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CONSERVACIÓN DE ZONAS DE ROMPIENTES, EL CASO DE LA RESERVA MUNDIAL DE SURF BAHIA DE TODOS SANTOS.

Tesis que para obtener el grado de

DOCTOR EN MEDIO AMBIENTE Y DESARROLLO

Presenta

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TÍTULO: Conservación de zonas de rompientes, el caso de la Reserva Mundial de surf Bahía de Todos Santos.

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RESUMEN.

El interés por la conservación ambiental en torno a la práctica del surf ha crecido a nivel mundial. Actualmente hay organizaciones centradas en la protección de zonas de rompientes y ecosistemas costeros, tales como Surfrider Foundation y Save the Waves Coalition-SWC, que promueven la protección de las zonas de rompientes y el hábitat que los rodea. Programas como Reservas Mundiales de Surf creado por SWC en 2009, desarrollan estrategias para la protección de zonas de rompientes en un esfuerzo global por la conservación marina y costera. La Bahía de Todos Santos en Ensenada, Baja California, fue declarada como Reserva Mundial de Surf en 2014, lo cual representa el primer paso hacia la protección de olas y la posibilidad de crear un modelo adaptable para otras zonas de rompientes en México. Estos esfuerzos novedosos imponen la necesidad de un marco integral enfocado en la conservación y manejo de zonas de rompientes. Esta tesis se estructura en cuatro capítulos: a) un análisis de compatibilidad de la protección de rompientes con las categorías de conservación de la Unión Internacional para la Conservación de la Naturaleza (IUCN), b) la propuesta metodológica y conceptual para la protección y manejo de zonas de rompientes, c) la evaluación de la sustentabilidad de las zonas de rompientes de la Reserva Mundial de Surf Bahía de Todos Santos (RMSBTS), y d) el plan de manejo co-adapativo para zonas de rompientes en la RMSBTS. Se combina el marco del sistema social-ecológico, el marco de Fuerzas Motrices-Presión-Estado-Impacto-Respuesta (DPSIR) y el marco de Co-manejo adaptativo con lineamientos teóricos y metodológicos para el manejo y la conservación de zonas de rompientes. Estos marcos se aplican en tres zonas de la RMSBTS. El sistema social-ecológico proporcionó las herramientas analíticas para la comprensión de las interacciones entre elementos sociales y ecológicos y para la definición de las estrategias y oportunidades para la conservación y manejo de la RMSBTS. Con el marco DPSIR se identificaron presiones que amenazan las zonas de rompientes de la RMSBTS, su impacto en el ambiente y las respuestas reales o potenciales a estas actividades, con las cuales se desarrolló el plan estratégico para el co-manejo adaptativo. La tesis se basa en un enfoque transdisciplinario que enfatiza la necesidad de abordar los problemas socio ambientales, a través de la apertura a nuevas formas de conocimiento. Este enfoque facilitó la síntesis de teorías y metodologías provenientes de diversas disciplinas y saberes locales para abordar los problemas complejos en la conservación y manejo de zonas de rompientes.

Palabras clave.
Bahía de Todos Santos, Reserva Mundial de Surf, zonas de rompientes, co-manejo adaptativo.

ABSTRACT.

Over the last two decades there has been an increased interest around the world regarding the protection of surf breaks. There are organizations such as Surfrider Foundation and Save the Waves Coalition-SWC that promote the protection of surf breaks and the habitat that surrounds them. Programs such as World Surf Reserves created by SWC in 2009, are promoting strategies for the protection of surf zones in a global effort for marine and coastal conservation. Bahia de Todos Santos in Ensenada, Baja California, was declared a World Surfing Reserve in 2014, this represents the first step towards wave protection and the possibility of creating an adaptable model for other surf zones in Mexico. These innovative efforts have developed the need for a comprehensive framework focused on the conservation and management of surf areas. This thesis is structured in four chapters: a) a compatibility analysis of surf break protection with the conservation categories of the International Union for the Conservation of Nature (IUCN), b) the methodological and conceptual proposal for the protection and management of surf breaks, c) the sustainability assessment of the surf breaks at Bahia de Todos Santos World Surfing Reserve (BTSWSR), and d) the co-adapative management plan for surf breaks in BTSWSR. The social-ecological system framework, the Driving Forces-Pressure-State-Impact-Response (DPSIR) framework and the adaptive co-management framework are combined with theoretical and methodological guidelines for the management and conservation of surf breaks. These frameworks are applied in three surf breaks of BTSWSR. The social-ecological system provided the analytical tools to understand the interactions between social and ecological components of BTSWSR, and to define strategies and opportunities for the conservation and management of surf breaks. With the DPSIR framework we were able to identify pressures that threaten surf breaks in BTSWSR, its impacts on the environment and the actual or potential responses to these activities. A strategic plan for an adaptive co-management was developed. This thesis is based on a transdisciplinary approach that emphasizes the need to address socio-environmental problems, through openness to new forms of knowledge. This approach facilitated the synthesis of theories and methodologies from various disciplines and local knowledge to address complex problems in the conservation and management of surf breaks.

Keywords

Bahía de Todos Santos, World Surfing Reserve, Surf breaks, adaptive co-management.

Contenido

1. INTRODUCCIÓN.

Una zona de rompiente es donde el carácter hidrodinámico del océano (oleaje, corrientes y mareas) se combina con la morfología del fondo marino y los vientos para dar lugar a una ola (Peryman, 2011). Las olas generadas en la zona de rompiente proporcionan una fuente de recreación para el ser humano, y su protección representa una oportunidad para preservar los ecosistemas costeros. En las últimas décadas ha incrementado el interés a nivel mundial por proteger las zonas de rompientes alrededor del mundo. Dos factores principales contribuyen a este movimiento global para proteger las zonas de rompientes y el hábitat que las rodea. Primero, las zonas de rompientes y los ecosistemas costeros alrededor del mundo están siendo amenazados, ya sea por impactos globales del cambio climático, como el aumento del nivel del mar, la acidificación de los océanos y el calentamiento del océano (Scavia *et al.*, 2002; Harley *et al.*, 2006; Caldwell y Segall, 2007; Hoegh-Guldberg y Bruno, 2010; Caldwell *et al.*, 2013; Hemer *et al.*, 2013; Reguero *et al.*, 2013; Espejo *et al.* 2014; Reineman *et al.*, 2017), o por actividades antropogénicas que causan el deterioro del hábitat, tales como desarrollo costero, descargas de aguas residuales directas al mar, desechos marinos, residuos sólidos, derrames de petróleo, erosión costera y acceso restringido a las playas (Corne, 2009; Caldwell *et al.*, 2013). En segundo lugar, el surf como deporte ha tenido un notable crecimiento en las últimas dos décadas, trascendiendo fronteras y consolidando una comunidad global de surf. Un ejemplo de este reconocimiento internacional es la integración de este deporte en los Juegos Olímpicos de Tokio 2020. Por estas razones, han surgido organizaciones y programas centrados en la protección de zonas de rompientes, tales como el programa de Reservas Mundiales de Surf (RMS) iniciado por Save The Waves en 2009.

El objetivo del programa de RMS es dar reconocimiento y apoyo internacional para la protección de las zonas de rompientes, a través de la valoración de los beneficios ambientales, sociales, culturales y económicos de las olas. Los criterios para la selección de RMS son: 1) la calidad y consistencia de las olas, 2) las características ambientales de la zona, 3) la cultura e historia del surf local y 4) participación y apoyo comunitario (www.savethewaves.org). Las RMS son un movimiento proactivo cuya misión es reconocer y proteger los hábitats de surf involucrando no sólo a la comunidad surfer, sino a la comunidad local, gobierno y organizaciones de la sociedad civil (Farmer y Short, 2007). Cuando se obtiene este reconocimiento, la comunidad local se compromete a proteger los recursos costeros y marinos y se crea un plan de trabajo para guiar las actividades de conservación. Cada RMS está dirigida por un comité local que supervisa el manejo general de la reserva y promueve las actividades de conservación. Save the Waves Coalition colabora con los comités locales para identificar los objetivos de cada reserva (principales amenazas y medidas concretas para mitigar las amenazas), y en la supervisión y manejo, a través de un plan de estratégico que guía las actividades locales. Este grupo de líderes locales varía en cada sitio, pero la mayoría de los comités de las RMS están constituidos por surfistas, científicos, empresarios, funcionarios de gobierno, asociaciones civiles y activistas de la comunidad. La responsabilidad del comité local es movilizar a la comunidad para proteger las zonas de rompientes, por lo que el éxito de una RMS depende principalmente de la participación y el compromiso de las comunidades locales.

El papel del comité local de cada RMS es representar los intereses de la comunidad local y adoptar un papel de corresponsabilidad. El comité local no tiene autoridad sobre el área, pero se espera que se consideren como actores clave dentro de la toma de decisiones en las actividades de planeación del entorno costero local. Las RMS no reciben fondos directos del gobierno pero pueden convertirse en una organización civil (Edwards y Stephenson, 2013). En este sentido, el principal reto de este modelo de protección de rompientes creado por Save The Waves, radica en generar estrategias de protección ambiental a partir de iniciativas locales basadas en la participación ciudadana, y vinculando esfuerzos con instituciones académicas, organizaciones civiles y el gobierno.

1.1 Antecedentes

1.1.1 La Reserva Mundial de Surf Bahía de Todos Santos.

El 21 de junio del 2014 Bahía de Todos Santos se suma a las RMS, las cuales ahora incluyen: Malibú y Santa Cruz en California, Ericeira en Portugal, Manly Beach, Gold Coast y Noosa en Australia, Huanchaco en Perú, Punta de Lobos en Chile, Guarda Do Embau en Brasil y Punta Borinquen en Puerto Rico. La Reserva Mundial de Surf de Bahía de Todos Santos está ubicada en la costa del pacifico, aproximadamente a 108 kilómetros de la frontera con Estados Unidos de Norteamérica. Los puntos de surf que incluye la reserva son Salsipuedes, San Miguel, Tres Emes, Stacks y las islas Todos Santos. Una de las primeras iniciativas de la Reserva Mundial de Surf Bahía de Todos Santos es la creación del primer Parque Estatal en Baja California en el Arroyo de San Miguel. El Parque Estatal tiene la finalidad de garantizar la protección legal así como el uso público, sostenible y ordenado del arroyo de San Miguel, lo cual ayudará a su vez a proteger la icónica ola de San Miguel. El programa de Reservas Mundiales de Surf sirve como modelo para la preservación de rompientes y sus entornos circundantes, ya que reconoce los beneficios medioambientales, socio-culturales y económicos para la región.

1.2 Problema, pregunta de investigación y objetivos.

Las zonas de rompientes alrededor del mundo están siendo constantemente amenazadas, principalmente por la privatización de la zona costera, introducción de infraestructura costera y contaminación por descargas residuales y residuos sólidos en los ecosistemas costeros. A nivel global, existen iniciativas independientes para la protección de zonas de rompientes, pero no existe un esquema teórico-metodológico integral para la conservación y manejo de zonas de rompientes. Por esta razón es necesario el desarrollo de un marco conceptual y metodológico para el diseño de estrategias de conservación para las zonas de rompientes, donde se reconozcan las olas como un recurso natural con un alto valor socioeconómico y cultural.

1.2.1 Pregunta de investigación.

¿Cuáles son las interacciones entre los componentes ecológicos, sociales, culturales, económicos y políticos que integran la Reserva Mundial de Surf Bahía de Todos Santos, que determinan las diversas opciones de estrategias de conservación y un esquema de co-manejo para las zonas de rompientes?

Algunas de las interrogantes que derivan de esta pregunta principal son:

i) ¿Cuáles han sido las estrategias para conservar las zonas de rompientes y los paisajes costeros en América?

ii) ¿Cuáles son y cómo se articulan los componentes ecológicos, culturales, políticos, sociales, y económicos que integran la Reserva Mundial de Surf Bahía de Todos Santos y cómo podría plantearse un esquema analítico global para zonas de rompientes?

iii) ¿Cuáles son las actividades humanas que impactan y condicionan las estrategias para la protección y co-manejo de zonas de rompientes de la Reserva Mundial de Surf Bahía de Todos Santos?

iv) ¿Cómo se pueden determinar las opciones de estrategias de conservación y co-manejo para la Reserva Mundial de Surf Bahía Todos Santos?

1.2.2 Objetivo general

Conocer las interacciones entre los componentes ecológicos, sociales, culturales, económicos y políticos que integran la Reserva Mundial de Surf Bahía de Todos Santos, y realizar la construcción conceptual y metodológica de estrategias de conservación y un esquema de co-manejo para las zonas de rompientes bajo el modelo de Reservas Mundiales de Surf.

Objetivos particulares:

1. Analizar los lineamientos para el desarrollo de estrategias de conservación para las zonas de rompientes en América.
2. Conceptualizar y analizar las interacciones entre los componentes ecológicos, sociales, culturales, económicos y políticos en un modelo universal y ejemplificar con la Reserva Mundial de Surf Bahía de Todos Santos.
3. Identificar y establecer vínculos entre actividades antropogénicas que tienen un impacto en las zonas de rompientes de la Reserva Mundial de Surf Bahía de Todos Santos.
4. Construir estrategias de conservación ambiental para zonas de surf, a partir del análisis de la relación entre las variables socio-culturales, económicas, políticas y ambientales de la Reserva Mundial de Surf Bahía de Todos Santos.

1.3 Artículo 1: Surfing and marine conservation: exploring the compatibility of surf break protection with IUCN protected area categories and other effective area-based conservation measures (In press in Aquatic Conservation: Marine and Freshwater Ecosystems. Article: aqc_3054).

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Abstract.

The expansion of surfing as a multi-billion-dollar industry and sport has, on the one hand, increased awareness about threats posed to marine and coastal environments, but has also brought growing acknowledgement of the environmental, cultural and economic value that surfing provides. This has been accompanied by a growing movement of surfers and related stakeholders (e.g. communities and manufacturers that rely on the surf tourism and industry for income) that seek to protect surf breaks. This paper argues that certain emblematic surf breaks should be protected not only for their value to surfers, but also for the ecosystem services they provide and other potential benefits for marine conservation. Through a series of case studies from Peru, Chile and the USA, the paper discusses how in areas where there is significant biodiversity or iconic seascapes, surf breaks can be integrated with marine conservation. Suggestions are given regarding the IUCN categories of protected areas that are most appropriate for such cases. The paper also explores how in certain cases, several existing surf break protection mechanisms could qualify as other effective area-based conservation measures (OECM), including Chile's proposed TURF-Surf model, the international World Surfing Reserves, and Peru's "*Ley de Rompientes*". In this way, certain surf break protection mechanisms could help contribute to countries' progress toward achieving the Convention on Biological Diversity's Aichi Target 11. Overall benefits of marine conservation groups and surfers joining forces are discussed, including how this can help reduce negative impacts of the sport on natural ecosystems.

Key words: Aichi Target 11; Ley de Rompientes; marine conservation; marine protected areas; OECMs; surfing; surf breaks; TURFs; World Surfing Reserves

1. Introduction.

In Polynesia, Hawai'i and what is now Peru, people began riding waves thousands of years ago using simple boards of wood or reed craft (Lazarow, Miller & Blackwell, 2008). Despite its ancient origins, surfing was suppressed for many years by the colonizers in Hawai'i and was only popularized by Hawaiians in the early 20th century (*ibid*). Since then, the sport has grown continuously, and is now practiced across the globe. Indeed, in 2020, surfing will be included as part of the Olympic Games for the first time in history. Surfing contributes billions of dollars to the global economy each year through surf tourism and the surf equipment and apparel industries. Millions of people surf worldwide, with estimates ranging from 18-50 million participants globally (*ibid*).

