Received: 10 May 2021 | Revised: 12 October 2021 | Accepted: 15 October 2021

DOI: 10.1111/cobi.13855

Conservation Biology

ESSAY

# Power, politics, and culture of marine conservation technology in fisheries

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**Article impact statement**: Better incorporation of human and societal dimensions in marine conservation technology may improve conservation function and benefit.

**Abstract**
The term *conservation technology* is applied widely and loosely to any technology connected to conservation. This overly broad understanding can lead to confusion around the actual mechanisms of conservation in a technological system, which can result in neglect and underdevelopment of the human dimensions of conservation technology. Ultimately, this hinders its effectiveness as technological fixes for conservation problems. Through a process of concept mapping based on key case studies and literature, I devised precise definitions of *marine conservation technology* and *technological marine conservation system*. Concerns about the use of marine conservation technologies included unintended consequences, halfway technologies that address the symptoms but not the causes of problems, and misguided techno-optimism (i.e., technology is a panacea that can solve any problem). Technology and technological systems can have power, politics, and culture, and these characteristics can influence the contextual fit of a technology, requiring that technology be thoughtfully created or adapted to the circumstances in which it will be used. Power, politics, and culture inherent in technology can also influence the distribution of conservation risks and benefits and potentially widen gaps in wealth, privilege, opportunities, and justice. Addressing these concerns can potentially be achieved through the better integration of social sciences in marine conservation technology and technological marine conservation system design and development and the application of the social-ecological-technological systems framework. This framework melds key concepts from the socioecological systems framework and science and technology studies. It recognizes as and elevates technology to be a central actor that can shape societies and the natural world. Such a framework incorporates broader understanding, so that the values and concerns of society are more effectively addressed in the creation and implementation of marine conservation technologies and technological marine conservation systems.

**KEYWORDS**
bycatch reduction devices, human dimensions, science and technology studies, social-ecological systems, social-ecological-technological systems, societal dimensions, technological fixes, technological systems

Poder, Política y Cultura de la Tecnología de Conservación Marina en las Pesquerías

**Resumen:** El término *tecnología de la conservación* es aplicado extensa y ligeramente a cualquier tecnología vinculada a la conservación. Este concepto excesivamente generalizado puede resultar en una confusión en torno a los mecanismos actuales de conservación incluidos en los sistemas tecnológicos, lo que puede llevar al descuido y subdesarrollo de las dimensiones humanas que tiene la tecnología de la conservación. Como última instancia, esto obstaculiza su efectividad como arreglo tecnológico para los problemas de conservación. Construí las definiciones precisas de *tecnología de conservación marina* y *sistema tecnológico de conservación marina* mediante un proceso de mapeo de conceptos basado en estudios importantes de caso y en la literatura. Las inquietudes en cuanto al uso de la tecnología de conservación marina incluyen las consecuencias accidentales, tecnología a medias que aborda los síntomas, pero no la causa de los problemas y tecno-optimismo mal dirigido (es decir, la tecnología es una panacea que puede resolver cualquier problema). La tecnología y los sistemas tecnológicos pueden tener poder, políticas y cultura, y estas características pueden influir sobre el ajuste contextual de la tecnología, lo que requiere que la tecnología sea creada o adaptada cuidadosamente a las circunstancias en las que será utilizada. El poder, las políticas y la cultura inherentes a la tecnología también pueden influir sobre la distribución de los riesgos y beneficios de la conservación y pueden potencialmente ampliar las brechas en la riqueza, el privilegio, las oportunidades y la justicia. La solución a estas inquietudes puede lograrse potencialmente por medio de una mejor integración de las ciencias sociales a la tecnología de la conservación marina y al diseño de sistemas tecnológicos de conservación marina y por medio del desarrollo y aplicación del marco de trabajo de los sistemas socio-ecológicos-tecnológicos. Este marco de trabajo combina conceptos clave tomados del marco de los sistemas socio-ecológicos con aquellos de los estudios científicos y tecnológicos. También reconoce y eleva a la tecnología como un actor central que puede moldear a las sociedades y al mundo natural. Dicho marco incorpora una comprensión más amplia, de tal manera que los valores e inquietudes de la sociedad se abordan de manera más efectiva durante la creación e implementación de las tecnologías de la conservación marina y los sistemas tecnológicos de conservación marina.

