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REVIEW ARTICLE

Salty stories, fresh spaces: Lessons for aquatic protected areas from marine and freshwater experiences

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Abstract

1. Marine protected areas (MPAs) and freshwater protected areas (FPAs), collectively aquatic protected areas (APAs), share many commonalities in their design, establishment, and management, suggesting great potential for sharing lessons learned. However, surprisingly little has been exchanged to date, and both realms of inquiry and practice have progressed mostly independent of each other.
2. This paper builds on a session held at the 7th World Fisheries Congress in Busan, South Korea, in May 2016, which explored crossover lessons between marine and freshwater realms, and included case studies of four MPAs and five FPAs (or clusters of FPAs) from nine countries.
3. This review uses the case studies to explore similarities, differences, and transferrable lessons between MPAs and FPAs under five themes: (1) ecological system; (2) establishment approaches; (3) effectiveness monitoring; (4) sustaining APAs; and (5) challenges and external threats.
4. Ecological differences between marine and freshwater environments may necessitate different approaches for collecting species and habitat data to inform APA design, establishment and monitoring, but once collected, similar spatial ecological tools can be applied in both realms. In contrast, many similarities exist in the human dimension of both MPA and FPA establishment and management, highlighting clear opportunities for exchanging lessons related to stakeholder engagement and support, and for using similar socio-economic and governance assessment methods to address data gaps in both realms.
5. Regions that implement MPAs and FPAs could work together to address shared challenges, such as developing mechanisms for diversified and sustained funding, and employing integrated coastal/watershed management to address system-level threats. Collaboration across realms could facilitate conservation of diadromous species in both marine and freshwater habitats.
6. Continued exchange and increased collaboration would benefit both realms, and may be facilitated by defining shared terminology, holding cross-disciplinary conferences or sessions, publishing inclusive papers, and proposing joint projects.

KEYWORDS

algae, coastal, fish, fishing, invertebrates, lake, marine protected areas, protected areas, river

1 | INTRODUCTION

Place-based approaches to fisheries management and conservation have gained widespread support in recent years through the proliferation of protected areas in both marine (Crawford, Kasmidi, Korompis, & Pollnac, 2006; Fox et al., 2014; Lester et al., 2009) and freshwater (reviewed in Abell, Allan, & Lehner, 2007; Saunders, Meeuwig, & Vincent, 2002; Suski & Cooke, 2007) environments. Collectively termed aquatic protected areas (APAs), these spatially discrete locations may restrict or prohibit extractive activities to recover depleted fisheries stocks and/or achieve conservation objectives; may be closed year round or temporarily (i.e. seasonal closures, rotating temporal closures); and can serve as examples of intact aquatic ecosystems that can be compared with exploited areas (Abell et al., 2007; Gaines, White, Carr, & Palumbi, 2010). As of 7 February 2017, the World Database on Protected Areas (WDPA) includes 15 336 marine protected areas (MPAs). Since the WDPA does not distinguish between terrestrial and inland water areas, no comparable global inventory exists for freshwater protected areas (FPAs), but it is expected these numbers are in the thousands as well (Juffe-Bignoli et al., 2016).

The extensive body of scientific literature that has developed around MPAs shows they can provide many beneficial effects, such as protecting critical habitats and ecosystem services, increasing fish abundance and biomass, conserving biodiversity, and supporting nearby fisheries through spillover (Halpern, Lester, & Kellner, 2010; Lester et al., 2009; Micheli, Halpern, Botsford, & Warner, 2004). This does not imply that the science behind MPAs is unequivocal or without controversy (Kaiser, Jennings, & Attrill, 2005; Woodcock, O'Leary, Kaiser, & Pullin, 2016). For instance, several studies illustrate social and governance challenges associated with the design and implementation of MPAs that need to be addressed (Christie, 2004; Jentoft, Chuenpagdee, & Pascual-Fernandez, 2011). Nevertheless, it is undeniable that a large volume of scientific studies has been published on MPAs, which is in stark contrast to those related to FPAs (Abell et al., 2007; Bower, Lennox, & Cooke, 2014; Saunders et al., 2002). The lack of publications related explicitly to FPAs could be in part because many are established at the community level, rendering them 'invisible' to the larger conservation community (Abell et al., 2007). Other FPAs are *de facto* embedded within terrestrial protected areas with underlying objectives that focus on terrestrial conservation and are disconnected from freshwater issues (Roux et al., 2008; Suski & Cooke, 2007).

Given the large base of experience in the marine realm, researchers are increasingly noting the potential for FPA practitioners to learn from their MPA counterparts (Abell et al., 2007; Cooke et al., 2014). However, there has been surprisingly little exchange to date, and both realms of inquiry and practice have progressed mostly independent of each other. Researchers from the two realms often publish in different journals and attend different conferences, with their disciplinary foundations and management strategies rather disconnected (Arthington, Dulvy, Gladstone, & Winfield, 2016; Cooke et al., 2014). Increasing dialogue between the two realms would also offer marine practitioners the opportunity to improve their knowledge of integrated land-management initiatives, which are more common in FPAs (Kingsford, Biggs, & Pollard, 2011). In all likelihood, lesson sharing and cross-fertilization of ideas among experts and practitioners of these two protected area systems could help improve the sustainability of FPAs and MPAs alike.

This proposition to share lessons between MPAs and FPAs was explored at the 7th World Fisheries Congress in Busan, South Korea, in May 2016. A session titled 'Salty Stories, Fresh Spaces: Crossover lessons for conserving biodiversity and sustaining fisheries with marine and freshwater protected areas' invited speakers from around the world to share experiences in the establishment, management, and monitoring of MPAs and FPAs. This paper builds off the examples shared during the session to describe how lessons from both MPAs and FPAs can inform each other. Given the numerous issues related to protected areas, this paper was not intended to be comprehensive, but rather reflects the experiences of the authors as a basis for sharing lessons learned through a variety of case studies. Nine case studies representing four MPAs and five FPAs (or clusters of FPAs) in nine countries are included in the analysis (Table 1). Lessons learned are grouped into five themes: (1) ecological system; (2) establishment approaches; (3) effectiveness monitoring; (4) sustaining APAs; and (5) challenges and external threats. For each theme, similarities, differences, and opportunities for exchange between MPAs and FPAs are discussed (Table 2). The paper concludes with a discussion of how MPA and FPA researchers can work together, and further directions for bridging marine and freshwater realms.

2 | THEME 1: ECOLOGICAL SYSTEM

Aquatic protected areas are often considered an ecosystem-based approach to aquatic management (Halpern et al., 2010), and as such their performance depends on effectively addressing characteristics of the given ecological system in their design and management. Such characteristics include biogeographic representation; habitat representation and heterogeneity; endemism; connectivity among habitats; and processes or habitats that support diversity and fisheries production, such as spawning habitats and vulnerable life stages (Roberts et al., 2003). While marine and freshwater settings are usually managed as separate realms, they do share some general environmental similarities that can provide a common basis for sharing management strategies. For example, a lake and an ocean share many physical processes that drive biology (e.g. food web dynamics, nutrient cycling), as do a river and an estuary (e.g. spawning habitat) (Cooke et al., 2014). Therefore, tools and approaches related to these shared processes may be transferred between marine and freshwater realms, including spatial planning, protecting key habitats and species, using species life history to inform APA design, and using networks of APAs to protect migratory species (Table 2).