The expansion of surfing as a multi-billion-dollar industry and sport has, on the one hand, increased awareness about threats posed to coastal environments, but has also brought growing acknowledgement of the environmental, cultural and economic value that surfing provides. There is an increasing body of literature focused on surfing that has raised understanding of the sport and its relationship with conservation, human wellbeing, and economics – see for instance the bibliography being compiled by the Centre for Surf Research of San Diego State University. Elsewhere, in their extensive literature review of 162 research-based surfing publications, Scarfe, Healy and Rennie (2009) show that surfing is only a recent topic in coastal literature. This has been coupled by a burgeoning movement of surfers and related stakeholders (e.g. communities and manufacturers that rely on the surf tourism and industry for income) that seek to protect surf breaks. The overlap between environmental conservation and surf break protection is the focus of this paper.

This paper argues that certain emblematic surf breaks should be protected not only for their value to surfers, but also due to the ecosystem services they provide. Second, it demonstrates how the protection of surf breaks is possible under certain categories of protected areas or other effective area-based conservation measures (OECMs) recognized by the International Union for Conservation of Nature (IUCN), thus contributing to countries' progress toward the Convention on Biological Diversity's Aichi Target 11. The possibilities for integrating surf break protection with protected areas or OECMs is explored in a series of case studies from around the world, including Peru, Chile and the USA. The authors encourage governments and the conservation community to recognize the value of surf break protection as part of the global marine and coastal conservation effort.

1.1 The conservation value of surf breaks.

A surf break is a rideable wave that breaks in one direction consistently and can be enjoyed by a surfer. As summarized by Reiblich (2013), a surf break has three main components: the sea floor in the area where the wave breaks (which may be a reef, rocks, sandy bottom or other substrate), the swell corridor along which the ground swell travels before reaching the point where the wave breaks, and access for surfers. The effective protection of surf breaks needs to include all of these components, as well as water quality. It should be noted that although the majority of high-quality surf breaks are natural formations, not all surf breaks are necessarily entirely natural. For instance, several surf breaks along Peru's Costa Verde in Lima are some of the most visited surf breaks in the country and are the result of rocky piers and land-reclaiming projects in the area. The following will discuss the conservation and economic value of natural surf breaks, the threats thereto, and examples of the surfing community's conservation efforts.

1.1.1 Ecosystem services and surf breaks.

Surf breaks are natural resources that provide people with recreation, aesthetic inspiration, cultural identity, and spiritual experiences related to the natural environment. Their protection represents an opportunity not only to perpetuate these benefits to human wellbeing, but also to support the integrity of coastal ecosystems. The multiple benefits that nature provides to society and that make human life possible are known as *ecosystem services* (Constanza *et al.*, 1997). Surf breaks provide many *cultural* ecosystem services. Surf breaks are natural spaces with high recreational value, with benefits to both mental and physical health. With regards to the benefits of spending time in marine environments in general, this is the focus of the UK-based 'Blue Gym' psychology research group, which shows that there are positive effects on both health and happiness for people living close to coasts (White, Pahl, Wheeler, Fleming, & Depledge, 2016). Elsewhere, researchers have investigated the specific effects of surfing, where various studies show the cognitive benefits of surfing on special needs groups (Armitano & Clapham, 2015), and demonstrate the physical health benefits of surfing for children with disabilities. Studies from around the world also show how surfing significantly increases wellbeing and confidence among youth with mental health issues or those suffering from social exclusion (see Godfrey, Devine-Wright, & Taylor (2015), Stuhl & Porter (2015), Hignett, White, Pahl, Jenkin, & Le Froy (2017) and Gaspar de Matos *et al.* (2017)).

Many surf breaks are integral parts of iconic seascapes where there is a strong local surfing culture, in places such as Malibu (California, USA), Jeffrey's Bay (South Africa), or the north shore of O'ahu, Hawai'i. Usually, these emblematic surf breaks are considered 'world class', that is, they are of exceptional quality and provide an excellent surfing experience in comparison with most other surf breaks. Such surf breaks have inspired many forms of art, from fashion (e.g. brands such as Quiksilver) to indigenous tattoo art in the Polynesian islands. In a survey of over 1000 California surfers, Reineman and Ardoin (2018) find that the majority of surfers have a significant place attachment to their surf spots. Furthermore, emblematic surf breaks have high economic value, with new research on 'surfonomics' demonstrating this in monetary terms. Lazarow *et al.* (2008) review multiple studies that estimate the contribution of surfing to different economies. The review shows that the numbers vary greatly, anywhere from several hundred thousand USD to hundreds of millions USD, depending on the locale and the study methods. Other examples of surfonomics include Lazarow's (2009) estimate that the Australian Gold Coast generates around USD $180 million per year due to surfers' expenditures. Scorse, Reynolds & Sackett (2015) estimate that a home near a surf break in Santa Cruz, California, is valued about USD $106,000 more than a similar home further away from the surf break.

1.1.2 Surfers as environmental activists.

There is emerging evidence in social psychology that surfing raises environmental awareness among surfers, some of whom are therefore more inclined to protect the environment and support conservation causes. For instance, Brymer, Downey & Gray (2009) show how many extreme sports athletes, including surfers, care for nature due to their nature-based sport, while Hignett *et al.* (2017) show that at-risk youth achieved higher environmental awareness after engaging in surfing. A survey conducted by the NGO Sustainable Surf and the University of Plymouth show that of 500 respondents, 84% indicate that surfing raises their environmental awareness, due to both their greater level of connection with nature, as well as their direct confrontation with negative human impacts on the ocean, such as pollution (Sustainable Surf, 2018). White *et al.*'s (2016) Blue Gym group mentions a number of studies that show a link between time spent in marine environments and higher propensity for environmental activism, with this being a primary focus for future research by the group.

The connection between conservation and surfing may be due to surfers' frequent and long interactions with the marine environment, and importantly, because negative environmental effects also tend to be detrimental for surfing, e.g. plastic pollution, sewage, industrial construction that threatens a surf break. Notably, there are several conservation organizations around the world that were founded by surfers (Table 1), most of which focus on both the protection of surf breaks as well as the conservation of marine ecosystems. Though the above-mentioned research by no means implies that all surfers are environmental activists by default, it does seem to show that a significant number of surfers will engage in environmental action due to their relationship with surf breaks and their self-interest in protecting their activity. The challenge for the conservation community is to leverage this potential pool of human and capital resources for marine conservation.

Table 1: Examples of campaigns, organizations and initiatives for the protection of surf breaks and their surrounding marine-coastal environments.

Organization/Initiative	Active years	Objective
Surfrider Foundation (International)	1984 - present	Protects marine and ocean environments, including surf breaks. https://www.surfrider.org/
Surfers Against Sewage (UK)	1990 - present	Campaigns against destruction and threats to coastal-marine ecosystems and surf breaks through infrastructure development, sewage disposal, etc. https://www.sas.org.uk/
Association for the Conservation of Peruvian Waves and Beaches (ACOPLO) (Peru)	1992 - 2001	Protected emblematic waves in Peru. It played a key role in pushing for legislation to protect waves in Peru, passed in 2001.
Surfers for Cetaceans (International)	2004 - present	Campaigns for the protection of cetaceans worldwide. https://www.s4cglobal.org/
Save the Waves Coalition: World Surfing Reserves Program (International)	2009 - present	Creates a network of protected surf breaks around the world through the World Surfing Reserves mechanism. https://www.savethewaves.org/
Surfbreak Protection Society (New Zealand)	2012 - present	Conservation of the emblematic surf breaks of New Zealand through the preservation of their natural characteristics, water quality, marine ecosystems and public low-impact access. http://www.surfbreak.org.nz/
HAZla por tu Ola (Act for your Wave) (Peru)	2015 - present	Citizen-led campaign for the protection of surf breaks in Peru and their inclusion in the national register of protected breaks. http://hazlaportuola.pe/
Fundación Punta de Lobos (Chile)	2016 - present	Protects the terrestrial area surrounding Punta de Lobos surf break in Pichilemu. http://puntadelobos.org/en/
Fundación Rompientes (Chile)	2017 - present	Seeks legal protection of surf breaks in Chile. Combines marine conservation with community-based approaches. http://www.rompientes.org
Surf & Nature Alliance (International)	2017 - present	Campaigns for the protection of surf breaks as well as sustainable coastal development. https://surfnaturealliance.org/

Biodiversity and seascape value.

More site-based research is needed to understand the potential biodiversity value of specific intact surf breaks, while accounting for the diverse types of surf breaks that exist (e.g. sandy bottom, reef breaks). Natural surf breaks require the continued intactness of the bathymetric conditions that generate the break. Alterations to these conditions, for instance through dredging or pier construction, would usually adversely impact the surf break. Since the associated biodiversity (particularly benthic) also depends on the intact bathymetry or nearshore conditions, the protection of surf breaks could also have benefits for local biodiversity in tropical, sub-tropical, temperate and even polar systems.

Coastal biodiversity associated with a surf breaks can include sandy bottom, coral reef, rocky reef and kelp forest ecosystems. These systems are key to sustaining communities of reef-fish, benthic resources and infauna. For instance, rocky reef ecosystems in the surf break of Roca Cuadrada in Chile sustain a kelp forest ecosystem (*Macrocystis*) with more than 32 species of sessile macro-invertebrates, 19 mobile invertebrates and 20 species of reef fish (Ilustre Municipalidad de Navidad, 2008). Species include the red sea urchin, whose habitat is mainly associated to rocky reef breaks, and *Graus nigra*, a reef-fish endemic to the southern Humboldt-Current ecosystem and described as threatened by overfishing (Godoy, Gelcich, Vasquez & Castilla, 2010).

An important discussion is the value of surf breaks as part of larger land- and seascapes. For instance, the Illescas Peninsula in northern Peru is currently a Reserved Zone, which is a temporary designation before a protected area category is agreed upon. The area includes spectacular coastal desert landscapes, sand dunes, and pristine beaches. It is home to South American Sea Lion colonies (*Otaria flavescens*) and is one of the few places along the Peruvian coast where the Andean Condor (*Vultur gryphus*) is regularly seen, a species considered Near-Threatened by the IUCN Red List (Birdlife International, 2017), and Endangered within Peru (MINAGRI, 2014). Punta Malnombre is a world class surf break that forms part of this land- and seascape and is one of the principal reasons why tourists visit the area. In Chile, Punta de Lobos is one of the most important surf breaks for big-wave surfing globally. It is part of a stunning coastal landscape with sheer cliffs, pillar rock formations in the sea, and sandy beaches. Noteworthy terrestrial biodiversity here includes the cactus *Echinopsis bolligeriana*, considered Endangered on the IUCN Red List (Walter, Faundez, & Guerrero, 2013). The surf break is the area's main attraction.

Conservation International and Save the Waves, having launched a new partnership in 2018, have published a map (Figure 1) showing overlap between biodiversity hotspots (as defined by the Critical Ecosystems Partnership Fund) and a list of top iconic surf breaks around the world. Although this analysis is at a very large scale, it provides a baseline for understanding opportunities for integrating conservation with surf break protection. [FIGURE 1]. Not all surf breaks have significant value in terms of biodiversity or land- and seascapes. The overlap between a surf break and biodiversity or seascape of high conservation value must be evaluated to assess the compatibility of conservation with surf break protection measures.

2. Threats to surf breaks and the surfing community's response.

Around the world, both surf breaks and coastal-marine ecosystems are threatened by a variety of factors related to climate change, such as rising sea levels, ocean acidification and ocean warming (Harley, *et al.*, 2006; Hoegh-Guldberg & Bruno, 2010; Espejo, Losada & Mendez, 2014; Reineman, Thomas, & Caldwell, 2017).

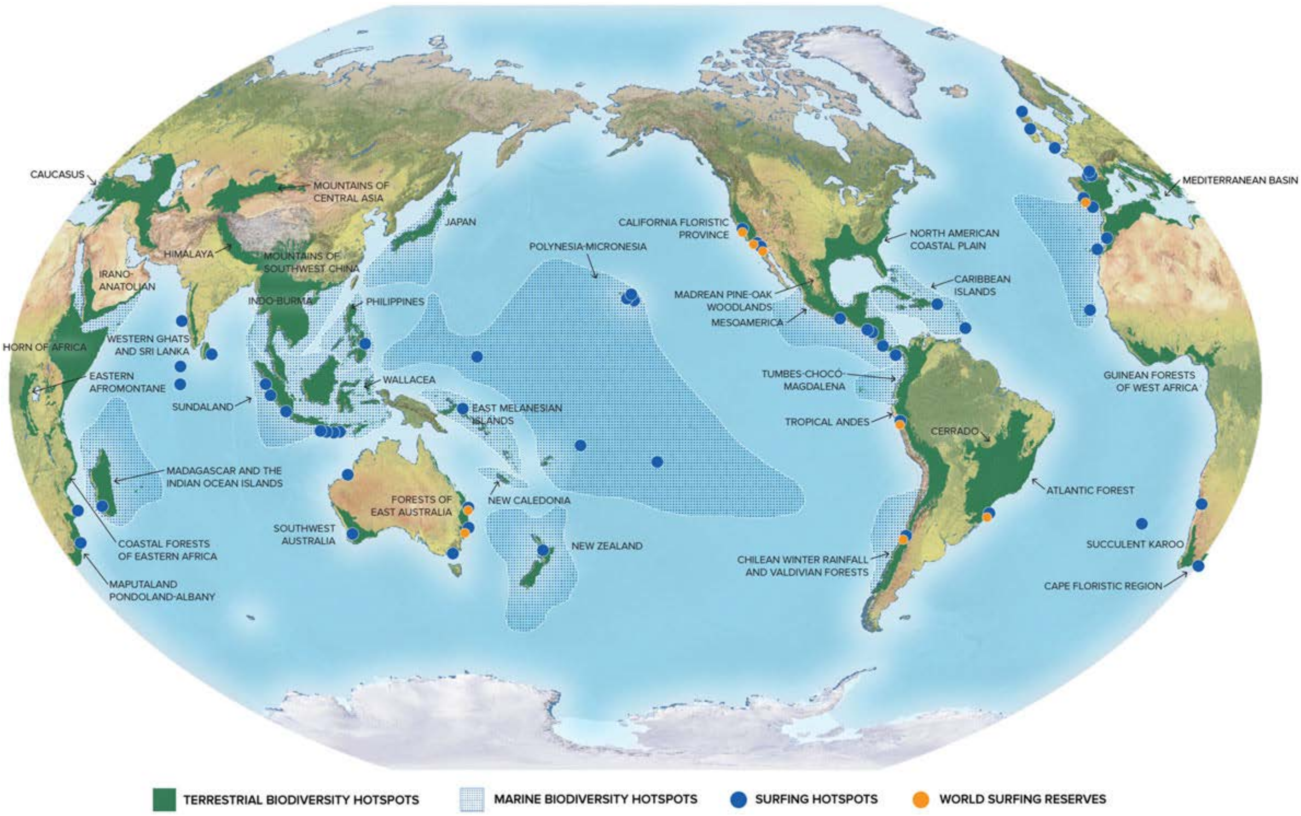


FIGURE 1 Map showing overlap between biodiversity hotspots, iconic global surf breaks, and World Surfing Reserves

Simultaneously, there are multiple other anthropogenic threats including coastal development, marine pollution, oil spills, coastal erosion, and restrictions to public beach access (Corne, 2009). Surf breaks easily lose their quality or cease to exist altogether if key conditions are altered, such as the swell corridor (e.g. interrupted by a wave breaker), sedimentation (e.g. due to the construction of a pier that changes the movement of sand with the currents), water quality (e.g. oil spills, or sewage that is pumped directly into the sea), or limitations to public beach access (e.g. due to private beach condominiums). Table 2 lists some emblematic surf breaks that have been destroyed or are currently threatened by human activity.

Table 2: Examples of high-quality surf breaks threatened, altered or destroyed by human activities

Surf break name	Location	Threat by category
Playa Encuentro	Dominican Republic	*Public access*. Hideaway Beach Resort closed public access to the break as part of its infrastructure expansion project.
Killer Dana	California, US	*Access and infrastructure*. The Army Corp of Engineers closed the beach to all marine activities to build a recreational harbour.