**PALABRAS CLAVE**

arreglos tecnológicos, dispositivos de reducción de la captura incidental, dimensiones humanas, dimensiones sociales, estudios científicos y tecnológicos, sistemas socio-ecológicos, sistemas socio-ecológicos-tecnológicos, sistemas tecnológicos

**【摘要】**

“保护技术” 一词被宽泛地用于任何与保护有关的技术, 但这种过于宽泛的认识会混淆技术系统中实际的保护机制, 可能导致保护技术的人类维度被忽视并发展不足, 最终将影响保护技术作为保护问题的技术解决方案的有效性。研究者通过基于关键案例研究及文献的概念映射过程, 提出了 “海洋保护技术” 和 “海洋保护技术系统” 的精确定义。人们对使用海洋保护技术的担忧包括产生意外后果, 技术治标不治本, 不能彻底解决问题, 以及被误导的技术乐观主义 (即认为技术可以解决任何问题) 。技术和技术系统也具有权力、政治和文化, 这些特征可以影响技术的环境适应性, 要求对技术的创造要经过深思熟虑, 并确保技术适应其使用环境。技术中固有的权力、政治和文化也会影响保护中风险和利益的分配, 并可能扩大财富、特权、机会和正义的差距。这些问题的可能解决方案包括更好地将社会科学整合到海洋保护技术和海洋保护技术系统的设计和发展之中, 以及应用社会-生态-技术系统框架。该框架融合了社会生态系统框架和科学技术研究中的关键概念, 并将技术的地位提升为塑造社会和自然世界的关键驱动力。这一框架还包含了更广泛的理解, 从而可以在创造和实施海洋保护技术和海洋保护技术系统时更有效地应对社会价值及社会关注问题。**【翻译: 胡怡思; 审校: 聂永刚】**

**关键词:** 社会-生态-技术系统, 技术系统, 人类维度, 技术解决方案, 社会维度, 减少副渔获物装置, 社会-生态系统、科学和技术研究

## INTRODUCTION

Benefits that result from the use of marine conservation technology (MCT) vary depending on the context. The literature on MCTs in fisheries, such as bycatch reduction devices, focuses on how physical and biological factors, such as fishing gear configurations or species assemblages, influence the function and beneficial outcomes of MCTs. How social factors, such as power, politics, and culture, influence the conservation function and benefits of MCTs has not been explored deeply. Although the same physical technology may be transported and applied around the world, the people who invent, modify, or use it differ in where and how they live and work, what they believe and value, and their education and wealth. These factors can influence conservation outcomes.

Power, politics, and culture may be external components to the physical technology, but they are still an inherent component of the technology (Barry, 2012; Jasanoff, 2016; Pacey, 2014; Winner, 1986). A useful analogy would be the dependence of the human body on air, food, and water. People tend to view these as associated and important, but not a connected component of the body. But, though external, they are inherently necessary because without them the body dies. Likewise, power, politics, culture, and technical matters are interdependent systems that must all work together to form successful conservation technology.

The process of invention and innovation must begin to attend more to these social elements. As John Barry (2012) states,

> The transition from unsustainability is one in which innovation is absolutely vital, and that includes technological innovation. But it also requires and involves what might be called 'full spectrum innovation', new ways of doing, collaborating, governing, and thinking at different scales and in different places. It requires in short social innovation, which is much more difficult, longer term and more uncertain than the easier and less uncertain (though of course not without risks) path of technological innovation.

This interaction between technology and people and society is a critical consideration in obtaining conservation benefits from MCTs. In creating MCTs, the field of marine conservation must begin to attend to the human and societal aspects of technology as much as they attend to engineering aspects and ecological impacts. In the words of the science and technology studies scholar, Sheila Jasanoff, "new and emerging technologies redraw the boundaries between self and other and nature and artifice. Technological inventions penetrate our bodies, mind, and social interactions, altering how we relate to others both human and nonhuman" (Jasanoff, 2016). The redrawing of boundaries and the alteration of nature and society will flow from the creation and use of MCTs, so we must actively and consciously engage in shaping these boundaries and guiding these alterations.

I considered the problems that can arise from not thoroughly accounting for social issues, such as power, politics, and culture, when creating and implementing MCTs and associated technological systems. These social problems include the potential for societal risks that are not anticipated and addressed and inequitable benefits and harms experienced by different segments of society. Failure to consider and resolve such issues can prevent MCTs from reaching their full potential of conservation benefits.

I determined key terms and clarified definitions related to MCTs and fleshed out some of the problems and criticisms with the current use of MCTs. I also considered in depth how MCTs and associated technological systems have critical social elements (i.e., power, politics, and culture). Incorporating an understanding of MCTs that is inclusive of these social elements can help develop and implement MCTs that are more effective by addressing a range of critical values and concerns of people and society. The social-ecological-technological systems framework can be used to incorporate social elements and address social concerns in the development and implementation of MCTs and technological systems.

## DEFINITIONS

Although the term *conservation technology* originated in agricultural literature around techniques for soil conservation, it was first applied to marine conservation in 1996 to refer to technological approaches for reducing overfishing (Chopin et al., 1996). Subsequently, the conservation community has used it broadly, and current understanding of conservation technology is problematically wide yet shallow. It is wide in that it encompasses most any technology that can aid conservation, even indirectly. An example is remote sensing and telemetry technologies (e.g., GPS, sensor tags, satellites, and drones), which yield information but do not have a direct conservation function (Nyman, 2019). The current understanding is also shallow because it overly focuses on high-tech devices (Berger-Tal & Lahoz-Monfort, 2018).