2.1 | Spatial ecology in planning

Appropriate spatial planning is essential to the design of both MPAs and FPAs, particularly those intended to protect a focal species or habitat, and it relies on surveys of ecological context and

connectivity that occur before establishment (Cooke et al., 2016). While the specific survey methods to gather spatial ecological data may differ between marine and freshwater habitats or species, the approaches for incorporating these data into MPA or FPA design (e.g. species distribution models, conservation planning software) could be transferred between realms. A common design approach of both MPAs and FPAs is to protect specific habitats used by a focal species during a crucial life stage. A key success in the freshwater case study of the Gull Island Shoal Refuge in the Laurentian Great Lakes of North America was extensive spatial planning that identified critical spawning and nursery habitats of lake trout (*Salvelinus namaycush*), a focal species of the FPA (Table 1). Locating such critical habitats may alternatively draw on the local ecological knowledge (LEK) of stakeholders (Cooke et al., 2014), as in the freshwater case study of Probarbus Fish Conservation Zones on the Mekong River in Lao People's Democratic Republic (Lao PDR) (Table 1), where fishers identified spawning and refuge habitats used by endangered *Probarbus* fish species that subsequently became the focus of four community-established FPAs (Loury, Ounboundisane, & Leslie, 2015). Similarly, technical surveys and LEK may also be incorporated in the design of MPAs for focal species (Sánchez-Carnero, Rodríguez-Pérez, Couñago, Le Barzik, & Freire, 2016), and ideas on how to utilize both sources of information in spatial planning could be shared between realms, particularly for community-managed APAs.

One approach of APAs intended to broadly conserve aquatic biodiversity is to protect a habitat-forming keystone species, such as corals, macroalgae, mangroves, or submerged aquatic vegetation. In a marine case study from Chile, the Navidad Sanctuary MPA was established around kelp forests (*Macrocystis pyrifera*) to protect the kelp itself from overharvest, as well as the numerous invertebrates and reef fishes using the kelp as habitat (Oyanedel, Marín, Castilla, & Gelcich, 2016; Table 1). Similarly, in the marine case study of the Actam Chuleb MPA in Yucatan, Mexico (Table 1), fishers recognized the importance of seagrass habitat for fisheries productivity based on their LEK, and thus proposed an MPA to protect this habitat (Chuenpagdee, Fraga, & Euán-Avila, 2002). While it appears less common for communities to establish FPAs around a single habitat-forming species, similar approaches may be used to conserve a general freshwater vegetation type, such as wetland plants.

Spatial planning processes for both MPAs and FPAs are likely to reveal that management boundaries rarely represent ecosystem processes or the spatial ecology of focal species; therefore, collaboration across fields (e.g. water management, fisheries management, development) and across relevant ecosystem spatial scales provides opportunities to address threats in a more holistic manner, and to pool management resources and knowledge across realms. For example, the Great Lakes Fishery Commission, a bi-national agency between the United States and Canada, facilitates meetings to discuss fishery issues and management decisions across disciplines, including for migratory species such as walleye (*Sander vitreus*) that frequently cross management jurisdictions. Matching the scope of the FPA or MPA with the overarching governance structure is critical for sustaining APAs by ensuring that managers and policy makers can address ecological threats at adequate spatial and temporal scales

2.2 | Temporal ecology in planning and managing

In addition to spatial ecology, the temporal ecology and life history of focal species should also inform APA design and regulations, irrespective of the realm. APAs may be enacted to provide refuge for slow-growing, long-lived species, as in the case of lake trout in the Gull Island Shoal case study, which can live for 25 years. In the marine case study of the Velondriake Locally Managed Marine Area (LMMA) in Madagascar, the short lifespan and reproductive patterns of the target species, the reef octopus (*Octopus cyanea*), favours management in periodic closures, or temporary bans on harvesting in a designated area (Table 1). Given the 12-to-15-month post-settlement lifespan of the octopus, brief closures of 2–3 months can boost daily fisher catch by almost 90% in the month after reopening (Oliver et al., 2015). MPAs and FPAs could exchange strategies based on the management of short-lived or long-lived species, as life history determines the time scale of expected responses to protection, and should inform the timing of long-term monitoring.

2.3 | Migratory species

Protecting discrete spatial areas through APAs presents a connectivity challenge for conserving highly migratory species in both freshwater and marine realms (Bower et al., 2014). Such species may utilize widely disparate habitats and are vulnerable to harvest at multiple points on their extensive migrations, requiring both spatial and temporal considerations in planning and management. For example, the Probarbus Fish Conservation Zones in Lao PDR protect *Probarbus* spp. during their 2-to-3-month spawning season. The fish are less protected during the rest of the year as they may travel great distances and cross borders into Thailand or Cambodia. To address this challenge in the marine realm, there has been a push for protecting pelagic ocean habitat for migratory species in international waters (Game et al., 2009; Sumaila, Zeller, Watson, Alder, & Pauly, 2007; White & Costello, 2014). The importance of networks for migratory species has also been discussed in both realms, including regional networks of MPAs (Horigue, Alino, & Pressey, 2014), and catchment-scale approaches for freshwater conservation (e.g. 'catchment management zones', Abell et al., 2007; Cowx & Portocarrero Aya, 2011).

While MPA networks are connected by ocean currents in contrast to catchments that are hydrologically connected through linear channels, both rely on similar ecological concepts such as metapopulation dynamics and migration corridors, suggesting areas for exchanging ideas between realms. The exceptional examples of diadromous species, such as salmonids (anadromous) and eels (catadromous), that have critical habitats in both freshwater and marine environments provide clear opportunities to directly connect FPAs and MPAs. Species that may benefit from both types of APAs necessitate increased collaboration between researchers who are working with the same species in different realms (Arthington et al., 2016). This may require proposing changes to management structures that currently do not facilitate direct coordination between marine and freshwater habitat managers, such as creating joint committees or working groups. The success of both MPA and FPA networks depends on similar management approaches to appropriately incorporate spatial ecology information, and ensure a high degree of coordination among management entities throughout the network.

TABLE 1 Case studies of marine and freshwater protected areas, including ecological, social, and governance context.