Male Point	Maldives	*Infrastructure*. Tetrapods were placed around the island for coastal protection, thus destroying the surf break.
Molle	Sweden	*Infrastructure.* Building of a breakwater to protect harbour boats destroyed the surf break.
Jardim do Mar	Madeira	*Infrastructure*. Construction of a promenade changed the wave dynamics, greatly reducing the 'surfability' of the wave.
Mundaka (Spain)	Spain	*Dredging.* Over 300,000 cubic metres of sand were dredged from the sea floor, thus affecting the shape of one the world's highest quality waves.
Bastion Point	Australia	*Infrastructure:* A boat ramp and jetty were constructed, thus destroying the wave.
Cabo Blanco	Peru	*Infrastructure.* A fishing pier essentially cut the surf break in half, while a new pier is currently under construction that could further impact the wave.
La Herradura	Peru	*Infrastructure*. An unsuccessful road project destroyed the natural hill surrounding the bay, changing the ocean floor and thus affecting the surf break.
Topocalma	Chile	*Public access*. A private owner closed public access to the break due to a real estate project developed in the adjacent beach of Puertecillo.

Importantly, threats to surf breaks not only threaten the surfing sport, but also the various ecosystem services and related benefits discussed above. The development threats posed to surf breaks have evoked various responses by the surfing community to protect their favourite surfing spots, and several non-governmental organizations exist that work in this field. The Surfrider Foundation has run campaigns for over 30 years to protect both surf breaks and the wider marine environment through a network of thousands of activists. The Save the Waves Coalition protects surf breaks and coastal ecosystems globally and implements initiatives such as World Surfing Reserves and campaigns to protect emblematic locations under threat. Surfers Against Sewage focuses in particular on plastic and other pollution threats to surf breaks and coastlines. While these actors operate internationally, there are many more instances of national and local-level initiatives, such as HAZla por tu Ola in Peru or Fundación Punta de Lobos and Fundación Rompientes in Chile (see Table 1).

Scarfe *et al.* (2009) found that in most countries, management of surf breaks is not practiced at the government level, and even places with rich cultural surfing histories like California, surfers have only recently started to have a political say in the management of their recreational space.

The mechanisms used to protect surf breaks vary widely. New Zealand, for instance, is one of the few countries where the government actively protects surf breaks by explicitly including them in its coastal and marine planning process (Peryman, 2011; Peryman & Skellern, 2011). Elsewhere, Peru has created a registry through which specific waves are protected by the navy. On an international level, the Save The Waves Coalition has created a mechanism called the World Surfing Reserves, through which communities commit to protecting their iconic surf breaks. Word Surfing Reserves are not legally-binding but may be coupled with local legal mechanisms for surf break protection, where these exist. To help inform such efforts, Martin and Assenov (2014) have developed a Surf Resource Sustainability Index that provides a wide set of criteria for assessing a surf-break's aptitude for protection, based on social, economic, environmental and governance criteria.

3. Surf break protection through the IUCN protected area framework or other effective area-based conservation measures.

Emblematic surf breaks have significant conservation value due to their provision of cultural ecosystem services, their importance for human wellbeing, their role in creating spaces that foster environmental activism, and in certain cases, due to their importance for biodiversity and the integrity of land- and seascapes. At the same time, many are acutely threatened by various forms of human activity. Encouragingly, there is an active community of people who are both able and willing to implement innovative mechanisms for surf break protection, while also considering wider marine conservation targets. The authors argue that surf breaks should and can be considered under certain frameworks for area-based protection as defined by the IUCN. Their protection could contribute to countries achieving Aichi Target 11, which is:

"By 2020, at least 17 percent of terrestrial and inland water areas and 10 percent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape." (CBD, 2010, 2)

3.1 Surf breaks and protected areas.

The IUCN defines a protected area as:

"A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley, 2008, 8).

To the authors' knowledge, no marine protected area has been created with the principal purpose of protecting a surf break. However, there are examples of surf breaks that are located within protected areas that were created for other conservation reasons. For instance, surf breaks along the Santa Cruz, Cayucos and Montana de Oro coastlines in the USA have benefitted from the existence of the Monterey Bay National Marine Sanctuary, the Point Buchon Marine Reserve and the White Rocks Conservation Area in California, and the limitations they have placed on further development of nuclear and energy infrastructure. The Gnaraloo, Dunes and Red Bluff surf breaks are part of the Ningaloo Marine Park in Western Australia, with strict rules regarding visitor carrying capacity. Roca Bruja in Costa Rica is part of the Santa Rosa National Park and also has rules regarding the number of visitors/surfers. The big-wave surf break of Killers at Todos Santos Islands is part of the Biosphere Reserve of the Islands of the Pacific Ocean, and the draft management plan specifically includes surfing. However, so far, there has not been a comprehensive study that analyses how many surf breaks exist within the boundaries of protected areas and how access to those surf breaks is regulated.

The IUCN considers six main categories of protected areas, which are summarized in Table 3. This paper argues that there are four categories that are particularly appropriate for the protection of surf breaks: Category III for cases where the surf break is the primary focus of protection and Categories II, V and VI when the surf break is part of a wider set of marine and coastal features considered important. Since protection of surf breaks implies access and use of the site by surfers and related stakeholders, surf break protection is particularly appropriate to those IUCN categories and zoning areas that allow recreational activities. Indeed, surf breaks' strong visitor attraction factor creates an excellent opportunity to use sustainable tourism approaches and interaction with nature to generate funds for protected areas.

Table 3: IUCN categories of protected areas, highlighting those considered by the authors of this paper as most appropriate for surf break protection (Dudley, 2008)

Category Number	Description
Ia	Ia Strict Nature Reserve: Category Ia are strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphical features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.
Ib	Ib Wilderness Area: Category Ib protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.
II	II National Park: Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.
III	III Natural Monument or Feature: Category III protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.
IV	IV Habitat/Species Management Area: Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many Category IV protected areas will need regular, active interventions to address the requirements of

	particular species or to maintain habitats, but this is not a requirement of the category.
V	V Protected Landscape/ Seascape: A protected area where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.
VI	VI Protected area with sustainable use of natural resources: Category VI protected areas conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

Surf breaks and Category II National Park.

The 'National Park' category is appropriate for protecting surf breaks that are part of a larger natural area set aside to maintain ecological integrity at ecosystem scale. Objectives of national parks include promoting education, recreation and contributions to local economies through sustainable tourism (Dudley, 2008). Surfing can be a recreational and educational experience promoted in National Parks, if regulations and zoning measures are in place to minimize and mitigate impacts of surfing visitors to the protected ecosystems. For instance, G-Land in East Java, Indonesia, is part of the Alas Purwo National Park. G-Land is one of the most iconic waves in Indonesia. Only three surf camps have been allowed in the area with a specific limit to the number of surfers permitted entry.

Surf breaks and Category III Protected Areas: Natural Monument or Feature.

The 'Natural Monument' category is appropriate for protecting emblematic surf breaks where these are not part of a larger land- or seascape that needs protecting. The surf break itself, and the immediate surrounding features such as rock formations, are the conservation targets. In addition to the definition shown in Table 4, the IUCN further stipulates that Natural Monuments are:

"perhaps the most heavily influenced of all the categories by human perceptions of what is of value in a landscape or seascape rather than by any more quantitative assessments of value […] Management is usually focused on protecting and maintaining particular natural features." (Dudley, 2008, 18)

In this case, the value of the surf break is based on the value that surfers attribute to it, as well as the related stakeholders that rely on the surfers (e.g. tourism operators, restaurants, surf schools). Meanwhile, management focuses on preventing the bathymetric, water quality and similar changes that could affect the quality and functioning of the surf break. For instance, the Lobitos surf break in northern Peru is considered one of the most 'perfect' waves the country has to offer. It was included in a list of potential terrestrial and marine pilot sites for creating the first natural monuments in Peru (SPDA, 2016). Lobitos is highly visited by both national and international surfers, providing a source of income for local businesses such as hotels, restaurants, and surf schools. Designation of the surf break and the surrounding beaches as a natural monument would not only help increase visibility of the area, but also help ensure management measures and sustainable use rules, such as regulating infrastructure development and waste management.

Surf breaks and Category V Protected Areas: Protected Landscape/Seascape

Category V is appropriate for the protection of surf breaks that are part of a wider marine and coastal landscape/seascape that is worth protecting mainly for its scenic value, and the sustainable interaction between humans and nature in the area. In this case, the surf break does not need to be the primary focus for the creation of the protected area, however, it should be explicitly mentioned, so that it can be included in management measures. This allows, for instance, for controlled surf tourism to provide income to the protected area.

The Monterey Bay National Marine Sanctuary in California is considered a category V protected area (Protected Planet, 2018), encompassing over 1.5 million hectares of marine and coastal habitats while considering a multitude of human uses. Two of the most prominent surf breaks in the Sanctuary are Mavericks, an iconic big-wave surf break, and Steamer Lane in Santa Cruz. The management plan for the Sanctuary explicitly deals with surf, for instance, by regulating the use of motorized personal watercraft that are used particularly for big-wave surfing, in order to minimize impacts on wildlife (National Marine Sanctuaries, 2008).

Surf breaks and Category VI Protected Areas: Protected area with sustainable use of natural resources.

Category VI focuses on large areas that combine conservation with sustainable use of the natural resources. As is the case for Category V, surf breaks are part of a broader set of conservation objectives. Surfing and surf tourism are part of a series of sustainable use types in the area, such as locally managed fishing regimes.

A successful example of this is the 217,594 hectare Paracas National Reserve in Peru, a Category VI marine protected area established in 1975. The reserve includes a highly-valued surf break at the island of San Gallan, accessible only via boat. For most of the reserve's history, the surf break was part of a strict protection zone, hence surfing was officially prohibited (INRENA, 2002). However, surfers continued to visit the spot and even organized annual surf competitions (W. Wust, 2018, pers. comm., November 2018). Around 2015, dialogues were initiated between surfers and the reserve management committee to legalize and regulate surfing at San Gallan, and to value surfing for its potential income for the reserve, while ensuring that impact to wildlife be kept to a minimum (*ibid*). The process was a success: in 2016, the new management plan of the reserve changes the zoning regulations around the surf break to allow for sustainable use (SERNANP, 2016). Another significant step is that the surf break is now explicitly mentioned as an asset of the reserve, and access to the surf break is regulated via licensed tour operators (SERNANP, 2016).

3.2 Surf break protection mechanisms as other effective area-based conservation measures (OECM).

The topic so far has been showing why decision-makers should consider surf breaks as part of marine and coastal protected areas planning, and how this could integrate with current IUCN protected area categories. Meanwhile, the following discussion focuses on how existing, innovative surf-break protection measures from around the world can be integrated with marine conservation and thereby help achieve international conservation targets. The Convention on Biological Diversity allows for several conservation management measures to count towards Aichi Target 11, beyond the traditional national protected areas: these measures are called other effective area-based conservation measures, or OECMs. Having been introduced only recently, the draft guidelines on OECMs define them as follows:

"A geographically defined space, not recognized as a protected area, which is governed and managed over the long-term in ways that deliver the effective in-situ conservation of biodiversity, with associated ecosystem services and cultural and spiritual values." (IUCN WCPA, 2018, 14) .

The IUCN differentiates between OECMs and protected areas as follows: "while protected areas should have a *primary* conservation objective […], the defining criterion of an OECM is that it should *deliver* the effective and enduring *in-situ* conservation of biodiversity, *regardless* of its primary management objectives." (*ibid,* 12). The main elements of an OECM are listed in Table 4.

Table 4: Main elements for defining other effective area-based conservation measures as recognized by the IUCN (Source: IUCN WCPA, 2018).

Criterion	Description
a) A geographically defined space	Spatially defined with agreed and demarcated boundaries, which can include land, inland waters, marine and coastal areas or any combination of these.
b) Not protected areas	Areas that are already designated as protected areas or lie within protected areas should not also be recognized or reported as OECMs.
c) Governed	The area is under the authority of a specified entity, or an agreed upon combination of entities, including: i) Governments, ii) Shared governance (various rights-holders), iii) Private individuals, organizations or companies, and iv) Indigenous peoples and/or local communities.
d) Managed	The area is being managed in a way that leads to positive biodiversity conservation outcomes.
e) Long-term	The governance and management of OECMs is expected to be long-term in intent. Short-term or temporary management strategies do not constitute an OECM.

f) Effective	OECMs should be effective in delivering the *in-situ* conservation of biodiversity.
g) *In-situ* conservation	OECMs are expected to achieve the conservation of nature as a whole, rather than only selected elements of biodiversity.
h) Biodiversity	OECMs must achieve the effective and sustained *in-situ* conservation of biodiversity.
i) Ecosystem services	Protection of these ecosystem services will be a frequent driver in the recognition of OECMs.
j) Cultural and spiritual values	OECMs include areas where the protection of key species and habitats and management of biodiversity may be achieved as part of long-standing and traditional cultural and spiritual values.

Where an at-risk, iconic surf break is not located within a protected area that protects it *de facto*, other forms of protection are necessary. Some of the diverse actors mentioned in Table 1 have developed different mechanisms to protect surf breaks around the world. Some surf break protection mechanisms use legal approaches, while others focus on community-based, voluntary protection. The following case studies illustrate some of the most successful examples of surf break protection. Importantly, some of these cases of protected surf breaks could qualify as OECMs, and thereby contribute to countries achieving Aichi Target 11. So far, none have been officially recognized as OECM. The compatibility of these surf break protection mechanisms with OECM criteria are discussed here.

Case Study 1: The World Surfing Reserves.

The World Surfing Reserves (WSR) programme was created by Save The Waves Coalition and partners in 2009. The WSR programme is a global network of informally conserved areas that protect unique surfing locations and their coastal environments and builds capacity with local partners for long-term conservation of each WSR. Save The Waves guides the community through a stewardship planning process that identifies critical threats to the WSR, root causes, strategies, and concrete actions to protect the WSR, including avenues toward legal protection. The network currently includes 10 WSR sites worldwide (shown in Figure 1): Malibu (CA), Ericeira (Portugal), Manly Beach (Australia), Santa Cruz (CA), Huanchaco (Peru), Bahia de Todos Santos (Mexico), Punta de Lobos (Chile), Gold Coast (Australia), Guarda Do Embaú (Brazil), and Noosa (Australia).

WSR-eligible waves and surf zones are evaluated by a panel of independent, international experts called the Vision Council, and chosen based on the criteria in Table 5. Importantly, a key criterion for WSR qualification is whether or not a surf break is also located in an area of biodiversity significance, demonstrated by the presence of endangered species, or recognition as a biodiversity hotspot (see Environmental Criteria in Table 5).

Table 5: Selection criteria for World Surfing Reserves (Save the Waves)

1) Quality and Consistency of the wave(s)	1. Quality of wave(s) (defined by Surfline.com ranking)	2. Surfeable days/year (defined by wannasurf.com estimate)	3. Site of pro contest (Defined by WSL, or ISA presence)	4. Wave variety (Defined by diversity of surfing levels)	
2) Environmental characteristics	1. Recognized biodiversity hotspot (as defined by CEPF or WWF)	2. Threatened species present (listed on IUCN Red List)	3. Connected to water resources (defined by Blue Line status or Ramsar site)	4. Past/present wave threat likely to be mitigated (Defined by applicant)	5. Protected Area designation (local, regional, state or national protected area designation)
	6. Undeveloped area (based on satellite imagery)	7. Key issue/threat identified (stewardship issue to be mitigated by the WSR)	8. Clear avenue for legal protection locally (preexisting legal regime or political feasibility for new regime)	9. Provides key ecosystem services (WSR has additional ecosystem benefits beyond surf protection)	
3) Culture and surf history	1. Site of national cultural significance (as defined by applicant)	2. Importance in surf history (as defined by applicant)	3. Site of regional significance (as defined by applicant)		
4) Capacity and local support	1. Support from surf community, government, civil society, private sector, academia (letters of support)	2. Sustainable financing (as defined by applicant)	3. Clearly identified manager (as defined by applicant)	4. Surf is key part of local economy (as defined by applicant)	5. Clearly identified WSR ambassador (as defined by applicant)

Once a WSR site has been approved, a Local Stewardship Council is formed and begins a stewardship planning process based on the Open Standards for the Practice of Conservation of the Conservation Measures Partnership. The Local Stewardship Council identifies coordinates for the WSR site, and outlines the vision and goals for the site, articulates threats and underlying factors, develops strategies for reducing or eliminating the threats, and outlines actions to be undertaken by the community partners.