The field of science and technology studies offers a nuanced and socially contextualized understanding of technology. *Technology* can be defined as a physical component with a practice (Rogers, 1995; Pacey, 2014). The physical component can be hardware, liveware, or both. Hardware consists of the tool that embodies the technology as a material or physical object (Rogers, 1995). Liveware is when a living thing is used as a tool in a technical process (Pacey, 2014), such as biological control of invasive species through predator introductions or gene editing (Owens, 2017; Berger-Tal & Lahoz-Monfort, 2018).

The practice component of technology is the information base, such as software, philosophy, or process (Rogers, 1995). But more expansively, practice includes the organizational component (e.g., economic, regulatory, and professional activities; governance; and stakeholder groups) and the cultural component (e.g., goals, values, and ethics) that create the system in which the technology operates, is supported, and constrained (Figure 1) (Pacey, 2014). These aspects give evidence to the fact that all technologies have a social (i.e., practice) component to some degree (Bergman et al., 2010). Also, in this broader sense, especially at industrialized scales, the technological practice is largely synonymous with a technological system.

Four terms can be used to differentiate and clarify the use of technology within marine conservation: *conservation function*, *conservation benefit*, *marine conservation technology*, and *technological marine conservation system*. I considered how these terms can sharpen the understanding of the use, power, and impact of technology on nature and society and how this improved understanding can lead to better practice around conservation technologies.

*Conservation function* is a purposeful design feature intended to yield a certain conservation outcome. *Conservation benefit* is a

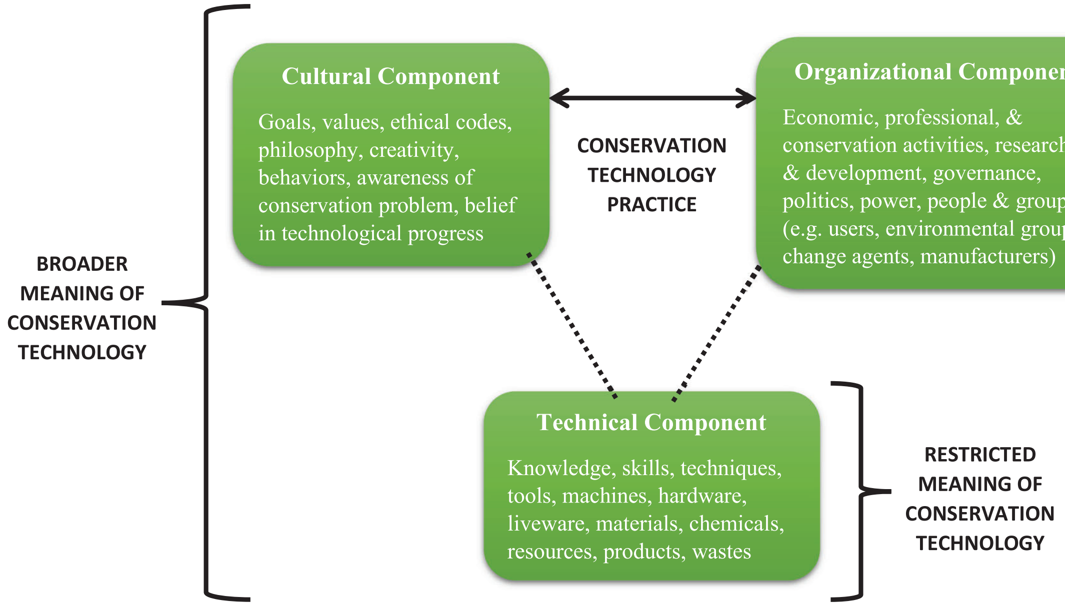


**FIGURE 1** Restricted and broader definitions of conservation technology (adapted from Pacey, 2014)

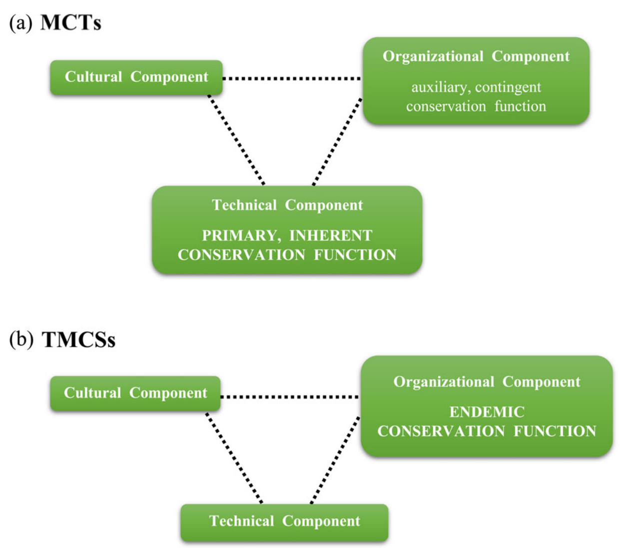


**FIGURE 2** Differences in location and nature of conservation function between (a) marine conservation technologies (MCTs) and (b) technological marine conservation systems (TMCSs)

positive conservation outcome. With these definitions in mind, MCT is best understood as a tool that directly protects marine organisms and habitats (e.g., bycatch reduction devices in fishing). For an MCT, conservation function is inherent to the tool. Although, like all tools, there is an associated practice, which can have a conservation function as well (Figure 2a). An example of this would be the governance (e.g., technology practice) of bycatch-reduction devices and whether their use is mandatory and enforced, which can increase conservation function (Jenkins, 2006; Eayrs et al., 2019).