					Ecological context	
Marine or freshwater	**Name of protected area(s)**	**Year(s) established**	**Location of protected area**	**Size of protected area**	**Ecosystem**	**Species/habitats of interest**
Marine	Actam Chuleb	1995	San Felipe, Yucatan, Mexico	20 km^2	Shallow, sandy area with seagrass and submerged aquatic vegetation	Lobster, octopus, and grouper
Marine	Velondriake Locally Managed Marine Area	2006	Southwest Madagascar	670 km^2	Near-shore marine environment including coral reefs, mangroves, and seagrass beds	Reef octopus *(Octopus cyanea)*
Marine	Navidad Sanctuary	2012	Navidad, Chile	0.2 km^2	Kelp forest	Kelp (*Macrocystis pyrifera*)
Marine	Koh Tao Environmental Protected Area	2014	Koh Tao Island in southern Gulf of Thailand	21 km^2	Marine and coastal resources	Coral reefs
Freshwater	Kampong Prak, Chroy Sdey, and Koh Kaeak	Kampong Prak est. 1950, Chroy Sdey and Koh Kaeak est. 2012	Pursat Province, Tonle Sap Lake, central Cambodia	500 km^2	Freshwater lake ecosystem surroudned by flooded forests	200 species of fish and a variety of mammals, birds, reptiles, and amphibians, including hairy-nosed otter, fishing cat, yellow-headed temple turtle, greater adjutant, and painted stork
Freshwater	Gull Island Shoal Refuge	1976	Lake Superior, Laurentian Great Lakes, Wisconsin, USA	1,000 km^2	Coastal environment within a system of 21 islands in a cold, deep, highly oligotrophic lake	Lake trout (*Salvelinus namaycush*) spawning habitats, lake whitefish, and lake herring
Freshwater	Fatki and Naboganga rivers; Goakhola and Isali floodplains; Porakhali and Bukbhora oxbow lakes	2002	Southern Bangladesh	<40 km^2 for all waterbodies. The 7 FPAs range in size from 0.008 – 0.3 hectares	Rivers, floodplains, and oxbow lakes	Small indigenous fishes (minnows and shrimps) and carps
Freshwater	Probarbus Fish Conservation Zones	2014–2015	Mekong River in Xayabouri, Luang Prabang, and Vientiane provinces, Lao PDR	4 areas totalling 2.8 km^2	Mainstem river habitat including deep pools and gravel bars	Jullien's golden carp (*Probarbus jullieni*) and thicklipped barb (*Probarbus labeamajor*)
Freshwater	Indawgyi Lake Fish Conservation Zone network	2016	Indawgyi Basin, Kachin State, Myanmar	8 areas totalling 3.4 km^2	Freshwater lake ecosystem with open-water habitat and herbaceous marshes, floating mats, limited emergent beds, and extensive areas of submerged macrophytes	Endemic pipe fish species (*Microphis dunckeri)*

Social context			Governance context		
Community size	**Primary livelihoods**	**Stakeholder groups**	**Governance structure**	**Protected area objectives**	**Drivers/responsible parties for establishment**
About 2,000 inhabitants in San Felipe (in 2000)	Fishing, supplemented by agriculture and ranching, with emerging tourism development	Small-scale fishers, fishers' cooperative, municipal government, San Felipe community	Community-based, locally initiated, with fishers participating in patrolling activities	Protect nursery grounds of lobster, octopus, and grouper (IUCN Category IV)	Fishers and members of fishers' cooperative
25 coastal villages, with a total population of approximately 7,200	Fishing (semi-nomadic lifestyle has seen a transformation into a more sedentary form over the past few generations)	Local resource users (fishers), the Velondriake Association (managing body), Copefrito and Murex (seafood collection companies), Blue Ventures Conservation	Managed entirely at the local level by the Velondriake Association, an elected body of community members	Managed primarily for sustainable use (IUCN Category V)	Consultations with local communities undertaken by international conservation NGOs Blue Ventures and the Wildlife Conservation Society, in partnership with the University of Toliara's Marine Institute and private seafood collection company Copefrito
About 1,200 people in the communities of Matanzas and la Boca de Rapel	Fishing, shore gathering (algae), and tourism	Fisher associations, municipality, government offices, watersport associations	Under the administration of the Navidad municipality, which consults with fisher associations	To conserve the kelp forest from kelp harvesting (IUCN Category V)	The fishers associations and the municipality, with collaboration from the Universidad Catolica
About 2,000 Thai registered living in the protected area, about 4,000 foreign laborers, 3,000–15,000 tourists per day	Tourism	Tourism operators, fishers, tourists, local government authorities	Decentralized: Decisions are made by the local appointed committee and implemented by the local government authorities	Promote sustainable use on the island (similar to IUCN Category VI)	Local people and the central government who were concerned about the un-controled expansion of tourism on the island
8 villages totalling 3,902 people	Fishing, fish processing and selling, livestock rearing, and seasonal fish farming	Community fisheries groups, Fisheries Conservation Department of the Fisheries Administration	Under the jurisdiction of the Fisheries Administration, with five areas zoned for community access and co-management with Fisheries Administration	Fish sanctuaries are permanently closed to use, conservation areas are open for use seasonlly (IUCN Category IV)	In 2012, commercial fishing lots were converted into either conservation or community access areas to ensure the sustainable management of fisheries resources. Conservation International worked to establish community fisheries.
1,266 members of Red Cliff Band of Lake Superior Chippewa living along the shore	Tourism, some limited tribal and commercial fishing	Fishers, Red Cliff Band, tourists, tourism operators	Mandated by Wisconsin Department of Natural Resources	Habitat/species management area for lake trout (IUCN Category IV)	Lake trout were in decline in all the Laurentian Great Lakes, prompting the mandate for the refuge by the Wisconsin Department of Water Resources
20 villages totaling 30,000–25,000 people living near the waterbodies	Farming and fishing	State government, fishers, farmers	Community access through rotating extractive reserves; co-management shared with the government	Fish conservation, access to traditional fisheries, and income (IUCN Category VI)	Overall reduction of fish production and lack of fisher access to traditional fishing grounds
7 villages totalling 3,400 people	Farming, fishing	Fishers, village committee, local officals from Department of Livestock and Fisheries	Community co-managed, with villagers participating in patrolling and management activities with government support	Habitat/species management area for *Probarbus* fishes (IUCN Category IV)	The International Union for Conservation of Nature (IUCN) and the consulting company FISHBIO initiated consultations with local communities and government officials to protect key habitat for endangered *Probarbus* fishes
13 villages around the lake totalling about 30,000 people	Fishing, rice farming, livestock grazing, daily labourers, extracting forest products from the surrounding watershed	Fishers, farmers, daily labourers, wildlife sanctuary staff, Department of Fisheries, Administrative Department, police	Management shared by the Indawgyi Wildlife Sanctuary and Department of Fisheries in collaboration with the local communities and other stakeholders such as police and Administrative Department	Habitat/species management area (IUCN Category IV)	Because fisheries are threatened by illegal fishing, Fauna and Flora International worked with Friends of Wildlife (a local NGO), the Forestry Department Department of Fisheries, and consulting company FISHBIO to initiate consultations with local communities

TABLE 2 A summary of similarities, differences, and lessons that can be exchanged between MPAs and FPAs