Options for legal protection of the site are articulated within the stewardship plan. The WSR mechanism is international in nature and is based on voluntary commitments by local stakeholders to protect the site. Where possible, Local Stewardship Councils pursue locally available options for legal protection of the WSR. In some cases, this may imply pushing for the creation of a protected area around the site, while elsewhere, legal mechanisms may be available to protect the surf break, as is the case in Peru (discussed in more detail in the next case study). In other cases, further legal protection may not be necessary, as is the case for the Santa Cruz WSR, which is located within the previously-created Monterey Bay National Marine Sanctuary.

It is the view of the authors that there are cases where the WSR site could be recognized as an OECM, namely when: i) the WSR coincides with an area of high biodiversity significance, which is recognized by the host government, ii) the site is under some form of legal protection that is also effective for biodiversity conservation, and iii) the site is not part of a protected area. How the WSR mechanism in general applies to OECM criteria is illustrated in Table 6.

Table 6. OECM criteria applied to the World Surfing Reserves surf break protection mechanism

OECM Criteria	Does the WSR Program meet the criteria?	Comments
a) Geographically defined space	YES	Each World Surfing Reserve (WSR) has geographic coordinates associated with a boundary created by the Local Stewardship Council.
b) Not a protected area	YES	Considered would be only those WSRs not already located within a protected area.
c) Governed	YES	WSRs have a Local Stewardship Council that includes stakeholders from the surfing community, local government, the NGO community, the business community and academia in a shared governance model (i.e. governance by various rights-holders and stakeholders together). In some cases, governance is led by private individuals, organizations or companies, in line with the WSR's Stewardship Plan.
d) Managed	YES	Each WSR is required to create a WSR stewardship plan, which is based on the Conservation Measures Partnership framework. The plan outlines reserve objectives, threats, root causes, strategies, and specific actions to be taken to manage the area's resources. The development of this plan implies collaboration and consensus within the Local Stewardship Council and key partners. Where the management measures for the surf break are based also on legal protection, they may provide *de facto* protection for some forms of biodiversity.
e) Long-term	YES	The WSR recognition is indefinite, unless the WSR is not meeting minimal criteria for stewardship.
f) Effective	YES	Because of the top-down and bottom-up combination of management for the areas, the WSRs have been very effective in addressing threats to the surf break, usually in the form of urban development such as jetty construction, which would also have damaged benthic ecosystems. In Punta de Lobos, a development threat of a hotel and underground parking structure was eliminated by the WSR process. In Huanchacho Peru, the WSR halted the planned construction of jetties that would have jeopardized the local artisan fishing culture and benthic biodiversity.
g) *In-situ* conservation	YES	The WSR protects a specific coastal area, the cultural ecosystem services and certain aspects of the biodiversity that depends on the area.
h) Biodiversity	PARTIALLY	WSRs are not exclusively focused on biodiversity, but may provide ancillary protection depending on the specific use restrictions that apply. WSRs usually protect those aspects of biodiversity that would be affected mainly by infrastructure development, such as sedimentation processes, benthic habitats, bird nesting sites, and marine mammal colonies. It should be noted that WSRs do not usually restrict fishing activity and can therefore be considered akin to protected areas with an emphasis on human use.

i) Ecosystem services	YES	WSRs protect cultural ecosystem services provided by the surf break, such as cultural identity, human well-being, recreation and tourism.
j) Cultural and spiritual values	YES	Surf breaks have cultural value not only to local communities near the break, but also the global surfing community. One of the criteria for the selection of a WSR is the surf break's relation to local history and culture. Examples like Peru's Huanchaco illustrate this point, where the WSR helps protect a traditional fishing and surfing culture thousands of years old.

The compatibility of OECM criteria with WSRs is demonstrated in three examples of WSRs from Peru, Chile and Mexico.

Huanchaco WSR, Peru: Huanchaco, located on the northern Peruvian coast, is widely known for a rich history in surfing. Archaeological evidence suggests that local fishers used their '*caballito de totora*' reed fishing vessels as one of the world's first surf-craft some 2,500 years ago: a technique still used on a daily basis by Huanchaco's fishers. Huanchaco is an example of a seascape with a long history of human interaction that depends on the intactness of the ecosystem, for both fishing and tourism. The Huanchaco WSR Local Stewardship Council, working with Save The Waves and the HAZla por tu Ola campaign, was one of the first sites in Peru that secured legal and permanent protection under Peru's '*Ley de Rompientes*' (described in more detail in the next case study). When put to the test, the WSR helped permanently halt plans for several jetties proposed for the town's main beach, which would have endangered the surf break and impacted the traditional fishing practice. However, so far there is only little information about the biodiversity significance of the site, and how the WSR is benefiting it. Until information is available to demonstrate that the WSR protects not only the surf break, but also significant biodiversity, the Huanchaco WSR could not yet qualify as an OECM.

Bahía de Todos Santos WSR, Mexico: The Bahía de Todos Santos World Surfing Reserve (BTSWSR) is located at the north end of the city of Ensenada, on the Pacific side of the Baja California peninsula in Mexico. In this region, there has been an important local planning process to protect the region's natural resources, a combined effort of the community, environmental and government actors, described by Arroyo, Levine and Espejel (2019). For example, the need to protect Ensenada's remaining natural coastal environments, together with the desire to have recreational areas for the local community, has encouraged diverse NGOs to promote the creation of protected areas in the region. One of the key initiatives of the BTSWSR, together with the Mexican NGO Pronatura Noroeste, was the creation of the first State Park in Baja California at the San Miguel watershed. Today, the BTSWSR is working with Pronatura Noroeste and the Secretariat of Environmental Protection to finalize this process. The designation of San Miguel stemmed directly from the efforts of the local community to preserve public open space for future generations and the need to protect

Ensenada's remaining natural coastal environments and the biodiversity of the watershed (Arroyo *et al.,* 2019).

Although the actual surf break is not inside the designated area for the State Park, this watershed is a critical riparian ecosystem that contributes necessary sand and cobblestones to form the iconic wave of San Miguel (Arroyo *et al.,* 2019). Bahía de Todos Santos WSR is now exploring mechanisms to extend the protection to the marine area and include the surf break. Should this not happen, the BTSWSR could qualify as an OECM.

Punta de Lobos WSR, Chile: Chile's Punta de Lobos was mentioned earlier for its significance for both surfing, seascape and biodiversity. After becoming the 7th WSR, the Local Stewardship Council sought to protect Punta de Lobos from the possibility of large-scale development projects by working with government officials and business leaders in Pichilemu, given that the zoning regulations would have allowed for new private developments. A local foundation (Fundación Punta de Lobos) was created to purchase key coastal properties and manage them under conservation easements ("*servidumbres voluntarias*"). Now, beyond protecting the surf break, Fundación Punta de Lobos also helps steward the land and works to safeguard biodiversity. Chile has not recognized the area as a private protected area, hence the scheme could qualify as an OECM for its protection of local biodiversity and the seascape.

These examples demonstrate the flexibility of the WSR approach to conserving surf resources, while providing ancillary conservation benefits for biodiversity and seascape protection. In those cases where WSRs legally protect surf breaks with demonstrably high biodiversity and seascape value, and there is no protected area, countries could consider recognizing the WSR as an OECM.

Case Study 2: The Peruvian 'Ley de Rompientes'.

In Peru, significant threats to the iconic surf breaks La Herradura and Cabo Blanco in the early 1990s encouraged a group of surfers to create the Association for the Conservation of Beaches and Waves (ACOPLO). ACOPLO, in cooperation with the National Surfing Federation and the navy, led the effort for the creation of the world's first legal framework specifically created to protect surf breaks, through the "*Ley de Rompientes*" (law for the protection of surf breaks), approved in 2000. It took another 13 years of negotiations to finalize the accompanying regulations to the law, making it possible to apply the framework to protect surf breaks.

Notably, the law is not part of the protected area legal framework, managed by the Ministry for Environment, rather, it falls under the responsibility of the navy, part of the Ministry of Defence, which manages the allocation of use rights over aquatic areas. The law defines surf breaks as being part of Peru's natural heritage and establishes that all surf breaks in Peru are state property. This means the public is entitled to access and enjoy all surf breaks. In order to protect a surf break, the National Surfing Federation must file a request to the navy, which includes technical (bathymetric) studies that justify the existence of the surf break. If the request is approved, the surf break is included in the National Register of Protected Surf Breaks.

A protected surf break implies that: "…no rights over the area or aquatic usage will be granted, nor for the development of infrastructure, or other rights which may affect or overlap with the area of the surf break and its surrounding areas" (Reglamento de la Ley de Preservación de Rompientes, 2013, Title IV, Art. 10). The law prohibits "…any action or activity which is foreign to the acts of nature, which deform, diminish and/or eliminate the normal or ordinary travel path of the wave appropriate for surfing, the sea bottom, or alters the normal course of currents or tides". (*ibid,* Chapter II, Art. 12). The only exception to this is if a planned project is declared of national interest (a complex procedure in itself), although this would still require a prior environmental impact study.

A campaign called HAZla por tu Ola (Act for your Wave) was launched in 2015 by the Peruvian Society for Environmental Law in collaboration with the National Surfing Federation to protect Peru's most important surf breaks via the "*Ley de Rompientes*". Through local leaders, the campaign crowdsources the funds to cover the costs of the bathymetric studies and follows up on the administrative processes necessary to register a wave. At the writing of this paper, 27 surf breaks have been protected (see Figure 2). Figure 3 shows an example of a protected surf break, La Herradura, and the area that is protected by the "*Ley de Rompientes*". A Surf Break Defence Commission of the National Surfing Federation groups experts to help protect threatened waves and represents the interests of surfers in negotiations with authorities and the private sector. [FIGURE 2] [FIGURE 3]

A surf break protected by the "*Ley de Rompientes*" creates legal restrictions on other use forms in the area, mainly related to infrastructure, oil and gas exploration, and aquaculture concessions, thus *de facto* protecting benthic habitats, sedimentation processes, and the intactness of the seascape. For this reason, in cases where there is significant marine biodiversity that benefits from this form of protection, a protected surf break could qualify as an OECM. Exactly how OECM criteria apply to the "*Ley de Rompientes*" is illustrated in Table 7.

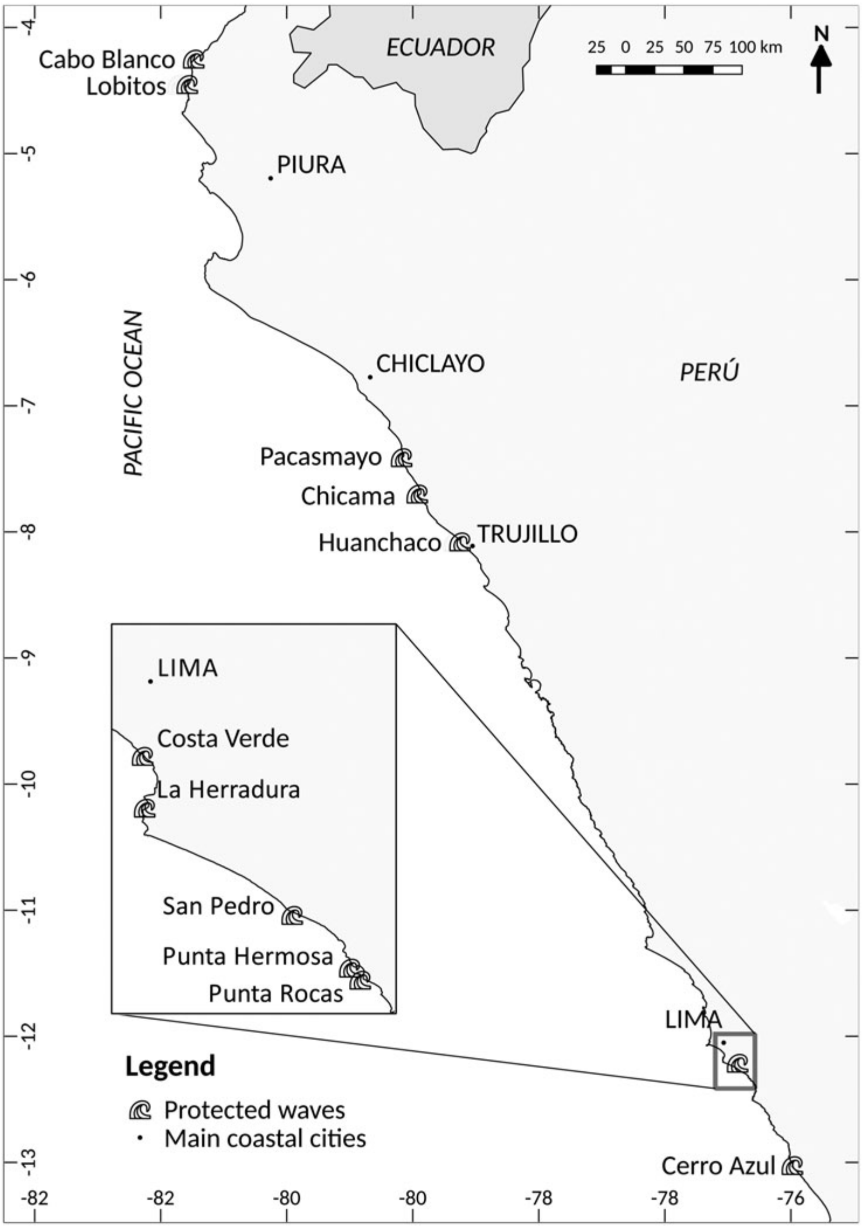
The “*Ley de Rompientes*” provides other opportunities for marine conservation in Peru, where changes to environmental regulations and poor relationships between the oil and gas sector have made it extremely difficult for new protected areas to be created – particularly in marine environments. However, since the “*Ley de Rompientes”* is not based on protected area law, protection via this mechanism is easier to achieve. Although the areas in question are usually small, the law could provide partial protection to areas where there is a surf break and significant biodiversity or seascape, but a protected area is unfeasible or the process for protected area creation is paralyzed. The latter is the case for the aforementioned Illescas Reserved Zone, which has been awaiting categorization for nearly a decade. Protection via the “*Ley de Rompientes”* of the area around Punta Malnombre could help protect some of the biodiversity and seascape of the area, while potentially qualifying as an OECM.