For other marine conservation approaches that incorporate technology, the term *technological marine conservation system* (TMCS) can be applied. For a TMCS, technology is used to contribute to a process of conservation, but the technology on its own cannot yield a conservation benefit (e.g., drones). In a TMCS, the technology does not have an inherent conservation function, rather the conservation function is embedded in the organizational component of the technology practice (Figure 2b). By its nature, a TMCS is a technological system. Importantly, MCTs are also usually incorporated in a technological system when being widely applied as a conservation solution or technological fix.

Notably, the intention behind the technology practice can lead to activities that negate the overall conservation benefit. For example, conservation technologies to protect habitat include rollers and sleds to lift trawl fishing gear so as to reduce damage to the sea floor. In some fisheries, fishers have used rollers not to protect habitat, but rather to fish in areas that were previously unfishable due to rough terrain, thus damaging areas that had been previously undisturbed by trawl gear (Morgan & Chuenpagdee, 2003). Here, the intent of the user changed the technology practice. The conservation technology was being used in a place where it was not intended for a purpose that was not intended (i.e., exploitation), so the magnitude of bottom damaged had increased compared with the status quo. The negation of conservation benefit because of a technology practice not aligned with conservation goals can occur with either MCTs or TMCSs.

## PROBLEMS AND CRITICISMS

In comparison with management options, such as time and area closures, in which technology is not the source of conservation function, conservation technology as a technological fix often requires fewer changes in the behavior of the resource users

(Sarewitz & Nelson, 2008). Consequently, conservation technologies can be an unjustified yet preferred management option subject to unrealistic expectations and misapplications. This has led to some criticisms.

## HALFWAY TECHNOLOGY

Frazer (1992) points out that some technological fixes are "halfway technologies" (i.e., technologies that address the symptoms of a problem but not the cause of the problem). Frazer (1992) backs his argument with the example of a misguided TMCS involving sea turtle captive breeding, hatcheries, and head-starting programs. The TMCS used these approaches to try to increase turtle populations, which are declining (i.e., the symptom) because of incidental capture and death in fisheries (known as bycatch) and disorienting beach lighting (i.e., the causes). Frazer cites several studies to support that the better solutions are to use turtle excluder devices (TEDs) to reduce the deaths of large juvenile and adult sea turtles in shrimp trawl nets and to use low-pressure sodium lighting on beaches to prevent disorientation of nesting females and natural hatchings (Crouse et al., 1987; Witherington & Bjorndal., 1991; Frazer, 1992). These MCTs directly address the causes of sea turtle mortality, unlike captive breeding and head-starting programs.

Halfway technologies can be seductive yet dangerous. In navigating the complexities and tensions of political and governance structures, halfway technologies can be a way to appear to be addressing a problem without requiring significant change in the behavior of stakeholders (i.e., any involved group ranging from resource users to managers and regulators). The danger is that this can expend political will and public attention so that people unknowingly move away from the issue before the problem is truly solved. (This is different from an informed and conscious choice not to truly solve a problem as a trade-off among societal priorities.)

## TECHNO-ARROGANCE AND RELATED CONCEPTS

Meffe (1992) argues that people have developed a "techno-arrogance," which is the failure to recognize or accept limitations and ramifications of the attempted control through technology of our human environment and nature. He states that

> humankind has adopted a shortsighted and ultimately self-defeating philosophy toward nature and our modification of it. We seem to feel that we can solve any man-induced problem in the natural world, be it habitat destruction, the spread of exotic species…and even global climate change, through even further modifications using a concerted application of technology. The notion is that we can right virtually any wrong, given enough money, motivation, and innovation. And if any of those "solutions" cause unanticipated problems, simply apply more technology (Meffe, 1992:351).

Meffe explains this idea with the example of the use of hatcheries to recover Pacific salmon (*Oncorhynchus*) populations without addressing the ongoing overfishing and habitat destruction that originally caused the crisis. These hatcheries have also created other problems, such as negative effects on the genetics of natural salmon populations, water pollution, and habitat alteration.

The concept of techno-arrogance is closely related to techno-optimism, techno-addiction, and human exemptionalism paradigm. Techno-optimism is "an exaggerated and unwarranted belief in human technological abilities to solve problems of unsustainability while minimising or denying the need for large-scale social, economic and political transformation" (Barry, 2012). Techno-optimism has been raised as an issue for the use of drones, automated identification systems for vessels, and satellite surveillance to combat piracy and illegal, unreported, and unregulated fishing (Nyman, 2019). Techno-addiction is the societal obsession with technologies that are illusory solutions to problems that are fundamentally social, psychological, or spiritual in nature (Huesemann, & Huesemann, 2011). The human exemptionalism paradigm is a worldview that justifies human dominance over nature through technology based on the belief that humans are unique from other organisms, independent from nature, and can solve any problem with human ingenuity (Williams, 2007; Gardezi & Arbuckle, 2018). The human exemptionalism paradigm, techno-arrogance, -optimism, or -addiction can lead to recklessly embracing the benefits of MCTs and TMCSs without addressing environmental, societal, and other associated risks. This may lead to problems that further innovation cannot solve, and then society and nature may be left to suffer the consequences.