Theme	Similarities between marine and freshwater APAs	Differences between marine and freshwater APAs	Lessons to exchange
1. Ecological system	Appropriate spatial planning is essential. APA locations often focus on key habitats for crucial life stages of focal species.	Different methods may be needed to study and monitor marine and freshwater habitats and species. More marine examples of protecting habitat-forming keystone species (e.g. coral reefs, sea grass beds, kelp forests).	Share tools related to spatial planning, using life-history information to inform APA design, and creating networks for migratory species. Use working groups or task forces to coordinate protected areas for diadromous species.
2. Design and establishment approaches	Need to engage stakeholders from the beginning to develop strong trust and communication networks. Co-management is a useful model in both realms, but legal authority may be required to legitimize community participation.	De facto protections from terrestrial protected areas are more often assumed for freshwater.	Exchange lessons from zoning for multiple uses. Lessons from long-term establishment processes are more widely documented in the literature for MPAs; can be used to inform FPAs. Tools like social network analysis can be transferred from MPAs to FPAs.
3. Effectiveness monitoring	Proliferation of APAs without adequate monitoring. More focus on biological monitoring in both realms, socio-economic and governance monitoring represents a data gap. Harder to obtain funding for long-term monitoring of existing APAs than establishing new APAs.	Visual census methods common for evaluating MPAs, but often not feasible for FPAs. Global conservation targets often group terrestrial and freshwater targets, making it difficult to track effectiveness of FPAs.	Well-established MPA monitoring guidelines should be shared, synthesized and adapted through joint workshops/meetings to inform monitoring of FPAs. As more FPAs are established, baseline data should be collected to facilitate BACI analyses. Work together to facilitate the collection of more socio-economic and governance data. Methods can be shared and results synthesized at meetings and in publications.
4. Sustaining APAs	Need to be well-financed and enforced, and receive ongoing support from local communities and government for long-term success. Disconnect between long-term nature of the initiative and short-term donor funding cycles. May be competing for the same donor funding.	More attention has been paid in the marine realm to diversifying income sources. MPAs have made more progress identifying ways to overcome conservation's opportunity cost through the development of models that are economically attractive to affected communities.	Explore options for diversifying sources of income. Work together on developing best practices in building and sustaining community support and motivation, for example through the use of innovative training and financial mechanisms that rapidly demonstrate how conservation can make economic sense to local communities. Best practices in sanction setting and enforcement for those who break rules governing the APA can be shared between APAs with similar governance contexts regardless of realm through synthesis literature and meetings.
5. Challenges and external threats	External threats from human activities (e.g. illegal fishing, development, pollution) need to be addressed with management actions. Adaptive management such as shifting APA boundaries may be needed to address large-scale threats such as climate change. Social and economic conditions of local communities pose threats to both, and require additional interventions.	Addressing ecological threats such as invasive species will require strategies specific to the species and environment. Hydropower and irrigation development pose unique challenges of fragmentation in the freshwater realm. Issues of scale pose greater challenges to effective fisheries management outside MPAs compared with FPAs.	Can share approaches for integrated land management to address threats at the watershed level through synthesis literature, meetings, and joint task forces Freshwater realm may be more familiar with addressing upstream impacts, and can inform MPAs. Coastal MPAs that are affected by river inputs could be integrated into catchment frameworks by including MPA managers in the catchment planning. Successful approaches to addressing socio-economic conditions such as improved market access or alternative livelihoods can be shared among APAs with similar socio-economic contexts regardless of realm.

3 | THEME 2: DESIGN AND ESTABLISHMENT APPROACHES

Both MPAs and FPAs are established through a variety of mechanisms, broadly characterized as top down (driven by government authorities), bottom up (driven by community members, often with the assistance of a facilitating organization), or some combination of the two. Establishing an APA in either realm often deals more with the users of the system than with the natural system itself; therefore, design and establishment processes are highly transferable between MPAs and FPAs with similar stakeholder scenarios (Table 2). A general challenge with the establishment of almost all APAs is that they limit resource harvest by design, and thus limit fishing opportunities for various stakeholder groups. Therefore engaging stakeholders at multiple levels and all stages of establishment is a crucial lesson for both MPAs and FPAs. The initial 'step zero,' which occurs when the idea of the APA is first introduced and discussed, as well as a participatory decision-making process, are particularly important to achieve community approval and support for the concept of an APA (Chuenpagdee et al., 2013; Oyanedel et al., 2016).

3.1 | Stakeholder participation and legitimacy

Community participation and legitimacy are key factors for successful implementation of both MPAs and FPAs. In a marine example, researchers in south-west Madagascar spent 2 years synthesizing biophysical data to develop a zoning plan for the Velondriake LMMA, only for affected coastal communities to request a wholescale boundary revision before implementation (Harris, 2007). The changes were made, and the resulting revision enhanced the legitimacy of the zoning plan among local stakeholders. This experience highlighted the preeminence of community attitudes and perceptions over biophysical considerations in developing a zoning plan, emphasizing the need to consult local stakeholders from the beginning (Cripps & Harris, 2009; Harris, 2007; Oliver et al., 2015). In the freshwater case studies from Lao PDR and Indawgyi Lake in Myanmar (Table 1), the facilitating organizations held consultation meetings with communities to seek stakeholder input and approval (Loury & Ounboundisane, 2015). In Lao PDR, the facilitating groups originally proposed a seasonal fishing closure during the spawning period of the focal species, but the communities instead chose year-round fishing closure in the FPAs to make the 'no fishing' zones more straightforward to enforce. This illustrates how community involvement in management can sometimes result in stronger APA protections.

Legal authority may be required to legitimize community participation. Co-management, in which responsibility for the protected area is shared between local communities and government officials, is a strategy applicable to both realms. Engaging local people to designate and enforce community-managed MPAs has gained acceptance in developing countries (Beger, Harborne, Dacles, Solandt, & Ledesma, 2005; Velez, Adlerstein, & Wondolleck, 2014), and is emerging in freshwater environments as well (Baird & Flaherty, 2005; Vermeersch, 2014). The Actam Chuleb MPA in Mexico is an example of a bottom-up establishment process, driven mainly by fishers and their cooperative, and supported by the community and local governments (Chuenpagdee, Fraga, & Euan-Avila, 2004). However, enforcement proved challenging because initially, the MPA was not officially recognized by the state government (Salas, Fraga, Evan, & Chuenpagdee, 2015), and the group of fishers patrolling the area was therefore not respected by the neighbouring community (Chuenpagdee et al., 2002). In the freshwater case study from Myanmar, the Fisheries Department must officially recognize FPAs according to relevant state freshwater fisheries laws. Because the Kachin State fisheries law previously recognized only government-established FPAs, establishing co-management in Indawgyi Lake required confirmation from the Fisheries Department and the Kachin State Parliament to provide legal recognition of community co-managed FPAs.

3.2 | Zoning for multiple uses

Another approach to address diverse stakeholder values that can be implemented in both realms is zonal management, which can establish regions that allow fishing as well as those that prohibit fishing (Oyanedel et al., 2017; Rocliffe, Peabody, Samoilys, & Hawkins, 2014). This practice is widely used in MPAs; for example, the Velondrikae LMMA in Madagascar incorporates multiple uses, such as temporary closures that are later opened for fishing; aquaculture; and eight permanent no-take marine reserves (Harris, 2011; Westerman & Gardner, 2013). Zoning is also common practice in lakes, such as the freshwater case study of the Tonle Sap Lake in Cambodia (Table 1), where a national zoning system includes no-take conservation areas, areas for seasonal community access, and open-water areas for year-round community fishing (Royal Government of Cambodia, 2006). Similarly to the Velondrikae LMMA, the freshwater case study from Bangladesh (Table 1) used a system of rotating closures on the Goakhola Floodplain, where one-third of the community's FPAs are open to fishing each year, while the rest are closed to regenerate (Mamun, 2013). Lessons on managing for multiple uses at different spatial and temporal scales could be exchanged between MPAs and FPAs to address the shared challenge of reducing fishing access through APA designation.