Table 7. OECM criteria applied to Peru’s “*Ley de Rompientes”* surf break protection mechanism

OECM Criteria	Does Peru’s *“Ley de Rompientes”* qualify?	Comments
a) Geographically defined space	YES	To protect a surf break, the technical file includes a detailed map, with geographic coordinates and bathymetric properties of the surf break area that is protected.
b) Not a protected area	YES	A protected surf break is not considered under the protected area system of Peru. There are specific cases where a surf break is located within a national protected area, as is the case of the San Gallan surf break in the Paracas National Reserve. In principle, both mechanisms could co-exist.
c) Governed	YES	The surf break is under the authority of the Peruvian navy, which controls whether other use-rights are assigned to the area. Additionally, the Surf Break Defence Commission of the National Surfing Federation is responsible for defending protected surf breaks.
d) Managed	YES	The protection measures for the surf break, although not explicitly targeting biodiversity, provide *de facto* protection by preventing the granting of other use rights over the area.
e) Long-term	YES	The law protects a surf break indefinitely.
f) Effective	YES	The law protects the designated area by effectively blocking the granting of other use rights. It is effective because the navy has sole control over the granting of these rights.
g) *In-situ* conservation	YES	The law protects a specific natural area and the biodiversity that depends on the area.
h) Biodiversity	PARTIALLY – depends on the type of biodiversity in the area	While the law does not require the justification of the importance of the site in terms of its value for biodiversity, the restrictions it generates protect benthic species and the intertidal marine ecosystem from infrastructure projects that could affect them (e.g. seabird nesting areas, marine mammal colonies). The law prohibits aquaculture concessions, but does not exclude extractive activities that do not affect the bathymetric conditions of the area (e.g. through fishing).
i) Ecosystem services	YES	Cultural ecosystem services are maintained because the sport continues to be viable.
j) Cultural and spiritual values	YES	The long-standing cultural practice of surfing in Peru goes back to pre-Inca cultures where ancient fishers used the “*caballitos de totora*” to ride waves. Modern surfing in Peru goes back to the 1950s and as a sport, is based on the connection with the ocean.

Case Study 3: Chile and the TURF-Surf Model.

Chile has no legal framework for the protection of surf breaks, however, the possibility of surf break protection through Chile's national Territorial Use Rights for Fisheries (TURF) policy is currently being explored by the NGO Fundación Rompientes.



Protected surf breaks	Nº. of surf breaks	Area protected (ha)
Cabo Blanco	3	22.14
Cabo Blanco		
Panic Point		
Pico Point		
Lobitos	5	46.46
Piscinas		
Muelles		
Lobitos		
El Hueco		
Baterías		
Pacasmayo	1	117.34
Chicama	1	130.05
Huanchaco	1	82.77
Costa Verde	4	187.76
Punta Roquitas		
La Pampilla		
Makaha		
Redondo		
La Herradura	1	6.93
San Pedro	1	22.75
Punta Hermosa	8	129.01
La Isla		
Kontiki		
El Silencio		
Caballeros		
Señoritas		
Pico Alto		
Playa Norte		
El Paso		
Punta Rocas	1	38.57
Cerro Azul	1	11.73
Total	27	795.53

FIGURE 2 Map showing surf breaks protected by the *Ley de Rompientes* in Peru.

FIGURE 3 Map of the La Herradura surf break in Lima, Peru, showing the area protected by the *Ley de Rompientes*

TURFs are concession-based, territorial use rights given to fishing collectives for the co-management of marine resources (Moreno & Revenga, 2014). Through TURFs, the Chilean Undersecretary of Fisheries assigns exclusive benthic resource extraction rights over areas of the seabed to fishing organizations, who are responsible for developing management plans for the resources and creating monitoring and anti-poaching measures. The Chilean legal framework has changed several times over the last few years, but currently prevents the assignment of conflicting use rights over TURF areas. TURFs account for more than 1100 km^2 of the nearshore seascapes in Chile, with an average size of 100 hectares each (Gelcich *et al.*, 2010). Importantly, research on TURFs shows that their management measures allow for the recovery and protection of resources and biodiversity in subtidal communities, specifically, increasing abundance and size of target species and increasing reef-fish biodiversity (Gelcich, Kaiser, Castilla & Edwards-Jones, 2008; Gelcich *et al.*, 2009). Therefore, TURFs provide ancillary conservation benefits, and given their management structures, could qualify as OECMs (Gelcich *et al.*, 2012).

Recreational activities often overlap with TURFs: surf breaks in particular. This co-existence has led to a growth in recreational activities for fishers and it is now common to see fishers becoming surfers. These communities are home to a broad range of user groups that rely on healthy environments and vibrant coastal communities. Surf tourism provides fishers with economic opportunities, which strengthen the surfer-fisher relationship and helps make the case for establishing protected surf breaks. A broad sphere of social, cultural, economic and environmental benefits can be maintained when access to surf breaks and TURFs is preserved.

Importantly, TURFs focus on benthic resources, and therefore fishers there also seek to limit infrastructure development that would threaten these resources. Such activities would also impact surf breaks, hence the interests of surfers and fishers in these areas overlap, albeit for surf breaks for the former, and marine resources for the latter. This crossover presents a unique opportunity for joint management schemes.

To assess the potential compatibility of a surf-break protection mechanism integrated with Chile's TURFs, an analysis was conducted to map where such sites overlap along the coast. The analysis was based on a list of key surf breaks listed on www.wannasurf.com, which records surf breaks' location, quality and other features, and the public database on TURFs maintained by the Chilean Undersecretary of Fisheries. The result shows that there are indeed ample cases of overlap between iconic surf breaks and TURFs, as illustrated in Figure 4.

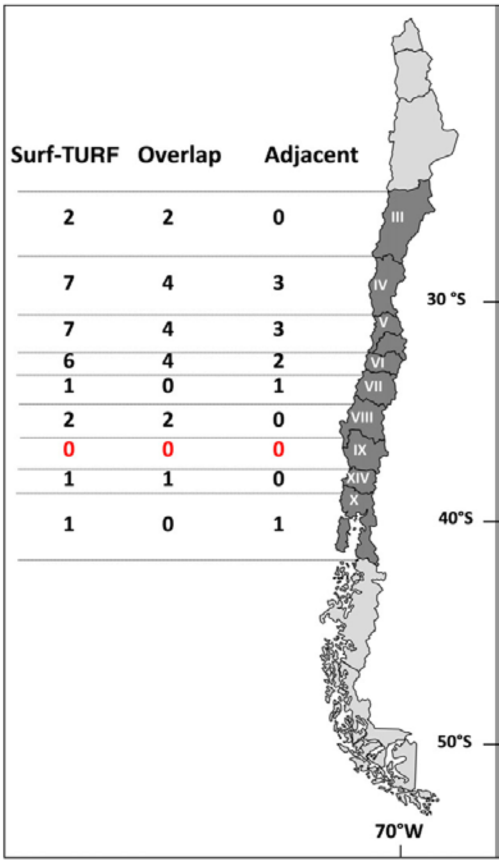


FIGURE 4 Map showing overlap between areas of assigned Territorial Use Rights for Fisheries (TURFs) in Chile, and important surf breaks.

Chile's TURF network presents a scalable opportunity to design joint sustainable fisheries and surf break protection programmes. These 'TURF-Surf' models would provide incentives for the protection of marine economic resources, biodiversity and recreational values, while securing public access. Key enabling conditions for governance are created by TURFs, which can be built upon to also include surf breaks in the

TURF area. Existing TURFs can provide the foundation for governance, coordination (Crona, Gelcich & Bodin, 2017), participation, social capital (Marín, Gelcich, Castilla & Berkes, 2012) and empowerment (Gelcich, Godoy & Castilla, 2018) for new TURF-Surf areas.

Fundación Rompientes, together with fishers and other local partners (i.e. fisher unions, local councils, NGOs, and universities), is currently developing the details of this TURF-Surf model. Critical factors for success include benefit-sharing, shared-governance systems, fishers' capacity to enforce TURF areas, and shared access with surfers. This relationship could take many forms, but should focus on the locally-based, co-management model of existing TURFs, with surfers as a new stakeholder group.

Furthermore, given the above-mentioned evidence that surfing can bring about raised environmental awareness, an interesting secondary benefit of a TURF-Surf model could be more positive attitudes towards sustainable resource management among fishers. Through TURF-Surf models, one would support and fine-tune a successful, existing policy framework that could benefit surf breaks, fisheries and biodiversity management in Chile.

Given the demonstrated benefits for biodiversity of TURFs, as well as their effective, local area-based management measures, TURF-Surf models could also qualify as OECMs once implemented (see Table 8). Notably, TURFs are currently not considered protected areas, and hence do not count towards Aichi Target 11.

Table 8. OECM criteria applied to Chile's TURF-Surf proposal

OECM Criteria	Does TURF & SURF qualify?	Comments
a) Geographically defined space	YES	TURFs are by essence geographically defined (on average 100 ha) and are created by an official decree by the Undersecretary of Fisheries.
b) Not a protected area	YES	TURFs are not equivalent to MPAs in Chilean legislation.
c) Governed	YES	TURFs are under the co-administration of artisanal fishers unions and the Undersecretary of Fisheries.
d) Managed	YES	Fisher unions are required to present a management plan for the creation of the TURF that ensures biodiversity conservation and appropriate extraction measures. This plan must be approved by the pertinent authorities.
e) Long-term	PARTIALLY, DEPENDS ON RENEWAL.	The law allows TURFs to be renewed every 4 years indefinitely. Management areas are subject to an annual monitoring plan that must be submitted by the union. This monitoring plan must include information on harvests, management actions and activity

		schedule.
f) Effective	YES	The protection of benthic habitats has been shown to benefit the whole ecosystem, including reef-fish communities.
g) *In-situ* conservation	YES	The law protects a specific natural area and the biodiversity that depends on the area. Management plans are designed to maintain and ensure viable population of the species.
h) Biodiversity	PARTIALLY	The law does not exclude extractive activities of benthic species that are part of management plans. However, extraction is based on sustainable use criteria.
i) Ecosystem services	YES	Research cited above shows a series of ecosystem services have been protected through TURFs, these include provision, cultural and regulation services.
j) Cultural and spiritual values	YES	TURFs protect traditional livelihoods. They allow fisher communities to continue with their long-standing traditions of extracting marine resources - sustainably.

4. Discussion.

In an increasingly urban world, connection with nature is no longer the norm, but something that must be promoted actively by society. In his book "Last Child in the Woods", Richard Louv (2008) coins the term 'nature-deficit disorder' to describe the psychological, physical and cognitive costs of humanity's increasing disconnection from nature. This paper has discussed some of the growing body of research that demonstrates the benefits to human wellbeing created by spending time in natural environments like the ocean. Surfing should be considered by governments and civil society for its potential for re-engaging citizens with natural marine environments. Meanwhile, given the threats they face, many emblematic surf breaks merit protection for their impact on human wellbeing and their potential for sustainable tourism.

This paper has explored the potential for integrating strategies for surf break protection and marine conservation in cases where these interests overlap. Where possible and appropriate, surf breaks should be considered by governments and civil society when planning protected areas (particularly categories II, III, V and VI). Meanwhile, existing surf break protection mechanisms, such as certain instances of WSRs or Peru's "*Ley de Rompientes*", may qualify as OECMs when these overlap with areas of high biodiversity and the protection mechanism is based on legal measures. Importantly, the protection measures would have to protect the biodiversity in question as well as the surf break. In the case of OECMs, opportunities exist particularly for benthic conservation targets because surf-break protection measures usually protect against infrastructure and related interventions, although this would still have to be assessed on an individual basis. In cases where such overlap is suspected but not scientifically demonstrated, rapid biological inventories could be commissioned to establish the conservation significance of the site. Surf break protection could thereby help countries reach international targets for marine conservation.

There are multiple benefits of surfers and environmental groups joining forces. Surfing could provide an important source of sustainable income to protected areas or OECMs, for instance, by regulating tour operator access. Meanwhile, surfers could be a critical mass of support for protected area proposals, particularly if the management plans include protection of a local surf break. The link between surfing and increased environmental awareness is an opportunity for conservation groups to harness support for marine conservation causes. These could include halting unsustainable coastal development, pushing for plans to reduce single-use plastics or marine species protection.

Surf break protection engages many actors that might not usually be involved in conservation. Arroyo *et al.* (2019) show that WSRs harness the support of a multitude of local stakeholders that can advocate for conservation objectives. In Peru, supporters of surf break protection have been civilians, municipalities and even the private sector. Private companies sponsored the technical files of several surf breaks that are now protected: the file for La Herradura was paid for by the Quiksilver surf brand, and the file for Chicama was paid for by a local resort. The Patagonia outdoor clothing brand sponsored the entire HAZla por tu Ola surf break protection campaign, and the making of a film about it ("*A la Mar*"). Going one step further, a new alliance between Conservation International and Save the Waves underscores the potential of common aims for surfers and the conservation community. There is room for further involvement of the multi-million-dollar surf gear, clothing and apparel industries to support joint surf break protection and marine conservation efforts.

Meanwhile, the possible negative impacts of surfing have not been discussed in this paper so far, and merit mention here. Davenport and Davenport (2006) review literature on the impacts of tourism and sports such as surfing, diving and use of motorboats on coastal environments. They find that impacts are worrying and range from degradation of natural ecosystems from sheer numbers of tourists, to trampling of intertidal zones such as reefs, to calls for more road access and parking in remote, uninhabited areas to access surf spots. Mentioned also are the many negative impacts of motorboats and personal watercraft, which are used for big-wave surfing, during surf events and to access certain waves. Impacts include noise pollution for cetaceans and collisions with large marine vertebrates such as turtles.

However, virtually all forms of natural resource use cause impacts on biodiversity, and the discussions on human wellbeing versus conservation will inevitably involve hard choices and trade-offs (McShane *et al.*, 2011), balancing conservation aims on the one hand, and human needs on the other. A report by the IUCN (2018) highlights the opportunities of sports for conservation and provides decision-makers with tools to help minimize and mitigate negative impacts of sports on biodiversity. The need for multi-stakeholder solutions to address these trade-offs highlights further benefits of joint action between surfers and conservation groups.

Surf breaks included in OECMs or protected areas provide opportunities for minimizing impacts of surfing on the environment. The aforementioned case of San Gallan in Peru is a good example of this, where joint planning between surfers and protected area authorities have turned previously clandestine surfing into an activity that brings income to the park and is closely regulated to reduce impacts on wildlife. The other example mentioned is the regulation of personal watercraft use at Mavericks, and their prohibition at Ghost Tree and Moss Landing, all surf breaks within the Monterey Bay National Marine Sanctuary. Clear communication is necessary for surfers to understand and comply with such use restrictions, such as designating certain access routes to minimize impacts on reefs, or marking allowed parking areas, to avoid parking on the beach. Surf groups, including NGOs and the private sector, should help socialize a sustainable surfing code of ethics, akin to the principles developed by the Leave No Trace organization in the USA (Leave No Trace, 2012).

More research is needed to identify the sites where surf breaks and areas of high marine or coastal biodiversity overlap, for this, surfers need the conservation community. A further research necessity is a comparative, international review of the different surf break protection mechanisms that exist, and whether and how these could integrate with marine conservation aims. Alliances between conservation organizations and surfer groups are key to building on the opportunities – and address the challenges – that exist at the crossroads between surf break protection and marine conservation.

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Figure Legends.

Figure 1: Map showing overlap between biodiversity hotspots, iconic global surf breaks, and World Surfing Reserves.

Figure 2: Map showing surf breaks protected by the "*Ley de Rompientes*" in Peru.

Figure 3: Map of the La Herradura surf break in Lima, Peru, showing the area protected by the "*Ley de Rompientes*".

Figure 4: Map showing overlap between areas of assigned Territorial Use Rights for Fisheries (TURFs) in Chile, and important surf breaks.

2. MARCO METODOLÓGICO Y CONCEPTUAL.

2.1 Artículo 2: A transdisciplinary framework proposal for surf break conservation and management: Bahía de Todos Santos World Surfing Reserve (Publicado en Coastal & Ocean Management).

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A transdisciplinary framework proposal for surf break conservation and management: Bahía de Todos Santos World Surfing Reserve

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ABSTRACT

This paper combines the Social-Ecological System (SES), the Driving Forces-Pressure-State-Impact-Response (DPSIR) and Adaptive Co-management frameworks to provide practical guidelines to address environmental issues facing surf breaks. We applied these frameworks to Bahía de Todos Santos World Surfing Reserve (BTSWSR), located in Ensenada, Baja California in northern Mexico. We gathered information through a literature review and a review of activities undertaken by the BTSWSR Local Stewardship Council (LSC) together with the local community (Ensenada town), regional and international environmental organizations, and government agencies. We also conducted participatory meetings with different stakeholders between 2014 and 2017. The SES framework provides the analytical perspective to have a better understanding of the multiple interactions among elements of the social and ecological systems to influence the opportunities for conservation strategies. DPSIR allows us to identify specific anthropogenic pressures threatening surf breaks within BTSWSR, their impact on the environment, and actual or possible responses to human activities, facilitating the development of an adaptive co-management plan. By combining these frameworks, we were able to describe the interactions between human and natural systems in BTSWSR, and we provide initial directions to improve the understanding of the anthropogenic activities affecting surf breaks, and targeted responses to address environmental impacts to the system. The surf break conservation and management framework presented in this paper is based on a transdisciplinary approach that emphases the need to address socio-environmental issues through openness to new forms of scientific and place-based knowledge.