## UNINTENDED CONSEQUENCES

Often people label consequences as unintended. There are several types of unintended consequences, including unexpected benefits, unexpected drawbacks, and perverse outcomes (i.e., a result contrary to what was intended). For instance, in Ecuador, an organization promoted the use of circle hooks to reduce sea turtle mortality in fisheries that resulted in an unexpected drawback. The fishers perceived that the hooks also increased the capture of profitable sharks, which the fishers could not legally target but could land and sell if they were captured incidentally. So, some fishers started using circle hooks not to protect sea turtles but to capture imperiled sharks (Jenkins et al., 2012).

Some science and technology studies scholars argue that *unintended consequences* is a misnomer. Jasanoff (2016) contends that consequences are foreseeable and that people, businesses, and society would rather not foresee them, so they place inadequate effort into considering consequences. Winner (1986) claims that the process of innovation is biased in favor of certain social interests, resulting in technologies that inequitably benefit and harm different segments of society. For the everyday person, our values and cultural norms greatly influence our thinking and thus the technologies we produce and use. Hence, I believe it is unlikely that without special training, adequate resources, and motivation, that the average innovator or user would anticipate anything but the most obvious consequences. However, Jasanoff and Winner reason that with social and political will and a "moral and political language" (Winner, 1986) for discussing and evaluating technologies, many consequences of technologies could be anticipated and preemptively addressed.

## POWER, POLITICS, AND CULTURE

Three elements (i.e., power, politics, and culture) of the social component of technology are often overlooked when creating MCTs and TMCSs. I examined knowledge from the science and technology studies literature about the importance of considering these elements and the problems that arise if they are not considered and drew parallels between the science and technology studies literature and fisheries examples that illustrate these concepts.

### Power

Technology can have power to shape nature, to shape society, and to shape people. Technology can have the power and authority to rule and govern people (Jasanoff, 2016). Jasanoff (2016) illustrates this idea with the example of traffic lights that supersede human judgment of safety and have the authority to regulate human behavior.

Likewise, MCTs and TMCSs can have power. An excellent example is the current development of autonomous vessels to police marine protected areas. These vessels use artificial intelligence to patrol marine protected areas, to identify the presence of vessels, to determine whether they are just transiting through or engaging in a prohibited practice (e.g., fishing), and to document their presence and activity with video and GPS. Currently, government lawyers and conservation and enforcement experts are trying to determine if evidence gathered from autonomous vessels would be admissible in court (Minke-Martin, 2020).

Although this TMCS has great potential to patrol large marine protected areas that are prohibitively expensive to police with typical crewed boats, there are also concerns around power that must be considered. These vessels have the power to identify and report someone as a lawbreaker. And unlike with traditional enforcement, there is no one to whom to explain one's circumstance. For instance, what if a fisher was outside of park boundaries and then experienced a power loss and drifted into park boundaries with fishing gear in the water? In California having gear in the water inside of a marine protected area is grounds for prosecution (Minke-Martin, 2020).

Autonomous vessels also have the power to potentially increase the wealth and power divide and worsen disparities in access to resources and opportunities. A touted direct benefit of marine protected areas to the local community is the creation of local jobs as guardians for the marine protected area. Would autonomous vessels take these jobs? Also, some developing countries cannot afford basic enforcement let alone an autonomous vehicle. Moreover, these same countries often lack the scientific resources and manpower to analyze all the data these vessels would produce (Nyman, 2019). Will the use of autonomous vessels in wealthy countries further push industrial-scale illegal fishing into the waters of developing countries and cost their people precious resources? While designing the conservation function of MCTs and TMCSs, one must actively design the social aspects of the technological system to address these questions around power.

### Politics

Technology can have politics. According to Winner (1986), "[t]he issues that divide or unite people in society are settled not only in the institutions and practices of politics proper, but also, and less obviously, in tangible arrangements of steel and concrete, wires and semiconductors, nuts and bolts." Winner (1986) supports this declaration with the classic case of Robert Moses, the so-called master builder of New York City. Moses embedded his prejudices into 200 overpasses, designing them with only nine feet of clearance for cars but not buses to pass under. Thus, he gave access to recreational nature areas, such as Jones Beach, to car-owning, middle-class or better, primarily white people, while effectively excluding access to lower-class and minority people who rode buses (Winner, 1986).

Technologies can also have politics due to inattentiveness. Until the passing of the Americans with Disabilities Act, people with disabilities were excluded from many aspects of public life because of neglect. Architects, designers, and engineers neglected to consider the needs of people with disabilities when creating buildings, transportation systems, and communication systems (Winner, 1986). Subsequently, these were and are being redesigned and rebuilt, illustrating that with political will even major technologies and technological systems can be reworked to remove injustices embedded in them.