3.3 | Engaging stakeholders in top-down processes

Establishing APAs in a top-down fashion can be successful if the establishing authority consults extensively with stakeholders, and if stakeholders actively participate in the process (Sayce et al., 2013). In the marine case study of the Koh Tao Environmental Protected Area in Thailand (Table 1), the designation of a top-down driven MPA was successful because the central government in Thailand was committed to reducing widespread unsustainable coastal development, and the government agency responsible for designating the MPA provided many opportunities for stakeholder and community participation. A committee of relevant stakeholders was appointed in Koh Tao after the formal MPA designation to allow stakeholder input to management (Satumanatpan, Moore, Lentisco, & Kirkman, 2017). Natural resource management agencies may also represent stakeholder groups in discussions that affect multiple jurisdictions, as in the case study of the Gull Island Shoal Refuge. The FPA was established through a top-down process by the state of Wisconsin, USA, as the shoal lies solely within

Wisconsin's jurisdiction. However, the decision to establish the FPA was not unilateral, and management actions were coordinated among provincial, state, federal, tribal, and binational institutions that share the goal of restoring lake trout in Lake Superior (Zuccarino-Crowe, Taylor, Hansen, Seider, & Krueger, 2016). Coordination and transparency are important to the governance of both MPAs and FPAs, which can affect many groups of diverse stakeholders.

3.4 | Coordinating with terrestrial protected areas

One difference between marine and freshwater systems is that it is often assumed including a body of freshwater within a terrestrial protected area will ensure sufficient protection for the aquatic environment; however, this is not necessarily the case (Abellan, Sanchez-Fernandez, Velasco, & Millan, 2007; Herbert, McIntyre, Doran, Allan, & Abell, 2010). In the freshwater case study from Myanmar, the Indawgyi Wildlife Sanctuary did not include specific protections for fishes in Indawgyi Lake, located within the sanctuary, which prompted the establishment of FPAs. However, the process encountered overlapping jurisdictions of the Forest Department, which is responsible for the overall wildlife sanctuary, and the Department of Fisheries, which is responsible for lake management and FPA approval (Loury & Ounboundisane, 2015). Thus, establishing an FPA may require coordination with the legislation and management of nearby or surrounding terrestrial protected areas, as well as terrestrial and aquatic government departments. Lessons from this process could inform the establishment of MPAs adjacent to coastal terrestrial protected areas, which may not provide sufficient protections for aquatic resources as presumed.

3.5 | Social networks

Strong communication and trust must be considered in the design and establishment of both MPAs and FPAs, and tools such as social network analysis that have been used in MPA settings could be easily adapted for FPAs. For example, the Navidad Sanctuary in Chile was the first bottom-up community-based MPA established in the country, which brought together fisher associations, government agencies, and university researchers. Although the establishment process took more than 7 years, a valuable communication network developed in the process, and stakeholders indicated a high level of satisfaction and local involvement with the initiative (Oyanedel et al., 2016). Communication networks can also facilitate the replication of bottom-up models based on perceived successes. In Madagascar, the Velondriake LMMA was the country's first such locally managed MPA that became a demonstration and learning site for other coastal communities, and prompted a wave of grassroots replication of both the LMMA approach and periodic octopus closures (Rocliffe et al., 2014). While APA establishment approaches can be very similar between marine and freshwater realms, these processes have been more broadly researched and documented for MPAs in the literature (Chuenpagdee et al., 2013; Gaymer et al., 2014; Oyanedel et al., 2016). Therefore, lessons learned from long-term establishment processes could be transferred from MPAs to inform FPAs.

4 | THEME 3: EFFECTIVENESS MONITORING

Simply establishing APAs in either realm does not ensure their success, which requires monitoring, evaluation, and adaptive management as needed. While the importance of monitoring has become widely recognized in the marine realm, leading to the creation of established monitoring guidelines and resources (Bunce, Townsley, Pomeroy, & Pollnac, 2000; Hoon et al., 2008; Pomeroy, Watson, Parks, & Cid, 2005), few such resources exist for the freshwater realm (Hermoso, Abell, Linke, & Boon, 2016; Juffe-Bignoli et al., 2016). Therefore, there is a need to transfer lessons learned from the monitoring of MPAs to develop tools and guidelines specific to monitoring the effectiveness of FPAs (Table 2).

4.1 | Socio-economic and governance monitoring

Recognizing that an APA represents an institutional arrangement that restricts interactions between human activities and the natural environment, APA effectiveness is often evaluated based on governance, socio-economic, and biophysical indicators (Pomeroy et al., 2005). However, a global analysis of MPA assessments indicates that managers evaluate biophysical indicators much more frequently than socio-economic or governance indicators (Fox et al., 2014; Pomeroy et al., 2005). Focusing solely on biophysical indicators while failing to assess a community's perceived benefits, impacts, and general satisfaction with a protected area highlights how both MPAs and FPAs risk becoming 'biological successes, but social failures' (Christie, 2004). While implementing an APA may lead to achieving biodiversity or conservation objectives, it may create conflicts and tension between various users, some of whom may have access to the areas while others may face restrictions. Non-compliance might follow as a result.

The data gap in socio-economic or governance monitoring for both MPAs and FPAs presents an opportunity for collaboration between realms. The methods for collecting such data on the human dimension of APAs are largely interview and survey based (Bunce et al., 2000; Hoon et al., 2008), and can therefore be used with stakeholders in either realm. For example, a mixed-methods socio-economic assessment used at the Velondriake LMMA in Madagascar included household and individual surveys, focus groups, and structured interviews (Blue Ventures, unpublished data). Socio-economic or governance studies of community-managed FPAs are especially lacking in the literature (but see Vermeersch, 2014), and as the same methods may be readily transferred between realms, freshwater and marine researchers could work more closely together by exchanging resources and best practices to address these gaps at joint meetings or through review publications

4.2 | Biophysical monitoring

Perhaps more effort has been invested in biophysical monitoring of both MPAs and FPAs because of the emphasis placed on protecting and replenishing fish populations. The Gull Island Shoal Refuge illustrates how field studies can be combined with modelling for a robust biological assessment, a lesson applicable to both marine and

freshwater realms. Field studies found the abundance of lake trout, the focal species, to have increased inside the FPA (Zuccarino-Crowe et al., 2016), as well as a faster growth rate and lower mortality compared with outside the FPA (Johnson, Hansen, & Seider, 2015). A simulation study also found that with the removal of the FPA, all simulated levels of fishing mortality could collapse the lake trout population, thus affirming the need to maintain the FPA (Akins, Hansen, & Seider, 2015).

