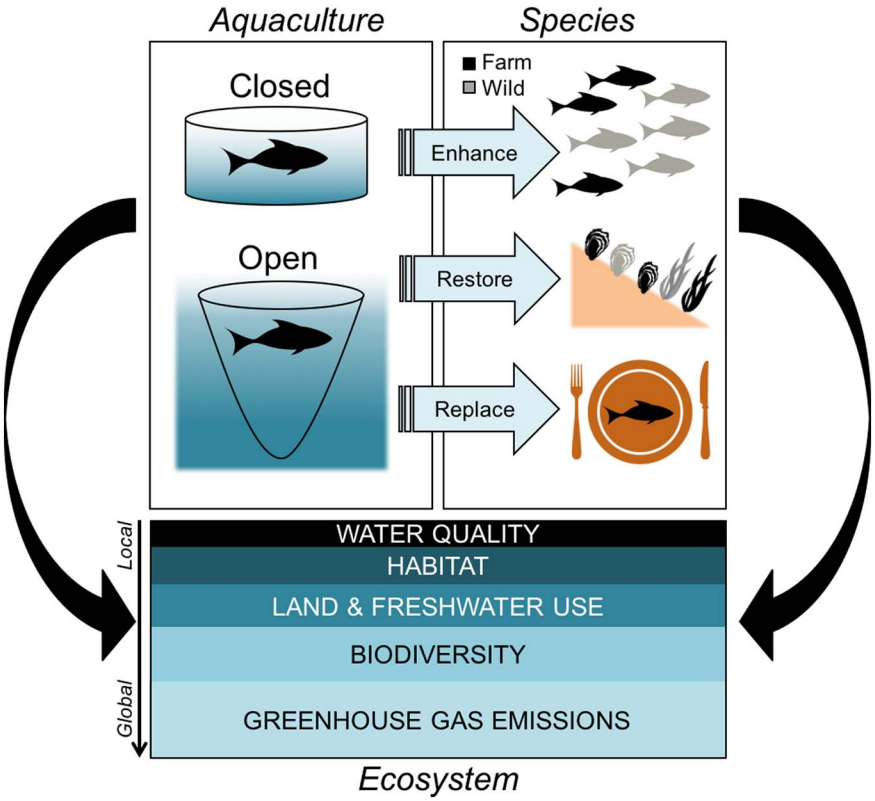

Fig. 1. Conceptual framework of how aquaculture is or can be used for conservation at a species and ecosystem scale. *Large arrows* indicate conservation links. At the species level, *enhance* refers to supplementing a wild population (hatchery), *restore* indicates biogenic restoration, and *replace* signifies farmed species replacing wild species – particularly overexploited or threatened – on the market (food or ornamental). Each component can apply to numerous taxonomic groups (finfish, bivalves, crustaceans, and seaweeds). Connections to ecosystem-level objectives can occur relative to the aquaculture type (*left panel*) and species (*right panel*). *Closed* versus *open* aquaculture denotes the generalized farming practices with differing resource requirements and impacts (e.g., freshwater use). Broad categorization of local to global ecosystem scale is reflected in the size of each box. Note, not all aquaculture practices for conservation result in every ecosystem component depicted.

this tool. Furthermore, aquaculture has been, and is expected to continue to be, one of the fastest growing food sectors in the world (FAO, 2016). Conservationists have the opportunity (and really, the necessity) to steer that growth in the industry toward sustainable practices that can benefit conservation objectives.

Any human use of the natural environment has a level of impact, at least to some species and/or habitats. Since aquaculture is no exception, any aquaculture practice will have some environmental consequences of varying degrees based on the initial objectives. Conservation aquaculture is therefore not a net-zero environmental pursuit, but instead can be used to explore how to use aquaculture in the service of conservation objectives, while still allowing and acknowledging a level of (ideally minimized) environmental impact.

Anders (1998) first coined 'conservation aquaculture' as the "*use of aquaculture for conservation and recovery of endangered fish populations*." This definition is somewhat narrow in scope and reflects the perception of aquaculture and conservation nearly two decades ago. Although a useful starting point, it does not echo the evolving conservation approaches. In redefining conservation aquaculture, we draw on (but do not limit ourselves to) the definitions of each term: conservation represents "*a careful preservation and protection of something; planned management of a natural resource to prevent exploitation, destruction, or neglect*" (Merriam-Webster, 2017), while aquaculture is defined as "*the cultivation of aquatic organisms, especially for food*" (Merriam-Webster, 2017; NOAA Fisheries, 2017). The definition of aquaculture is particularly important; the primary intent tends to be for consumption. Yet, aquaculture is widely used for other purposes, including cultivating certain life-stages of aquatic organisms for wild populations (i.e., hatcheries) or species for the aquarium trade (FAO, 2016). To that end, we focus on aquaculture as any human intended interference in the cultivation of aquatic organisms and define 'conservation aquaculture' more broadly as "*the use of human cultivation of an aquatic organism for the planned management and protection of a natural resource*."

Although the idea of combining aquaculture and conservation objectives through hatchery practices dates back over a century (Costa-Pierce, 2008), we focus on the formal documentation of the joined words for several reasons. First, while Anders' definition of conservation aquaculture nicely reflects the historical connotation, it is already captured by the term 'conservation hatchery' (Flagg and Nash, 1999). Second, the definition was published at one of the largest growth periods of aquaculture (FAO, 2016), during which many of the environmental wrongs occurred. It was around this time aquaculture was identified globally as a conservation concern (e.g., Clay, 1997; Flaherty and Karnjanakesorn, 1995; Goldburg et al., 1997). The purpose of our paper is to demonstrate the term 'conservation aquaculture' can encompass much more, matching the changes and progress in both fields since its inception.

Strategies for conservation of aquatic species and systems generally include federal or state protection, habitat restoration, and harvest-control rules. For example, large areas of the oceans are being set aside as marine protected areas (MPAs) to buffer the direct impact of human disturbance on critical habitats and/or species (Halpern, 2014). Listing of endangered or threatened species offers focused attention and resources for conservation planning (Harris et al., 2012). Once-degraded habitat, such as oyster beds or seagrass meadows, is restored with the aim to provide natural ecosystem services (Bayraktarov et al., 2016; Costanza et al., 2014). Simultaneously, catch-limits, gear restrictions, and/or seasonal bounds are incorporated into exploited species management to conserve species of economic or cultural significance (Kvamsdal et al., 2016). All of these interrelated approaches have ties to aquaculture that are typically overshadowed by aquatic farming's checkered past. Here we expound on the many ways aquaculture can work with, instead of against, conservation.

Conservation aquaculture ultimately needs to support the sustainable use (or recovery) of natural resources, whether through mitigation, prevention, or restoration measures. How best to achieve this goal requires explicit consideration of the scale at which conservation aquaculture is being pursued. In particular, we explore how conservation aquaculture can protect and manage (1) specific wild species/stocks through commodity production and direct (i.e., hatcheries) and indirect