1. Introduction

Over the last two decades, there has been an increased interest around the world regarding the protection of surf breaks. A surf break is a natural feature where the hydrodynamic character of the ocean (swell, currents and water levels) combines with seabed morphology and winds to give rise to a wave that can be caught and ridden by a surfer (Peryman, 2011). Surf breaks are a natural resource that provides both a source of recreation as well as aesthetic benefits for people, and the protection of surf breaks represents an opportunity to perpetuate these human benefits as well as the integrity of coastal ecosystems.

Two main factors contribute to this global movement to protect surf breaks and their surrounding environments. First, waves, surf breaks and coastal-marine ecosystems worldwide are under threat, either from global impacts of climate change, such as sea level rise, ocean acidification and ocean warming (Scavia et al., 2002; Harley et al., 2006; Caldwell and Segall, 2007; Hoegh-Guldberg and Bruno, 2010; Caldwell et al., 2013; Hemer et al., 2013; Reguero et al., 2013; Espejo et al., 2014; Reineman et al., 2017), or from the impacts of nearby human activities that cause habitat deterioration and reduce water quality, such as coastal development, sewage, marine debris, solid waste, oil spills, coastal erosion, and restricted access (Corne, 2009; Caldwell et al., 2013). Second, surfing as a sport has experienced remarkable growth in its popularity in the last two decades, transcending borders and bringing together a global surfing community. An example of this international recognition for surfing is its upcoming integration to Tokyo's 2020 Olympics Games. .

As a consequence of these global trends, formal organizations and programs focused on surf break protection have emerged, such as the Surfrider Foundation in 1984 and Save the Waves Coalition (STW) in 2001. These organizations promote the idea that protecting surf breaks and their surrounding environment help to preserve people's wellbeing

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and connection to the ocean, support sustainable coastal economies and ecological resilience and protect both biodiversity and coastal resilience in the face of climate change and sea level rise (Personal communication, Executive Director STW 2017). New programs, such as the establishment of World Surf Reserves (WSRs) initiated by STW in 2009, are currently working to promote and formalize surf break protection in many locations around the world as part of a global coastal and marine conservation effort (Scheske et al., 2018). For example, New Zealand has included surf break protection in their coastal and marine planning process (Peryman, 2011; Peryman and Skellern, 2011).

However these efforts are relatively new, and a management framework focused on the sustainability and conservation of surf breaks is urgently needed (Martin and Assenov, 2015; Edwards and Stephenson, 2013; Scarf et al., 2009b; Buckley, 2002; Peryman and Skellern, 2011). Additionally, inter- and transdisciplinary research is necessary to bring together and synthesize knowledge, methods, and scholarship from different disciplines relevant to surf break conservation, including, for instance, economic drivers, sociocultural aspects of oceans and coasts, and the oceanographic effects of coastal development on surf habitats (Scarfe et al., 2009a,b). A transdisciplinary approach, in particular, can help facilitate the synthesis of theories and methodologies from different disciplines to better address the complex problems faced in the conservation of the world's natural surf breaks.

In this paper, we present a management framework that can inform surf break conservation for initiatives such as the WSR and other surf-break protection programs. By combining the Social-Ecological System (SES), the Driving Forces-Pressure-State-Impact-Response (DPSIR), and Adaptive Co-management frameworks, this study provides practical guidelines to manage surf breaks. We apply this combined framework to a WSR case study, the Bahía de Todos Santos World Surfing Reserve (BTSWSR). This innovative research approach demonstrates the opportunities for combining SES analysis with DPSIR and Adaptive Co-management frameworks as a more effective way to pursue surf break conservation and management, rather than using a single framework alone. The SES framework provides a useful theoretical tool to describe the complexity of the interactions between human and natural systems in BTSWSR but does not provide sufficient detail regarding the causal dynamics and impacts of individual and institutional social responses to ecological issues. We argue that adding the DPSIR framework helps to provide specificity regarding linkages between anthropogenic activities affecting the ecosystem, as well as indicators to track and measure these activities and their impacts, and together with the Adaptive Co-management framework, provides a grounded and more comprehensive approach to surf break conservation and management.

2. Case study

Bahía de Todos Santos is located at the north end of the city of Ensenada, on the Pacific side of the Baja California peninsula in Mexico (Fig. 1), approximately 68 miles south of the Mexico-United States border. The bay covers approximately 116 km^2, with depths up to 50 m (Mateos et al., 2009). The limits of the bay are Punta San Miguel to the north and Punta Banda Peninsula to the south, with a couple of islands in the center (Isla Todos Santos, Fig. 1). A coastal lagoon known as Estero de Punta Banda is located in the southern part of the bay (Peynador and Méndez-Sánchez, 2010). The bay has a 39 km long coastline composed of cliffs, pebble, and sandy beaches. The WSR includes five surf breaks, four located within Bahía de Todos Santos (San Miguel, Tres Emes, Stacks, and Todos Santos surf breaks) and one located at Bahía de Salsipuedes (Salsipuedes surf break), about 10 km to the north of Punta San Miguel (Fig. 2). This region was officially designated as a WSR on June 21 of 2014 for five reasons: 1) it is one of the main surf destinations in Mexico, 2) the high quality and consistency of its waves, 3) its unique marine ecosystem, 4) the outstanding role it plays in the history of surfing in Mexico, and 5) strong community support. BTSWSR provides an example of a region where local and global actors have recently taken action to protect surf breaks.

The reserve is known for its high-quality waves for surfing and a landscape with towering cliffs and headlands, islands, natural bays and points, and Mediterranean climate (Nájera, 2014). However, as is the case with many surf breaks worldwide, BTSWSR is threatened by coastal development, beach access restrictions, poor water quality, land degradation, and beach contamination by solid wastes, especially in urban areas and during rainy periods when polluted water flows from creeks and sewers (Nájera, 2014). The City of Ensenada, centered in the bay, has a population of 519,813 inhabitants. There are two harbors and tuna mariculture in the south. Most economic activities in Ensenada are related to commerce and services, with tourism as the most important (Cervantes and Espejel, 2008). Both harbors of the bay show high levels of trace element contaminants, but the levels do not currently represent a threat to the local biota (Huerta-Diaz et al., 2008). While most of the time the water and the beaches of the region are clean, harmful algae blooms and high pollution levels at local beaches after rainstorms have been documented (Silva-Iñiguez and Fischer, 2003).

3. Conceptual approach

3.1. Transdisciplinary approach

The multi-scalar and interdisciplinary nature of the world's current environmental problems have given rise to new theoretical and methodological approaches. Coastal zones, for instance, are characterized by cross-boundary institutions and interactions, existing at the interface of land and sea, as well as socio-institutional boundaries, diverse ecosystem types, and contrasting forms of human actions and enterprise. Such complex systems create challenges for sustainability because the multitude of interacting biophysical, social, cultural, and economic drivers and processes require simplification to understand and manage (Baldwin et al., 2016). Analyzing contemporary socio-ecological systems requires coherent models and methodologies that recognize the complex and interconnected nature of society and the environment and questions traditional modes of governance (Holling, 2001; Berkes et al., 2008; Koontz et al., 2015; Biesbroek et al., 2017; Tàbara et al., 2018).

A combination of theory development and multiple research approaches linking diverse disciplinary perspectives is needed to develop an integrative understanding and build capacity to sustainably manage socio-ecological issues (Collins et al., 2011). In this sense, research focusing on transformation and sustainability is advancing in making a richer representation of the role of agency, using a complex systems perspective in modeling as well as assessment tools and methods. Newer approaches such as the Complex Systems approach (García, 2006) and Transformative Climate Science (Tàbara et al., 2018), which are inherently transdisciplinary, are better suited to address the growing complexity and interlinked nature of problems related to social and ecological change. These new approaches emphasize the need to address complex social-ecological problems through openness to new forms of non-expert knowledge, as well as strategies and solutions to overcome the dualism between scientific knowledge and practice (Fry, 2001; Tress et al., 2003; Wickson et al., 2006; König et al., 2013; Challenger et al., 2018).

In this paper, we use a transdisciplinary approach to explore surf break conservation and management at the BTSWSR, integrating scientific knowledge and place-based, experiential knowledge to address the uncertainty and complexity of social-ecological systems.

We acknowledge the need for an integrated understanding of the ecosystem for coastal planning (Lloyd et al., 2013) and to evaluate, monitor and manage surf breaks. Thus, we combine three different frameworks to aid our analysis:

1. *The Social-Ecological Systems framework (SES)* (Berkes and Folke, 1998; Ostrom, 2009; McGinnis and Ostrom, 2014) allows us to

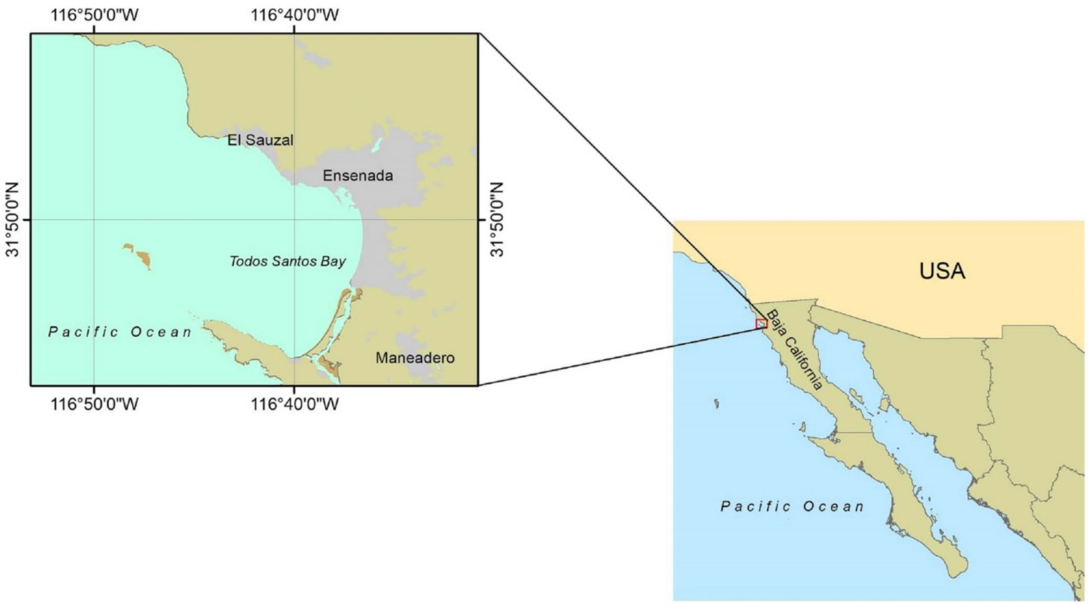

Fig. 1. Location of Bahía de Todos Santos in Ensenada, Baja California, México.

conceptualize the social, ecological, and governance components of the BTSWSR, their interactions, and the outcomes of these interactions.

2. *The Drivers, Pressures, State, Impact, Response (DPSIR) framework* (OECD, 1994; Carr et al., 2007; Svarstad et al., 2008) enables us to identify and establish causal links between anthropogenic activities affecting surf breaks and the environment, allowing for the concrete development of indicators and metrics of sustainability at BTSWSR.
3. *The Adaptive Co-management framework* (Olsson et al., 2004; Folke et al., 2002; Sandström and Rova, 2010) provides a grounded approach to address the process of knowledge generation, organization and problem-solving for the further development of a conservation and management planning for surf breaks at BTSWSR.

3.2. Social-ecological systems framework (SES)

Drawing on the complex systems approach, SES is based on the idea that, if human activities affect all natural ecosystems, the environment is best viewed as an integrated social-ecological system, and understanding and learning how to manage feedbacks between ecosystems and humans is vital if we want to move toward a more sustainable world (Collins et al., 2011). The framework provides a common set of potentially relevant variables to consider in the analysis of complex social-ecological systems and helps to identify factors that may influence the effectiveness of policy interventions for sustainability (Ostrom, 2009). We propose using the SES framework as the first step towards building a theoretical understanding of the relationships between social and ecological components of a system and a common vocabulary to construct models or theories to understand what influences on system processes and outcomes are critical across diverse geographies and biophysical conditions (McGinnis and Ostrom, 2014).

The SES framework, initially proposed by Ostrom (2007) and later modified by McGinnis and Ostrom (2014), describes the following first-tier variables for the analysis: i) resource units that are part of ii) resource systems, and iii) governance systems that define and set rules for iv) actors, and the resultant interactions and outcomes and feedbacks. In this framework, each of the categories contains multiple variables, and action situations are inputs transformed by multiple actors into outcomes. In the SES framework, governance and actors are considered to be components of a focal action situation, interacting and generating outcomes and affecting the variables of the integrated system. The framework also considers exogenous influences from related ecological systems or social-economic-political settings (at larger or smaller scales than that of the focal SES), that can affect any component of the SES (McGinnis and Ostrom, 2014).

For our purposes, the SES framework is a useful analytical tool to conceptualize social-ecological systems, as it makes explicit the different components of, and interactions within, a system, and provides the theoretically grounded means to integrate data from diverse natural and social disciplines and test hypotheses about the dynamics and implications of social-ecological interactions (Leslie et al., 2015). However, as Ostrom (2009) explains, understanding the drivers of, and interactions among, different components of the system is key to solving problems that deal with the protection and use of natural resources. However, this also presents one of the greatest challenges for social-ecological science, and an opportunity for more research, particularly regarding the establishment of causal linkages among factors and determining the relevance of different factors to local contexts, as well as regardless of context (Basurto et al., 2013). Many contributions to understanding social-ecological systems come from efforts to apply the SES general framework to the analysis of particular cases (McGinnis and Ostrom, 2014) and by combining it with other frameworks. Challenger et al. (2018) describe the opportunities and challenges of this approach in Mexico. Here, we propose that the SES framework can be useful for characterizing the SES of surf breaks and can serve as a diagnostic tool for knowledge accumulation and synthesis by defining variables and their interactions based on expert and local knowledge (Basurto et al., 2013). As a next step, to take analysis from a theoretical to a more applied level for surf break management and conservation, we use the DPSIR framework, a popular research framework used in Europe and Latin-American countries for guiding action toward sustainable development (OECD, 1994).