A before-after-control-impact (BACI) sampling design is another powerful tool for accurately assessing the ecological effectiveness of APAs. In a marine example from the Velondriake LMMA in Madagascar, a BACI assessment based on a 6-year fish abundance dataset indicated that the biomass of fishery-targeted families was significantly higher in permanently established reserves than fished control sites, but the biomass of untargeted families was not. BACI assessments can help disentangle the effects of APA protection from the effects of displaced fishing effort, although they are not the only means of assessment (Lester et al., 2009; Ojeda-Martinez et al., 2011; Smokorowski & Randall, 2017). Studies have noted a general lack of BACI assessments for MPAs, as most studies assess MPA impacts after they have been established, and lack data collected before establishment, highlighting the collection of baseline data as a key lesson that can be transferred to the freshwater realm as the establishment of new FPAs increases.

4.3 | Challenges to monitoring

Despite the fact that monitoring is integral to the success of both MPAs and FPAs, they often face similar challenges of insufficient funding and resources to perform long-term assessments. This is particularly the case for locally managed APAs, which frequently lack necessary leadership, technical knowledge, and financial support (Gutierrez, Hilborn, & Defeo, 2011; Jupiter, Cohen, Weeks, Tawake, & Govan, 2014; Léopold, Beckensteiner, Kaltavara, Raubani, & Caillon, 2013; Levine & Richmond, 2014). The case study of community-managed FPAs in Lao PDR illustrates insufficient monitoring due to a lack of funding and thorough management plans. For APAs established in a top-down fashion, a lack of administrative will can also inhibit effective monitoring, such as the government-backed MPA in Koh Tao, Thailand, in which MPA compliance is monitored by a committee that meets infrequently (Satumanatpan et al., 2017). These challenges may exist in both marine and freshwater realms in part because establishing new protected areas is often perceived as having greater conservation impact than long-term monitoring of existing protected areas, and thus establishment may attract more funding and support.

Indeed, the current push towards increasing the global coverage of protected areas to achieve Aichi Biodiversity Target 11 under the Convention on Biological Diversity risks the creation of 'paper parks' that are poorly designed, enforced, and managed (Barnes, 2015). Similarly, Pomeroy et al. (2005) described an increasing concern for the 'reckless proliferation' of MPAs based on 'over-zealous advocacy or unrealistic expectations', which can lead to development of ineffective protected areas. Greater scrutiny is similarly needed for FPAs, as global conservation targets often group terrestrial and freshwater targets together, creating challenges for deciphering the actual extent and effectiveness of global freshwater protection in FPAs (Abell et al., 2007; Amis, Rouget, Lotter, & Day, 2009). Amid the recognition that increased protections are needed specifically for bodies of freshwater (Herbert et al., 2010), and as community-managed FPAs are increasingly being established in developing countries such as Bangladesh, Cambodia, Lao PDR, and Myanmar, the freshwater realm should heed lessons learned from MPAs to ensure a focus on effectiveness grounded in monitoring and realistic expectations of performance, and not just the quantity or coverage of FPAs.

5 | THEME 4: SUSTAINING APAs

Given the considerable effort and funding that often goes into establishing APAs, there is understandable interest in ensuring their long-term effectiveness. In addition to being robustly monitored and evaluated (Theme 3), APAs need to be well financed and enforced, and receive ongoing support from both local communities and government if they are to be successful over the long term (Table 2).

5.1 | Sustainable financing

Of these aspects, financing is arguably the greatest challenge facing the sustainability of both MPAs and FPAs, especially in the developing world, and in APAs established from the bottom up. Such APAs are often developed on a project-by-project basis, and it is difficult for communities to sustain project activities once donor funding ends (Poonian, Hauzer, & Iboura, 2008). In the marine realm, the most recent global evaluation suggests that less than 16% of MPA managers feel they have adequate funding for effective conservation (Balmford, Gravestock, Hockley, McClean, & Roberts, 2004), that 91% of MPAs do not have adequate staffing, and that only 35% of MPAs are appropriately funded (Gill et al., 2017). While no such global synthesis exists for FPAs, funding shortfalls also occur for freshwater conservation (Thieme, Rudulph, Higgins, & Takats, 2012). For example, in the case study from Bangladesh, links and relationships between stakeholders, such as government agencies, neighbouring communities, and community groups (mosques, local NGOs) were lost once donor funding stopped, and many FPAs ceased functioning (Mamun, 2013).

By contrast, in the Cambodia Tonle Sap Lake case study, financial sustainability was found to be the most important contributor towards management and conservation success. The project established savings groups in two communities to help safeguard members from income shocks and debt, and earnings have been used in part for community fisheries management, including FPAs. To ensure management is sustained once the donors have exited, a community trust fund scheme was created, which generates sufficient interest for three community fisheries to execute management activities like patrolling the flooded forest, and enforcement to reduce illegal fishing activities. However, more than 200 community fisheries groups, many with FPAs, have been set up on the Tonle Sap Lake alone, presenting substantial long-term financing needs.

Another strategy to ensure sustainable long-term financing is to diversify sources of income. Funding for the Velondriake LMMA case study in Madagascar comes from a variety of mechanisms including: (i) revenue from the long-running marine ecotourism operations of Blue Ventures, the LMMA's technical partner; (ii) donor support; (iii)

fees levied on catches landed by local fishers on the opening days of the temporary octopus closures (Theme 1); and (iv) fines accrued through enforcement of rule-breaking penalties. Spreading financial risk in this way has enabled Velondriake to guard conservation programming against short-term funding cycles or sudden shifts in donor priorities.

The lesson here for practitioners is clear, and applies to FPAs and MPAs alike; if an APA is to be sustained into the long term, it cannot always rely on donor support alone and should seek to incorporate durable income generating activities from the start. In the marine realm, more attention has been paid to diversifying income sources through tourism in particular, especially for MPAs in tropical countries popular with divers, snorkellers, and beach goers. Such options may not be applicable to FPAs, although examples of freshwater ecotourism exist (e.g. recreational catch-and-release fisheries; snorkelling in freshwaters such as the Pantanal wetlands in Brazil). There is a lesson for donors too: while the benefits from area-based conservation are worthwhile, they may be uncertain (Buxton, Hartmann, Kearney, & Gardner, 2014), diffuse (Hanna, 2004), and slow to accrue (Ovando, Dougherty, & Wilson, 2016; Russ & Alcala, 2011). In many cases, the hard work begins after an APA is established, as long-term endeavours require long-term support.

5.2 | Durable local support

In contexts where APAs are co-managed at the local level, building a broad base of community support and maintaining motivation are also important for sustainability. Crucial elements include community awareness of the APA, functioning community management committees, frequent reports on progress, widely agreed-upon management plans, adaptive management, and communities empowered with skills and knowledge necessary to deliver effective management (Latham & Rocliffe, 2016). In a freshwater example on the Tonle Sap Lake in Cambodia, community fisheries have received capacity building in how to write management and investment plans to receive funding from government authorities, as well as financial training in fee collection and administration (Chap, Touch, & Diepart, 2016). Consistent, locally-supported management has helped to build trust at the community level, and increased willingness to participate in conservation activities and pay the fees required.