Winner (1986) shows that technologies can be political in two ways. First, they can be inherently political, such as with nuclear power that requires a complex system to manage the hazardous, weaponizable substances needed to create it and produced by it (Winner, 1986). Second, there are cases where the design of a technology is used to resolve an issue within a community, such as curb cuts and other accommodations for people with disabilities.

Like these examples, MCTs and TMCSs also can have politics. An MCT is usually adopted at personal cost for the common good, especially in fisheries. Fishers bear a personal financial and time cost of purchasing, maintaining, and using MCTs to protect aspects of the marine environment, such as marine mammals, sea turtles, and seabirds, for the common good of the public that treasures these animals. The common good is expressed through laws, rules, and regulations, which by their nature are political. Ensuring compliance to these regulations requires a political system of monitoring and enforcement (Jenkins, 2006; Eayrs et al., 2019). Furthermore, the general study and practices around ecological problems are often political (Morgan, 2018). This can result in MCTs and TMCSs that are political intentionally or from lack of attentiveness to broader implications.

One instance of an MCT system that was political through lack of attentiveness was the failure to consider the politics of steel in the use of circle hooks to prevent the bycatch of sea turtles in Ecuador (Jenkins et al., 2012). The designers of the promotion system chose circle hooks made of stainless steel because they prevent rust and corrosion, but the designers did not consider the political implications of steel in different locations. Ecuador does not manufacture steel and places a tariff on the importation of steel products. The need to import hooks meant that fishing gear suppliers would need to buy circle hooks in large quantities. This coupled with the tariffs made the costs of circle hooks too high for the suppliers and their customers. In retrospect, from its inception, the MCT system should have included a mechanism to negotiate with the Ecuadorian government for a tariff exemption for circle hooks. (This did eventually occur but after initial enthusiasm for circle hooks had waned.) To avoid similar problems, the evaluation of MCTs and TMCSs must go beyond the obvious uses of a tool to also include a moral and political language for evaluation. Understanding of the broader implications of the design of MCTs and arrangement of TMCSs is needed (Winner, 1986; Vardouli, 2015).

Marine conservation technology and TMCSs can be inherently political or a way of settling a political issue. For example, with the passing of the Marine Mammal Protection Act and Endangered Species Act in the United States, the bycatch of dolphins and sea turtles became a political concern. In response, scientists, engineers, and fishers created MCTs, such as the Medina panel and TEDs, to help dolphins and sea turtles escape from fishing nets (Jenkins, 2007; Jenkins, 2010). These technologies settled much of the concern around dolphin and sea turtle bycatch. Subsequently, the United States passed a law requiring the use of TEDs in fisheries around the world that export seafood to the United States. The technological system for implementing this law was large, complex, and political because it was necessary for engaging and negotiating with other governments to implement a U.S. law in sovereign waters of foreign nations (Benaka et al., 2012; Senko et al., 2017). The technological system for international use of TEDs is an example of an inherently political MCT system.

Whether intentionally or unintentionally, societies choose structures for technologies that influence how people work, communicate, travel, and consume. Over the course of these decisions, various people are positioned differently and possess unequal degrees of power and information. In cases of inherently political technologies, the need to keep the large, complex technological system functioning is often prioritized over other moral or political concerns (Winner, 1986). For example, in the case of international use of TEDs, the United States initially recognized that different countries had different capacities for implementing and enforcing the use of TEDs. So, the United States gave more flexibility to some nations, especially developing nations, in how quickly and fully they became compliant with the regulations on TED use. This prompted other nations to sue the United States through the World Trade Organization, forcing the United States to treat every country the same, regardless of wealth or capacity (Brotmann, 1999; DeSombre & Barkin, 2002). The result was an MCT system that was equal but not equitable because the full cost of complying with the regulations was more burdensome for developing countries.

## Culture

Technology can have culture. To be useful, technology must be a part of life. It must fit into a certain pattern of activities, lifestyles, and values, such as practical uses, status symbols, required supporting technology and infrastructure, and required skills and expertise (Pacey, 2014). In short, technologies are often shaped in the image of their maker and imbued with the hallmarks of the maker's culture, sometimes to the extent of making the technology difficult to use in other cultural settings.

In a classic example from the science and technology studies literature, Pacey (2014) illustrates that technology can have culture with snowmobiles. Snowmobiles became a commercial success in the 1970s as a recreational vehicle marketed to the wealthy. The design of the machine was for brief periods of use in relatively balmy winter conditions, reflecting the purpose of recreation and the values of the target customer. When people in the artic began using snowmobiles for work and survival, they had to reengineer it to carry extra fuel for long trips, to hold tools for emergency repairs, and with the capacity to haul cargo and tow sleds. The history of the snowmobile is an example of how "a machine designed in response to the values of one culture needed a great deal of effort to suit the purposes of another" (Pacey, 2014).