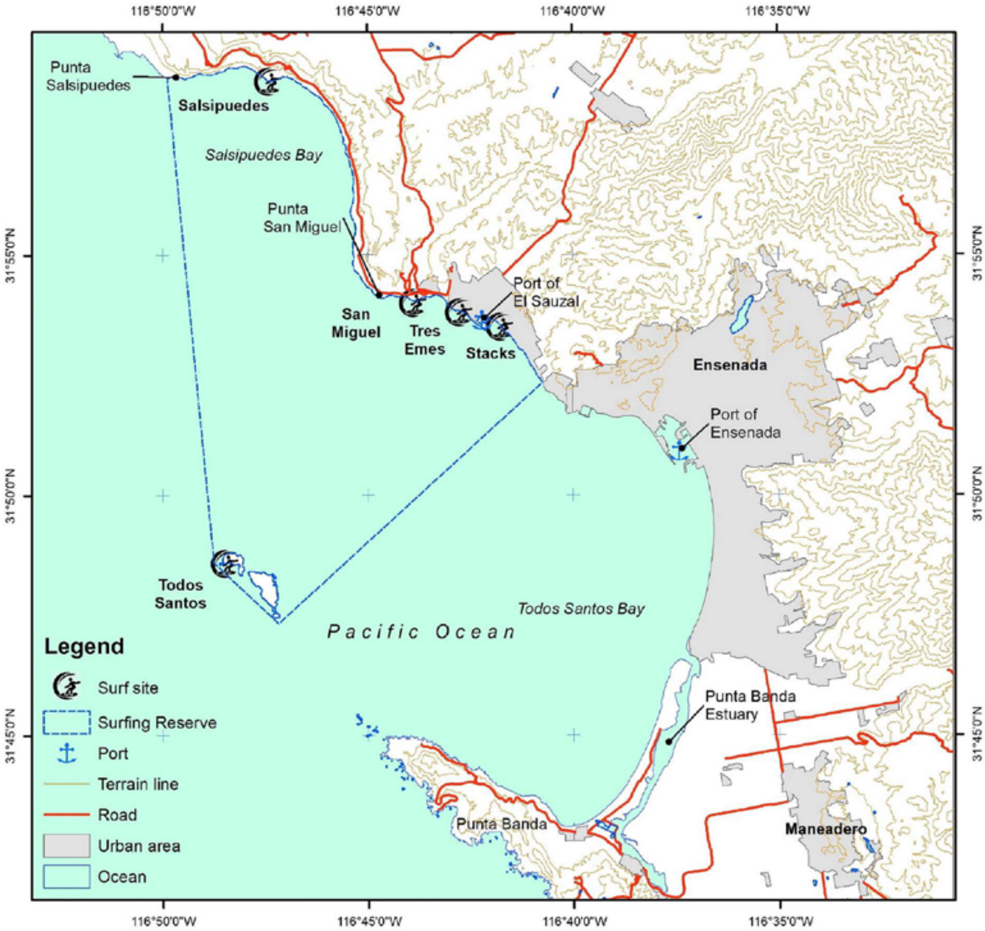

Fig. 2. Ensenada, Baja California and Bahía de Todos Santos World Surfing Reserve map.

3.3. Drivers, pressures, state, impact, response (DPSIR) framework

The DPSIR framework (Carr et al., 2007; Svarstad et al., 2008), developed by the Organization of Economic Cooperation and Development (OECD, 1994) and the European Environment Agency (Smeets and Weterings, 1999), is one of the most popular tools for adaptive management of social-ecological systems (Gari et al., 2015). The DPSIR framework was developed to provide a better understanding of indicators and appropriate responses to the impacts of human activities on the environment, with the aim of supporting decision making, by capturing key relationships between society and nature (Atkins et al., 2011). This framework has been widely used, especially in Integrated Coastal Zone Management (ICZM), as it integrates broad ranges of stakeholder perspectives and values and establishes multicause-effect relations between anthropogenic activities and their ecological consequences (Ojeda-Martínez et al., 2009; Gari et al., 2015). In México, for example, DPSIR is has been used for regional and marine ordinances and OCDE's sustainable development measurements (SEMARNAT, 2006). The European Environment Agency (2003) defines each category of the DPSIR framework as follows:

Driving forces: social, demographic and economic developments in societies and the corresponding changes in livelihoods;

Pressure indicators: describe developments in the release of substances (emissions), physical and biological agents, the use of resources, and the use of land by human activities;

State indicators: quantity and quality of physical phenomena (such as temperature), biological phenomena (such as fish stocks), and chemical phenomena (such as atmospheric CO2 concentrations) in a certain area;

Impact: changes in the functions of the environment, such as human and ecosystem health, resources availability, losses of manufactured capital, and biodiversity;

Responses: actions taken by groups (and individuals) in society as well as the governments' attempts to prevent, compensate, ameliorate or adapt to changes in the state of the environment.

As Gari et al. (2015) explain, the main objective of the DPSIR framework is to support sustainable management of natural resources by providing a common forum and language for environmental managers, scientists of different disciplines, and other actors. However, the DPSIR framework has been criticized for many reasons, including i) analysis is based on static indicators without taking into account the dynamic nature of social-ecological systems; ii) to identify trends one must repeat the study with the same indicators at regular intervals; iii) it suggests that there is a linear unidirectional cause and effect dynamic in complex environmental problems i) it ignores synergy between categories (Gari et al., 2015). Nevertheless, the applied indicator-focused approach of the DPSIR framework provides a useful and clearly defined starting point, and these shortcomings can be addressed when combining the DPSIR approach with complementary approaches that are more theoretical and less linear, such as the SES framework. The combined outcomes of analyses from these two approaches can then be moved forward with the more action-oriented and flexible approach of adaptive co-management.

3.4. Adaptive co-management

Because natural resources are affected by multiple dynamic social and ecological variables, one of the challenges for sustainable management of social-ecological systems is to understand and adjust to complex and constantly changing environments. Adaptive co-management is an emerging interdisciplinary as well as a transdisciplinary governance approach for complex social-ecological systems that combines the learning function of adaptive management (experimental and experiential) and the linking (vertically and horizontally) function of co-management (Sandström and Rova, 2010; Plummer et al., 2012). It is a collaborative and learning-oriented place-based process to achieve desirable environmental governance (Plummer et al., 2017), defined by a non-linear social-ecological feedbacks and cross-scale interactions to address complex social-ecological issues (Armitage et al., 2009). This learning process, a key quality of adaptive co-management, requires different actors and stakeholders to come together, interact, commit and collaborate to assess socio-ecological issues through repeated cycles of participation and learning (Fabricius and Currie, 2015). Armitage et al. (2009) outline five thematic areas of adaptive co-management: i) institutions, incentives, and governance; ii) learning through complexity; iii) power asymmetries; iv) assessment: monitoring, indicators and outcomes; and v) linking to policy. They also name five key attributes of adaptive co-management: (1) a greater recognition of different needs and an emphasis on distributive arrangements among actors; (2) continued effort to build on culturally embedded, formal and informal rules and norms; (3) formation of horizontal and vertical linkages and networks to foster trust building and social learning; (4) incorporating a wide variety of types and sources of knowledge, and the shared development of such knowledge among actors; and (5) enhanced capacity among resource management organizations to respond proactively to uncertainty.

While adaptive co-management is an emerging and promising approach to the management of natural resources, competing interests and values regarding how conservation and development should take place challenges the decision-making processes. Additionally, conventional institutional responses, including strictly enforced regulations, the development of protected areas, and other social and economic incentives are still needed for effective management of natural resources (Armitage et al., 2009). In this paper, we consider the adaptive co-management framework to be a promising tool for surf break management due to its inclusive and adaptive approach to addressing resource management problems by promoting partnerships. Also, its community-based 'bottom-top' approach can perceive dynamic and evolving problems and issues that are specific to a local area and may be approached from multiple perspectives. The SES and DPSIR, in turn, provide theoretical and applied analytical frameworks through which to conceptualize, analyze, and measure complex systems and make appropriate decisions and engage in monitoring for adaptive co-management. An illustration of the combined frameworks, applied to the BTSWR case study, is presented in Fig. 3.

4. Methodology

Responding to Benham and Daniell's (2016) call for the incorporation of participatory elements into research design and data collection to enhance transdisciplinary research, our work was based on participatory qualitative research. During the first phase of our research, we held two participatory workshops. The first workshop was held with the BTSWSR Local Stewardship Council (LSC), together with other relevant stakeholders including representatives from three nonprofit organizations (SurfEns, Costasalvaje, and Pronatura Noroeste), a local professional surfer, an academic (who is also a local surfer), and the BTSWSR manager.[1] A second workshop was held with representatives of the local surfing community. In these two workshops, we used Participatory Rural Appraisal tools (Anyaegbunam et al., 2004; Scoones, 2009; Corbett, 2009) to understand coastal issues from different perspectives. We used participatory tools including participatory mapping, problem tree, and social mapping, to facilitate identification of the main social and ecological components of BTSWSR, as well as social and environmental issues for each surf break. Using the information gathered in these workshops, together with the review of internal BTSWSR reports,[2] and minutes from LSC meetings held between 2014 and 2017, we generated a stakeholder-informed construction of BTSWSR as a social-ecological system using the SES framework.

During the second phase of this research, we participated in six formal meetings with representatives of different environmental Civil Society Organizations (CSOs) with the aim of discussing environmental issues in local beaches in the municipality of Ensenada, B.C., Mexico. By using input from these meetings, we were able to develop a general problem tree and an objective tree for all the beaches within Bahia de Todos Santos, including the WSR surf breaks.[3] By applying the problem tree tool, we were able to identify and understand what stakeholders considered to be the causes of key problems in the BTS area, as well as identify the downstream effects of a problem. With the objective tree tool, we were able to transform the problem into a vision of what it would take to reduce or eliminate each issue previously identified. In order to develop a schematic outline for BTSWSR using the DPSIR framework, we combined the information gathered from each of the meetings held with local actors (including both workshops and formal meetings with representatives of environmental CSOs), with a conceptual model of the Reserve developed by Save The Waves and the local committee in 2014 and revised in 2015 and 2016. The meeting outcomes and conceptual model informed our understanding of anthropogenic activities pressuring BTSWSR and what elements must be considered to measure the sustainability of surf breaks in BTSWSR.

Finally, we carried out 10 semi-structured interviews with the following individuals: 1) STW, executive director, 2) STW, director of programs, 3) President of the Baja California Surfing Association, 4) representative of CSO Costasalvaje, 5) representative of environmental nonprofit Pronatura Noroeste, 6) former president of the Mexican Surfing Federation, 7) representative of nonprofit United Athletes of the Pacific Ocean (UAPO), 8) representative of the municipality government, 9) local representative of the National Commission for Natural Protected Areas (CONANP), and 10) local representative of the Secretary of Environmental Protection (SPA). The interviews with representatives of environmental nonprofits covered three topics: i. the link between their work and coastal environment protection, ii.

[1] The first author of this paper is also employed as the BTSWSR manager.

[2] The Local Stewardship Council sends periodical internal reports to the Director of Programs of Save The Waves Coalition since 2015. These reports are sent every month to inform in detail about every activity the reserve participates in, as well as the progress made regarding the reserve's key project.

[3] This is part of the work being developed inside the Citizen Council for the Management Program of Clean Beaches for Ensenada and will be available for the public as soon as the new management plan is completed.

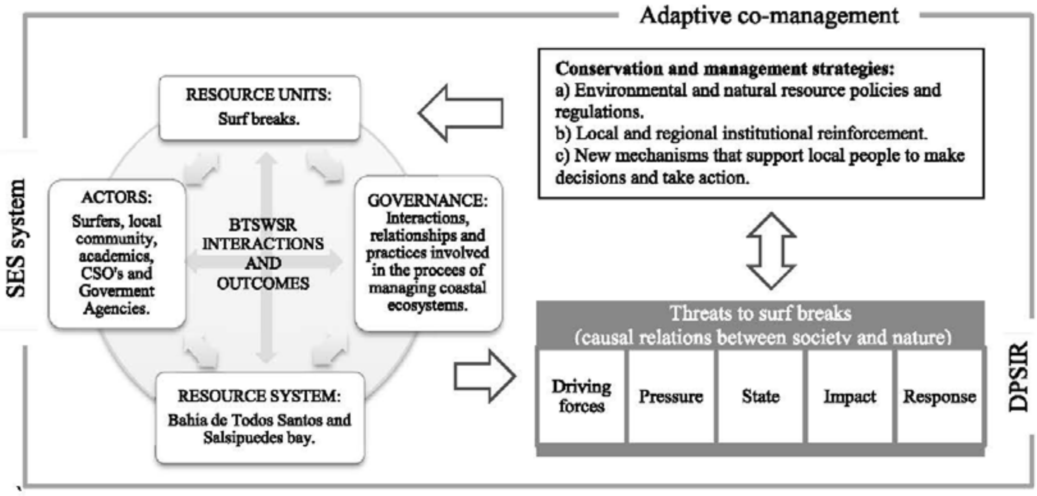

Fig. 3. Conceptual and methodological framework for Bahia de Todos Santos World Surfing Reserve. The integrated process to evaluate, monitor and manage surf breaks is represented as a cycle that starts with taking a diagnostic approach to analyzing the World Surfing Reserve (WSR) as a Social-Ecological System, by identifying the analytical variables under four categories in the SES Framework: resource units, resource system, actors and governance. The second stage of the analysis consists of identifying main threats to surf breaks under a causal-effect approach using the DSPIR framework. Finally, by applying an adaptive co-management lens to the analysis it will be possible to identify key actors, their assets and attributes, and their roles related to the WSR, in order to develop conservations and management strategies together with different actors.

conservation and local communities, and iii. alternatives to legal protection for surf breaks. The interviews with representatives of surfing organizations covered an additional three topics: i. the local and regional history of surfing, ii. the current and future context and issues for surfing in Mexico, and iii. the link between surfing and coastal conservation. The interviews with representatives of local and regional government agencies focused on two topics: i. mechanisms for legal protection of ecosystems and natural resources in Mexico (environmental laws and practices in Mexico) and ii. alternatives to legal and regulatory protection for surf breaks.

Additionally, the first author participated formally in BTSWR meetings and activities as the BTSWSR manager. This enabled unique insight into multiple components of the social-ecological system, including uses of the surf breaks, habitats, local and international activism, conservation strategies, responses to environmental threats, academic participation in support of the conservation of the BTSWR, and analysis and participation in decisions related to coastal planning and development. Also, it allowed the first author to have in-depth knowledge of the interactions between the "governance system" and the "actors" involved in the conservation of the "resource system". The outcomes of the interviews, together with the review of environmental conservation strategies developed and implemented by the BTSWSR local committee between 2014 and 2017, informed the transdisciplinary framework development and analysis presented below.

5. Results and discussion

By using the following conceptual diagram (Fig. 3) as the basis for the analysis, the combined approach of these three frameworks helped to 1) analyze the social and ecological components of BTSWSR, 2) develop indicators to measure sustainability of surf breaks and 3) develop conservation and adaptive co-management guidelines together with different actors.

5.1. Bahía de Todos Santos World Surfing Reserve as a social-ecological system

The SES framework facilitated a better understanding of the interactions between the social and ecological components of BTS WSR by integrating governance and sustainability of surf breaks into the analysis. Fig. 4 represents the SES framework for BTSWSR based on McGinnis and Ostrom's (2014) SES framework. To adapt this framework for the BTSWSR, we used data obtained from the two workshops held with the reserve's committee and representatives from the local surfer community, formal meetings held with different actors and stakeholders, ten semi-structured interviews, as well as from written reports of two years of the reserve's activities. Here, we describe the different components of the framework for the analysis of BTSWSR as a social-ecological system.

5.1.1. Resource system

The Resource System is characterized by particular ecosystem types and biophysical processes, at one or more geographic scales (Leslie et al., 2015). At the same time, the Resource System may contain diverse types of resource units which may be consumed in many forms and influenced by a particular governance system. For the Resource System of BTSWSR we define the Resource Units as surf breaks: four within the Bahia de Todos Santos area and Salsipuedes surf break, located on a small bay to the north of Ensenada (Fig. 2).