To sustain motivation over the long term, it is also important that communities recognize benefits from management. In a marine example from the Velondriake LMMA in Madagascar, initial attempts by the government to establish conservation activities were unsuccessful because the highly impoverished community perceived the short-term costs of marine protection (loss of a primary food source and income) to outweigh the future benefits (Oliver et al., 2015). However, the introduction of short-term reef closures rapidly boosted fisher catches and incomes from *Octopus cyanea*, demonstrating the benefits of local management. This motivated local communities to establish a LMMA that included measures like no-take MPAs that were rejected as unworkable by the same communities a few years previously. Identifying management models to make conservation economically attractive to communities could likewise benefit FPA practitioners seeking to establish durable and effective initiatives.

5.3 | Effective enforcement

Compliance monitoring is an important tool for managing both MPAs and FPAs and for feeding input on overall compliance back to community fishery management; without it, effective conservation and management are difficult to implement. Communities in the case studies from Cambodia and Lao PDR have received enforcement training for patrolling their FPAs, and while they have successfully apprehended some illegal fishers, broader government enforcement will be required to address the widespread threat of illegal fishing (Loury et al., 2015). However, many governments, particularly in tropical developing countries where the majority of the world's APAs are located (Wood, Fish, Laughren, & Pauly, 2008), lack the financing and capacity to support enforcement in this way. In these contexts, MPAs and FPAs might focus on finding the right incentives to build a broad base of local support, which will not eliminate the need for enforcement, but can substantially reduce the resources required.

5.4 | Institutional support

Good governance principles, including transparency, participation, accountability, access to justice, and equitable sharing of benefits are important during both strategic planning and implementation to help ensure the long-term success of APAs in both realms (Borrini-Feyerabend, Kothari, & Oviedo, 2004). Institutional support is also an important dimension for the sustainability of APAs, including areas that are community managed. In the case study from Cambodia, multiple government institutions are involved with community fisheries, but have overlapping mandates and lack materials and human resources, which poses challenges for effective governance (Seak, Schmidt-Vogt, & Thapa, 2011). Similarly in the case study from Lao PDR, relationships between communities and local fisheries authorities have improved through the co-management of FPAs (Loury et al., 2015), but government technical and financial resources for support remain limited. While the tools to support APA governance will often be context specific, general lessons could be shared between realms for cases with similar governance structures (e.g. coordinating co-management of APAs with government institutions in developing countries).

6 | THEME 5: CHALLENGES AND EXTERNAL THREATS

While APAs are often established to safeguard valuable, high biodiversity areas, they do not inherently address the underlying causes of the threats they endeavour to mitigate. APAs are not a comprehensive solution to the problems of overfishing and environmental degradation, and their success is influenced by external factors at multiple scales (Allison, Lubchenco, & Carr, 1998). As it is beyond the scope of a single APA, or even an APA network, to address these threats, managers must understand the larger ecological and human context of an APA in either realm, adapt management accordingly, and undertake concurrent interventions to mitigate or address external threats (Table 2). Similar management or planning strategies could broadly be used to address threats to both MPAs and FPAs, particularly those related to human activities at the local or regional scale, as seen in

Table 3. However, ecological threats, such as invasive species, may require different responses that are context specific.

6.1 | Invasive species

Invasive species benefit from the connectivity of the aquatic environment to infiltrate fluid APA boundaries, and addressing them is labour intensive in both MPAs and FPAs. In the marine realm, tools such as removal efforts and sighting report forms are being used to manage an increasing population of invasive, highly predatory lionfish, *Pterois volitans* and *Pterois miles*, at an MPA in the state of Florida, USA (Johnston et al., 2016). In a freshwater example from the Gull Island Shoal Refuge case study, chemical lampricide is applied to kill larvae of the invasive sea lamprey (*Petromyzon marinus*) by targeting the lamprey's migration to river-based spawning locations. This extensive, costly control method has succeeded in reducing the abundance of sea lamprey and attacks on native fish (Heinrich et al., 2003), but is freshwater specific. In the freshwater case study in Myanmar, invasive Nile tilapia (*Oreochromis niloticus*) were being released into Indawgyi Lake as part of government stocking and religious ceremonies; however, both practices are ending after discussions with the group facilitating the establishment of the lake's FPAs.

6.2 | Development and upstream impacts

Many threats to both MPAs and FPAs come from human actions that degrade or pollute the habitat surrounding an APA, or connected waterways upstream (Mach et al., 2017). For example, important wetlands that serve as fish spawning and nursery habitats in the case study of Indawgyi Lake in Myanmar have been lost or damaged by conversion to agricultural lands, and untreated discharge from upstream gold mining is impairing lake water quality. Addressing such threats requires integrated spatial planning that accounts for APAs as one of many uses, as well as restoration of degraded habitats both inside and outside APAs. Addressing connectivity is especially relevant to riverine FPAs because the linear nature of rivers means they are generally at greater risk of fragmentation and anthropogenic threats than marine habitats (Cooke et al., 2014; Cowx & Portocarrero Aya, 2011), making catchment-scale approaches particularly important (Hermoso, Cattarino, Kennard, Watts, & Linke, 2015; Linke, Norris, & Pressey, 2008). However, coastal MPAs are also affected by upstream terrestrial inputs at the land–sea interface. It may be useful to consider these coastal MPAs as a downstream-most endpoint within a catchment framework, which would require including MPA managers in catchment planning efforts. Managing land-based threats can improve the resiliency of APAs and mitigate the cumulative impacts of other systemic threats.

6.3 | Large-scale threats

The development of dams for hydropower and irrigation is a uniquely freshwater challenge that represents a large-scale external threat to FPAs, such as those on the Mekong River in Lao PDR or the Tonle Sap Lake in Cambodia. Dam operation will likely alter the timing of flows and primary productivity, and impede movements of migratory fishes (Dang, Cochrane, Arias, Van, & de Vries, 2016; Kummu & Sarkkula, 2008). While integrated planning can also improve the environmental outcomes of hydropower development (Opperman, Grill, & Hartmann, 2015), the pace and scale of such development may require an adaptive management approach to FPAs in the short term, which can draw on approaches being taken to manage both MPAs and FPAs in the face of climate change. APAs should not be viewed as static, but as tools that can be adapted to promote conservation and sustainable use. In response to changing species distributions, ocean acidification, and the spread of low-oxygen zones, APAs may need to be moved or altered to continue protecting species of interest based on new ecosystem characteristics (Heino, Virkkala, & Toivonen, 2009; Soto, 2002). Networks of APAs may be required to create corridors in both realms to facilitate the movement of aquatic animals in response to environmental changes. In the case of hydropower, appropriate fish passage structures are also needed to minimize the disruption to population connectivity.

