For example, in Mexico and Colombia, areas with the greatest MRE resource potentials often overlap fragile ecosystems such as seagrass meadows and mangrove swamps. In Brazil, experts have raised concerns around potential impacts on coral reef areas during installation, especially given the extreme vulnerability of these ecosystems and the potential irreversibility of any negative effects. Potential impacts on marine mammals from MRE development in Brazil is also an area of study.

Effects on biodiversity and ecosystems functions have been identified as the most important concern and there is a need to consider all species of an ecosystem, as well as interactions between species, when examining the environmental effects of MRE in tropical and subtropical regions, instead of focusing on a limited number of key species (e.g., sea turtles) as it is commonly done in temperate regions. Several species in tropical and subtropical regions contribute to the high biodiversity of marine ecosystems and are often listed as endangered or threatened (e.g., sea turtles, whale sharks, whales, manta rays, dolphins, corals).

III. Socio-economic concerns in tropical and subtropical regions

In tropical and subtropical regions, MRE development may have significant socioeconomic effects on nearby coastal and island communities if these needs are not considered during the project planning phase. These coastal and island communities are often small, isolated, and reliant on expensive diesel fuels for electricity generation.

As it is often the case with new renewable energy projects, impacts on local communities and tourism are important concerns for coastal communities. The acceptance of MRE projects along coastlines may be challenging due to impacts to viewsheds, to existing uses of the ocean, or in conflict from the "not in my backyard" effect. These concerns are often expressed as environmental concerns, as there is insufficient information about environmental effects of MRE. Coastal communities are keen observers of new project developments in their marine space and often participate in development process, so their social perceptions play a crucial role which can slow down or stop projects.

More than in temperate areas, coastal communities in tropical and subtropical regions rely heavily on nearshore fisheries and tourism activities to support their economies. In Chile for example, the Lafkenche law, passed in 2008, provides exclusive access rights to coastal areas and resources to indigenous communities. A need for new policies has been expressed in Chile to allow the co-existence of artisanal fisheries and MRE, based on potential interactions of MRE installations and support infrastructure with the fisheries. Other potential conflicts include interactions with tourism and recreation activities (e.g., wave energy and surf tourism), ports and navigation infrastructure, naval operations, etc. For instance, MRE projects in Brazil can be easily halted due to negative public perceptions and community opinions if perceived as a risk to the fishing and tourism activities in vulnerable coastal communities.

IV. Research needs and knowledge gaps

When considering the development of MRE in tropical and subtropical ecosystems, there is a lack of scientific information about the possible environmental effects, as compared to temperate regions. This lack of scientific information is largely due to the scarcity of MRE projects deployed in these ecosystems so far, as well as limited research funding available to investigate potential effects. The slow development of the MRE industry in these regions is generally linked to the lack of investment from government entities and to environmental and social constraints. The lack of long-term baseline environmental data prevents a comprehensive understanding of the natural variations of ecosystems, which is needed to evaluate the potential effects of MRE projects [10].

To get a better understanding of the environmental effects of MRE in tropical and subtropical ecosystems, studies need to go beyond the framework of stressor-receptor interactions that is being used in temperate regions. Except for interactions related to OTEC technologies that can only be deployed in tropical and subtropical regions, there are no interactions entirely specific to the tropical and subtropical regions; differences lie in the species and habitats that are potentially impacted. Therefore, considering the whole ecosystem and the linkages between species is key [11].

Social perception also plays a crucial role across tropical and subtropical regions and can become a barrier to the development of the MRE sector [12]. Concerns could be mitigated with strong community involvement from the inception of an MRE project, by engaging and consulting with local leaders and residents, and by educating stakeholders on MRE in general and environmental effects in particular. Awareness and education are key to community acceptance.

While access to research funding is often more limited in tropical and subtropical regions, baseline environmental research is needed to address concerns for environmentally protected marine areas that may include endangered or threatened species, coupled with socioeconomic research that will enable understanding of the potential impacts on local communities. Several recent studies have combined the investigation of both environmental and social effects to select sites for MRE projects in Mexico for salinity gradients [13], wave energy, current energy, and OTEC [14], and in China [15] and Colombia [16] for OTEC.

V. Conclusion

Tropical and subtropical marine ecosystems are composed of diverse habitats and complex ecological interactions spanning from the shoreline to the open ocean [17]. These ecosystems face unprecedented anthropogenic threats and are vulnerable to environmental variations [18]. All countries considered to be megadiverse are in the tropical zone and there is a clear overlap between these biodiversity hotspots and MRE resources [2]. These characteristics make tropical and subtropical ecosystems highly sensitive and increase their vulnerability to the cumulative effects of anthropogenic activities at sea, including MRE development.

To advance the knowledge on the environmental effects of MRE and enhance the acceptance of a MRE project in tropical and subtropical ecosystems, it is necessary to identify priority and vulnerable habitats to avoid when siting, engage with stakeholders from the planning stages, and develop eco-friendly technologies and structures to limit the negative impacts on the ecosystems.

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