Further evidence that conservation technologies change in different settings is the impact of cultural changes on the technical components of conservation technologies. As TEDs were implemented in various segments of the U.S. shrimp fishery, the structure of the device changed. For example, bycatch of juvenile red snapper was a concern for some stakeholders, especially for the Florida shrimp fishery. This concern was a value (i.e., part of culture) and specific to only a portion of the shrimp fishery. To address this value, federal government scientists and Sea Grant extension agents created TEDs that also reduced finfish bycatch (Jenkins, 2012). However, in some shrimp fisheries, especially in developing countries, the crew is paid in part or in whole with the bycatch of finfish, so a TED that also excludes finfish would not be embraced in these locations. If one neglects or separates the cultural component from the technology, then the MCT or TMCS will likely have less or no conservation function, resulting in fewer or no conservation benefits (Jenkins, 2006).

# MARINE SOCIAL-ECOLOGICAL-TECHNOLOGICAL SYSTEMS

I have shown that power, politics, and culture are important aspects of MCTs and TMCSs that deserve attention and research. Unfortunately, in comparison with technological

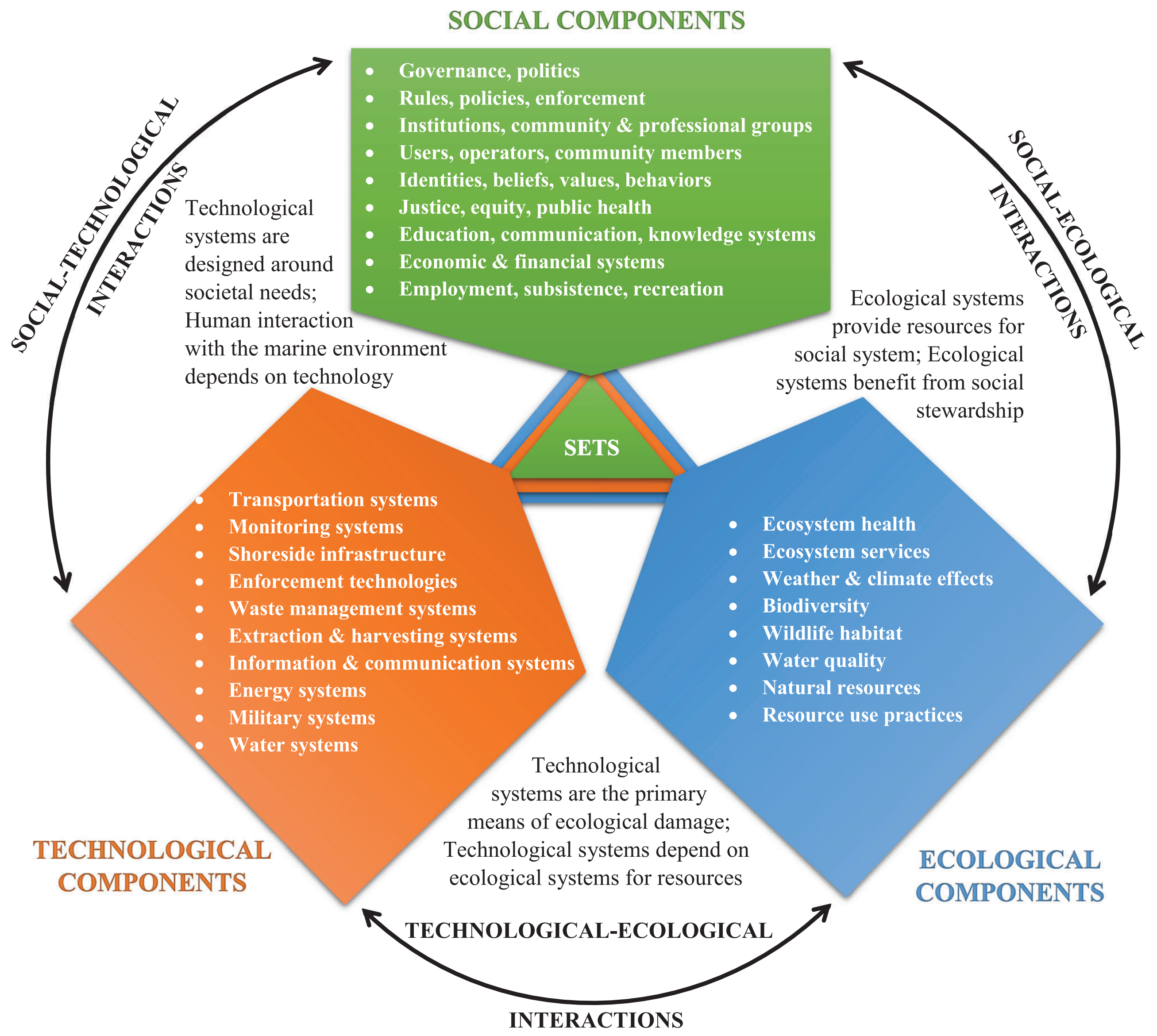


**FIGURE 3** Overview of social, ecological, and technological components and interactions of marine social-ecological-technological systems (adapted from Markolf et al., 2018)