6.4 | Poverty

In the social context, poverty of nearby communities places pressures on the effectiveness and sustainability of both MPAs and FPAs in the

TABLE 3 Comparison of threats and strategies for MPAs and FPAs. Italics denote the location of a case study example

Threat	Marine protected areas	Freshwater protected areas	Strategies to address
Invasive species	Lionfish (Johnston et al., 2016)	Sea lamprey (*Laurentian Great Lakes*) Tilapia (*Myanmar*)	Targeted fishing (lionfish) Chemical control of larvae (lamprey) Ban restocking of exotic species (tilapia)
Development	Coastal construction (*Thailand, Mexico*) Mangrove conversion	Hydropower (*Cambodia, Lao PDR*) Wetland conversion (*Myanmar*)	Integrated spatial planning or zoning Restoration
Upstream impacts	Erosion, pollutants, runoff	Erosion, pollutants, runoff Gold mining (*Myanmar*)	Watershed management Regulations for businesses
Climate change	Ocean acidification Warming water temperatures	Warming water temperatures	Adaptive management Protected networks/corridors Move APA boundaries
Poverty	Marginalization of fishing communities (*Madagascar*) Lack of compliance	Migration and increased fishing pressure (*Myanmar*) Lack of compliance	Improve market access/revenue Zoning, community access areas Alternative livelihoods (nature-based tourism)
Illegal fishing	IUU fishing (*Madagascar*)	Electrofishing, small-mesh nets (*Cambodia, Lao PDR, Myanmar*)	Fisheries management and enforcement beyond APA boundaries

developing world, and strategies to address this challenge may be exchanged between realms. APAs that restrict access to aquatic resources may interfere with daily sustenance and survival needs, leaving communities little choice but to exploit other natural resources outside the APA, or to violate the APA rules to continue fishing (Bennett & Dearden, 2014). In these cases, options such as improved market access and increases in revenue per unit caught and/or processed become essential parallel strategies for managing fisheries. The development of community access areas as well as alternative livelihood options, such as nature-based tourism, can help alleviate dependence on aquatic resources as an important complement to establishing an MPA or FPA (Pollnac, Crawford, & Gorospe, 2001).

6.5 | Illegal fishing

Related to poverty is the threat of illegal and unsustainable fishing inside and outside of protected areas, which affects both MPAs and FPAs (Kritzer, 2004). In the Myanmar case study, the collapse of fisheries at Inle Lake, a major freshwater fishery in Myanmar, has prompted many migrants to settle in the Indawgyi Lake area. This has increased both fishing pressure and the use of illegal, unsustainable fishing practices, such as electrofishing, which similarly threaten FPAs in Lao PDR and Cambodia (Loury & Ounboundisane, 2015). In the marine environment, illegal, unreported, and unregulated fishing activities can also take the form of large-scale commercial operations, like industrial trawlers and sponsored sea cucumber dive teams that threaten the Velondriake LMMA in Madagascar (Cripps, 2009), and may be harder to address locally given the marginalization of poor communities that lack authority and resources to control and defend their APAs.

The threat of illegal fishing underscores the essential need for appropriate fisheries management beyond the boundaries of both MPAs and FPAs for the health of fisheries, and to protect APA focal species that utilize habitats outside the protected area (Cowx & Portocarrero Aya, 2011). Such management strategies include enforcement of bans on illegal fishing gear, minimum legal size restrictions, and catch limits determined through rigorous scientific research. Differing issues of scale may make such strategies more difficult to implement in highly accessible marine environments compared with freshwater environments, where it may be more feasible to regulate fishing for entire waterbodies. It is important for both realms to recognize that APAs are just one of several tools in a broader ecosystem-based management process, and multiple management tools may be needed to address the range of threats facing marine and freshwater fisheries.

7 | CONCLUSIONS

While marine and freshwater realms are often managed separately, our synthesis found many shared attributes between MPAs and FPAs (Table 2), suggesting the need for greater exchange. Despite differences in ecology, both realms would benefit from sharing broader spatial planning and ecosystem-based management approaches, particularly regarding migratory species, and especially for diadromous species. Ultimately, freshwater and marine systems are connected, so collaborative work could begin to develop around protected areas that span systems, such as lagoons, deltas, estuaries, and river outflows.

Both MPAs and FPAs represent a range of establishment models, from top-down, government-driven initiatives to bottom-up, community-based initiatives, which provides ample opportunities to exchange best practices. Small, community-managed MPAs and FPAs, which represent the majority of the case studies presented here, may potentially have more in common with each other than with large, government-established APAs. Stakeholder engagement is crucial in both realms for all types of APAs, and well-documented lessons from MPAs can be applied as more FPAs begin to be established. Key lessons from the field of MPAs, such as the collection of baseline data before establishment, and approaches used for the long-term monitoring of MPAs, should inform the development of such tools for FPAs. Both realms can work together through synthesis of literature and collective meetings to address a shared data gap in socio-economic and governance monitoring, recognizing that APAs are not just spatial or ecological systems, but also complex social systems with multiple stakeholders interacting in various ways. The realms also face many similar threats and challenges, and could collaboratively develop mechanisms to address these through joint proposals, committees, and reviews. For example, identifying and understanding finance mechanisms is needed for both MPAs and FPAs in a global context, perhaps by engaging the private sector as a part of conservation activities, or exchanging successful strategies to diversify income sources. Both fields can also face challenges of active management from failing to adequately consider both biological and social goals, as well as inherent tradeoffs, which are issues that could be explored jointly (Balmford et al., 2004; Burke, Reytar, Spalding, & Perry, 2011; Christie & White, 2007).

Connecting people from marine and freshwater backgrounds could be better accomplished by improving understanding of the 'other' realm's terminology. Therefore, defining shared terminology would facilitate communication within and across realms. The scientific literature has generally converged on 'marine protected area' as a consistently used term to encompass the variety of spatially-defined approaches to managing and conserving marine environments and species, although variations exist (e.g. 'marine reserves,' 'marine parks'), and terms can be context dependent. In contrast, terminology for protected areas in freshwater environments is perhaps less unified, with examples from different countries as varied as 'fish conservation zones' (Baird, 2006), 'reserves' (Silvano, Ramires, & Zuanon, 2009), and 'freshwater fish safe zones' (Gupta, Raghavan, Sivakumar, & Mathur, 2014). Suski and Cooke (2007) recommend the term 'freshwater protected area' to standardize terminology, and to facilitate literature searches and dissemination of research. Using similar or the same searchable terms would allow case studies and examples to appear more frequently together when conducting a literature review. Viewing marine and freshwater protected areas as part of the larger study of 'aquatic' protected areas is one step in this direction.

One of the most direct ways to foster increased collaboration would be to provide mechanisms that enable continued sharing of information and lessons learned. Holding cross-disciplinary conferences or conference sessions, such as the session at the 7th World Fisheries Congress that is the basis for this paper, is one avenue for increased communication within the larger scientific community. Researchers and managers can close the gap between those working in marine and freshwater realms by actively engaging in a transdisciplinary learning approach; attending and hosting inclusive seminars and workshops; writing inclusive journal articles; and establishing collaborative networks, joint committees, and scholarly resources that bridge realms. Indeed, it is not the level of salinity that should define these interactions, but rather the common fundamental and applied questions, which clearly overlap.

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