innovation, social, cultural, and political innovation are often undervalued, receiving less funding and resources (Bergman et al., 2010; Barry, 2012). More fully exploring and incorporating human and societal dimensions of MCTs and TMCSs requires the expertise of marine social scientists. However, marine social science is underutilized, marginalized, and disempowered in the field of marine conservation, which often privileges natural science (Aswani et al., 2018). A more interdisciplinary approach to innovation of environmental technologies, such as MCTs, that includes social scientists, historians, and philosophers is needed (Moon & Blackman, 2014; Bennett et al., 2017). Moreover, a transdisciplinary approach is needed that empowers end users, citizens and stakeholders in the innovation and evaluation of environmental technologies (Barry, 2012). This can lead to bottom-up innovation by civil society and user-led innovation, which can result in contextually appropriate technologies that integrate social and cultural concerns (Ornetzeder & Rohracher, 2006; Bergman et al., 2010).

The social-ecological systems framework seeks to bridge these divides between natural and social sciences and systems. But, some social scientists find this framework lacking because of disciplinary differences in understandings of core concepts, such as system boundaries and function, and a failure to take up other important concepts, such as power (Aswani et al., 2018). Social-ecological systems framework also relegates technology to a subelement of the social component in the framework and is frequently overlooked, even though, arguably in the Anthropocene, the technologies created are powerful actors that are shaping nature and society (Jasanoff, 2016; Markolf et al., 2018; Ahlborg et al., 2019). As a solution, some scholars proposed combining ideas from the field of science and technology studies and the social-ecological systems framework, which led to the social-ecological-technological systems (SETS) framework (Ahlborg et al., 2019).

The SETS framework recognizes the agency of each component (Figure 3). The framework is predicated on an understanding that the components interact and are dependent on and have influence over each other. Although the ecological system could rationally exist without the others, this is rarely the case in the Anthropocene. Humans affect nearly every corner of the ocean (Halpern et al., 2015) and increasingly must manage it to sustain its biodiversity and ecosystem services, in this way, the ecological system is dependent on the social system. The social system depends on the ecological system for providing the resources for sustenance, shelter, recreation, and ecosystem services. The social system also depends on the technological system for providing services.

Within the SETS framework, scholars recognize technology as the frequent intermediary between the social and ecological components of the framework (Figure 3) (Markolf et al., 2018; Ahlborg et al., 2019). Technology is the means for obtaining and enhancing resources from the ecological system for the benefit and protection of the social system, for example, energy systems. Technology is also the conduit through which the social system most affects the ecological system, for instance, pollution and overexploitation. Further, most human interactions with the marine environment depend on technology.

The SETS framework is relatively new. Much of the literature is theoretical and being developed within the fields of urban ecology and infrastructure systems (Grimm et al., 2017; Markolf et al., 2018; Ahlborg et al., 2019). Although, a recent study applied the SETS framework to six case studies examining how green and blue infrastructure can provide ecosystem services in cities (Andersson et al., 2021). One of the case studies examined New York City, where previous efforts had mapped the availability of ecosystem services. However, with a SETS framing, the case study incorporated the history of segregation and environmental injustice in New York City, producing information on where green and blue infrastructure is needed to rectify unequal distribution of environmental risks and ecosystem service benefits. The study found that SETS can serve as a boundary object around which researchers from various disciplines, including fields of social science, can contribute their needed knowledge and expertise. The SETS framework allowed for the codesign of research questions, mixed-method approaches, shared superordinate goals, and development of a flexible common language, which allows for disciplinary differences. Through reflexive practice and self-positioning, SETS led to a transdisciplinary process that provided more direct links to technological spheres of urban planning (Andersson et al., 2021).

Current approaches in marine conservation cannot fully elucidate the human and societal dimensions and implications of MCTs and TMCSs. If society is to advance in creating technologies and technological systems that help address conservation problems more holistically, the social-ecological-technological systems framework is a promising avenue to explore. It could be a lens for considering all relevant aspects of MCTs and TMCSs more fully, such as politics, power, and culture. This then could expand and democratize who creates MCTs and TMCSs. It could transform how technology and technological systems are studied and created through context-based approaches and re-envisioned goals (Ahlborg et al., 2019). Like how the Americans with Disabilities Act led to transportation and communication systems being redesigned and rebuilt to remove embedded injustices, society can begin to transform how MCTs and TMCSs are conceived. Marine conservation can move toward technologies and technological systems that explicitly and inclusively engage the social elements embedded in them and the social systems in which they are situated. And, in so doing, one can design for conservation function better suited to the social context; in turn, this will allow society to reap more conservation benefits.

## ACKNOWLEDGMENTS

I would like to thank the Faculty Women of Color Caucus Writing Group at Arizona State University for their support and accountability in writing this article.

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**How to cite this article:** Jenkins, L. D. (2022). Power, politics, and culture of marine conservation technology in fisheries. *Conservation Biology*. *36,* e13855. https://doi.org/10.1111/cobi.13855