On the northern part of the bay, in a small community with a fishing harbor called El Sauzal, the coastline is composed of a combination of sand, cobblestones and rocky beaches surrounded by rocky cliffs which encompass the points of San Miguel, Tres Emes and Stacks. Another mixed type harbor (industrial, cruise, and fishing vessels) and the city itself disrupt the natural shoreline in its central part. Along the southern area of Ensenada, there are long sandy beaches interrupted by the entrance of the Punta Banda estuary, which covers a large area of the south end of the BTS. Local families and beginner surfers frequently visit these beaches. Waves for surfing most frequently come from the west and northwest, with the biggest waves observed during the fall

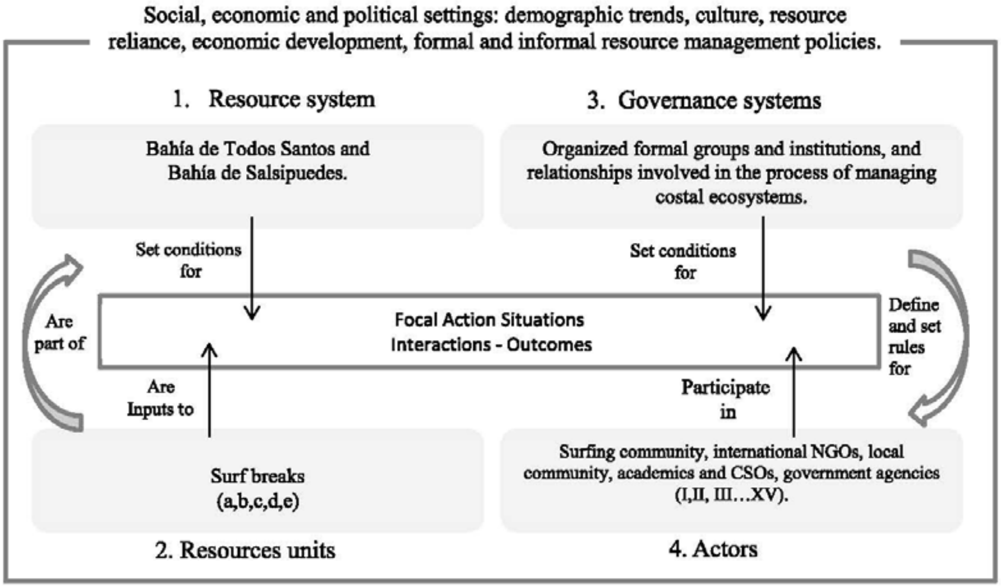

Fig. 4. Social Ecological Framework for BTS WSR adapted from McGinnis and Ostrom's (2014) SES framework. The letters that appear on Table 1 correspond to the Resource units. The roman numbers that appear on Table 1 correspond to the Actors involved in the SES.

and winter months. Waves are smaller and less frequent during the summer, coming predominantly from the southwest (Nájera, 2014).

The coastal sage scrub is characteristic of the Punta Banda region, and the Ensenada hills facing the sea have more endemics than other areas in the state (Vanderplank et al., 2017). The biodiversity of Bahía de Todos Santos is high, for example, Díaz-Castañeda and Harris (2004) report 203 species of polychaetes (64% of all invertebrate macrofauna). Temperate to cool-temperate dinoflagellate species were identified corresponding to 44 species of motile cells and 18 species of organic-walled dinoflagellate resting cysts (Peña-Manjarrez et al., 2005). The most charismatic species in the BTS is the Eastern Pacific gray whale (*Eschrichtius robustus*) that enters into the bay during the annual migration from Alaska to Baja California Sur (Heckel et al., 2003). Fishing and gathering are important in kelp forest environments (including for rockfish (*Sebastes macdonaldi*), California flaunder (*Parulichthys californicus*), and mussels (*Mytilus californianus*).

5.1.2. Resource units

San Miguel, Tres Emes and Stack's are located in the community of El Sauzal in the northern part of Ensenada. Coastal and small-scale fishing play a significant role in this area, especially for octopus and sea urchin, as the coast is characterized by vast tide pools, kelp forests and a rocky seafloor. This favorable habitat is very important for fish spawning and growth. In particular, the shores of Stack's are annually visited by reproducing grunions (Nájera, 2014). San Miguel is one of Mexico's most iconic surf spots and is considered the birthplace of Mexican surfing. This surf break is part of a San Miguel watershed, a critical riparian ecosystem that contributes necessary sand and cobblestones to form the classic wave. Tres Emes is located inside an industrial area and access is currently permissible although the Ports Administration which has the concession of the access road, reef and marine area. The LSC of BTSWSR is leading efforts together with the local community to protect the site from an industrial intake/outfall system that could endanger the wave and surfers in the line-up. Stacks is also located within the Port's Administration concession area and is threatened by restricted access and sewage outflow. New infrastructure has caused the wave to change over time, creating a left-hand reef break (Nájera, 2014). A big concern for Stacks, as well as Tres Emes, is a project proposal called "Puerto el Sauzal II y Baja Marina Nautica". This project includes the extension of the port to Tres Emes and Stacks, a project that would impact the waves, beach access and near-shore coastal and marine ecosystems.

Salsipuedes, located on the northern end of Bahia Salsipuedes, has global recognition for the boulder/rocks right point break to the south of the cove. After many years of ownership by a ranching family who maintained a camping area above the cove, the property was sold to development interests, and access was closed in 2005. The surf break is currently is only accessible by boat or via a 1-h walk down from the highway. The Islands of Todos Santos are located about 19.3 km (12.0 mi) off Ensenada's coast. One of the islands has an iconic lighthouse and a small field station. Islas de Todos Santos is home to one of the world's most famous big wave spots: Killers. The islands have some species of cactus and a species of endemic poppy only found on a few Pacific islands near California in the United States, and Baja California in Mexico, and very few other species of land-based vegetation. As kelp forests and small rocky islands surround the islands, fishermen specialize in lobster and small-scale fishing, using both islands as dry docks and storage. A permanent shellfish cultivation operation, mostly of mussels and abalone, is located on the southern island (Nájera, 2014). Todos Santos Islands are now part of the Biosphere Reserve of the Islands of the Pacific Ocean.

5.1.3. Governance

Ehler (2003) defines governance as the "process through which diverse elements in a society wield power and authority and, thereby, influence and enact policies and decision concerning public life and economic and social development". In the SES framework, the governance system is the process in which rules shaping the behavior of users of resource units and resource systems are set and revised (Ostrom, 2009; McGinnis, 2011; McGinnis and Ostrom, 2014), and can be influenced by government agencies, organized groups and institutions as well as the private sector. In general, environmental issues have

Table 1
Resources System, Resource Units and Actors for BTSWSR. The letters that appear on this table correspond to the Resource units (a,b,c,d,e), and the roman numbers correspond to the Actors involved in the SES that appear on Fig. 4: Key actors (I,II), Government agencies (III, IV), Users (V, VI, VII), CSOs (VIII, IX, X, XI, XII, XIII), academics (XIV), coastal stakeholders (XV).

Resource units (surf breaks)	Users	Other uses	Threats to resource units	Regulatory context	Actors involved IN resource governance
Salsipuedes(a)	Experienced surfers. Locals but mostly international visitors.	Tuna aquaculture.	Restricted access. Coastal erosion due to new developments and coastal highway repairs.	Unprotected Private land.	Currently none.
San Miguel(b)	Intermediate to experienced surfers. Locals and international visitors.	Camping. Recreational beach. Coastal fishing.	Human impact on watershed: deprived of land-based vegetation, solid waste, and sand extraction.	In the process to be declared as a Natural Protected Area under the category of State Park. Laws and regulations: General Law of Ecological Balance and Environmental Protection, Law of Environmental Protection for Baja California and municipal plans and programs.	Local Stewardship Council (I). Save The Waves (II). Secretariat of Environmental Protection (III). Pronatura Noroeste (VIII). Autonomous University of Baja California (XIV).
Tres Emes(c)	Beginners, intermediate and experienced surfers. Mostly local users.	Recreational beach. Coastal and small-scale fishing Diving. Marine industrial activities.	Water pollution. Industrial underwater infrastructure. Coastal development.	Unprotected. The Port Administration has the concession of the access road, cliff and marine area. Laws and regulations: General Law of Ecological Balance and Environmental Protection, Law for harbors, and municipal plans and programs.	Local Stewardship Council (I). Local Community (V). Local Surfing community (VI). Costasalvaje (XIX). ProEsteros(X). Terrapeninsular (XI). Baja California Surfing Association (XII).
Stacks(d)	Beginners to experimented surfers. Mostly local users.	Recreational beach.	Restricted access. Swage. Coastal development.	Unprotected. The Port Administration has the concession of the marine area. Laws and regulations: General Law of Ecological Balance and Environmental Protection, Law for harbors, and municipal plans and programs.	Local Stewardship Council (I). Costalvaje (XIX).
Todos Santos Islands (e)	Experienced surfers (manly international visitors).	Small-scale fishing, diving, whale watching.	Marine debris. Deprived of land-based vegetation.	Natural Protected Area (Pacific Islands Biosphere Reserve). Laws and regulations: General Law of Ecological Balance and Environmental Protection.	Local Stewardship Council (I). Local Community (V). Local Surfing community (VI). Visiting surfers (VII). National Commission for Natural Protected Areas (IV). Grupo de Ecología y Conservación de Islas (XIII). Costasalvaje (XIX).

triggered a new focus on environmental governance in the last two decades, with an emphasis on public participation. In Mexico, for instance, social scientists joined biologists in the design of participatory methods, especially in creating regional ordinances and integrated management plans for protected areas (Martinez and Espejel, 2015).

Governance in the BTSWSR is influenced by diverse actors and institutions, working in an adaptive governance approach to surf break conservation and management. Adaptive governance, which is increasingly advocated for the governance of social-ecological systems, is as a collaborative and learning-based process to manage natural resources in a way that can adapt to change to improve or maintain a desirable state, by combing leadership, experience, bridging organizations and setting common rules and strategies (Koontz et al., 2015; Cosens et al., 2018). The World Surf Reserve (WSR) program, which designated the BTWSR, was created in 2009 by Save the Waves Coalition (STW), a nonprofit organization based in Davenport, California, along with two key partners: National Surfing Reserves (NSR) Australia and the International Surfing Association (ISA). Save The Waves Coalition (STW) works with local communities, government, academics, and other key stakeholders through the LSC to protect surf zones and surrounding environments around the world. The mission of this program, according to the STW director of programs, is to obtain international recognition and local support for wave protection through a network of Surf Reserves, to protect the ecological resiliency of the surf zone at the world best surf sites. The WSR designation is largely symbolic, but when this international recognition is obtained, the local community commits itself to protect the coastal and marine resources of the Reserve.

As part of the WSR program, BTSWSR established a LSC that oversees the overall management of the reserve, and STW collaborates with the LSC to monitor and manage the reserve through a management plan that guides the conservation activities for every surf break. The composition of the LSC membership varies at each WSR site, but most LSCs are composed of surfers, scientists, business people, government officials, CSO's and community activists. Their role is to represent the interests of the local community and adopt a stewardship role. The LSC does not have any formal power, nor do they receive any government funding, but they can become an incorporated organization (Edwards and Stephenson, 2013), and it is expected that they will play a role as key local stakeholders who will be consulted in coastal environmental management and decision-making. Save the Waves works with each WSR to develop a strategic conservation plan by identifying unique targets for each Reserve, major threats to sites, root causes of threats, and concrete measures to mitigate these threats. The development of this plan implies collaboration and consensus within the LSC and with local or key partners under the current geopolitical system.

At a broader legislative and regulatory scale, multiple laws and government institutions shape political and legislative framework for BTSWSR. At the national scale, these include the General Law of Ecological Balance and Environmental Protection, the Secretariat of the Environment and Natural Resources (SEMARNAT), Secretariat of the Navy (SEMAR), Secretary of Governance (SEGOB), the National Water Commission (CONAGUA), the Federal Terrestrial Marine Zone (ZOFEMAT) and the National Commission of Natural Protected Areas (CONANP). At the regional scale, governance is shaped by the Law of environmental protection for Baja California and The Secretariat for Environmental Protection (*SPA*). Diverse municipal institutions of planning, such as the Municipal Institute of Research and Planning of Ensenada (IMIP), also play a role.

Particularly in Ensenada, Baja California, there has been an important local planning agenda to protect the region's natural resources, based on interactive processes between community, environmental, and government actors. For instance, the need to protect Ensenada's remaining natural coastal environments, together with the desire to have recreational areas for the local community, has encouraged diverse CSOs to promote the creation of Natural Protected Areas in the region. For example "La Lagunita", one of the last remaining wetlands within Ensenada's urban area, was recently designated as property of the nation (part of the process to become a protected natural area). Additionally, San Miguel watershed is in the process of being designated as the first State Park in Baja California. The designation of San Miguel stemmed directly from efforts of community members in El Sauzal to preserve public open space for future generations, particularly given the lack of public spaces in most Mexican coastal cities, and the beach often serves as a recreational area for families to spend their weekends (Puig, 2014). This community effort is now being led by Pronatura Noroeste, A.C., STW and the LSC, and the Secretariat of Environmental Protection. Within the BTSWSR specifically, bridging organizations and networking have allowed different stakeholders to develop appropriate strategies to address common issues such as 1) water quality and 2) solid waste pollution in beaches through the Clean Beaches program together with local governmental authorities and different CSOs; 3) plastic marine pollution through the "Libre de Plasticos" (Free of Plastics) campaign *lead by a member of the Ensenada City Council*; and 4) marine debris through a common project with The National Commission of Natural Protected Areas (CONANP); and the lack of laws or regulations directed to promote the sustainable use of coastal ecosystems together with the *Federal Maritime Terrestrial Zone (ZOFEMAT)*.

5.1.4. *Characterization of actors*

McGinnis and Ostrom (2014) explain that in the SES framework it is important to consider not only direct users of the resource units but also third parties linked to the SES. For BTSWSR, we identified that although the users of surf breaks are predominantly the local and international surfing community, there are now many formal groups involved in the activities of the WSR and there are other programs and projects that have a direct impact on surf break conservation and management at BTSWSR. Key actors include the local surfer community, the resident community, visiting surfers, academics, CSOs, and coastal stakeholders, as well as the LSC, WSR, and other local and international NGOs (Table 2).

The initial petition to designate Bahia Todos Santos as a WSR was submitted by NGOs including SurfEns and Pronatura Noroeste, with the support of Costasalvaje. One of the first initiatives of the BTSWSR, together with the Pronatura Noroeste, was the creation of the first State Park in Baja California at San Miguel watershed. Today, the BTSWSR is working directly with Pronatura Noroeste and the Secretariat of Environmental Protection to finalize this process. Three additional initiatives that have integrated new actors into the reserve's activities include: a) the community effort to protect Tres Emes beach from an industrial seawater intake and outfall system, b) the participation of BTSWSR representatives in the local government program "Clean Beaches", and c) Todos Santos Islands cleanup and monitoring project.

To protect Tres Emes beach from an industrial seawater intake and outfall system, the LSC had the assistance of scientists from the Autonomous University of Baja California (UABC) and Center for Scientific Research and Higher Education of Ensenada (CICESE), and the support of four different local environmental organizations. As a result of the participation of BTSWSR representatives in the Clean Beaches Program meetings, a collaboration network was initiated among civil society organizations to address the socio-environmental problems related to the beaches in Bahía de Todos Santos. In 2017, periodic meetings were held with representatives of the different organizations to work on the update of the Clean Beaches Management Program. This motivated the interest of other organizations in the activities of the reserve and the inclusion of issues that are a concern to the local surfing community on the agenda of the official meetings with the municipality. Also, BTSWSR is now officially part of the Citizen Council for the Management Program of Clean Beaches of Ensenada. Additionally, a local big Wave surfer led the local effort to remove solid waste and marine debris from the northern area of the Todos Santos

Table 2

SES framework components interactions, outcomes, and responses for BTSWSR. The roman numbers that appear on this table correspond to the Actors involved in the SES that appear in Fig. 4 and Table 1.

Exogenous factors: Policy and institutional factors that enable or limit the decision-making process.

SES components.	Interactions.	Desired outcomes or responses.
1. Resource system and 2.Resource Units: a) ABIOTIC: Physical characteristics of surf habitats (air, water, weather, bathymetric, topographic and hydrologic components) b) BIOTIC: Biological characteristics of surf breaks.	Provide the necessary conditions for surfing waves to break. Flora and fauna maintain the natural habitat of the surf break.	To maintain the natural conditions of the surf break. To preserve and protect biodiversity.
3. Governance and 4. Actors: Laws and regulations, STW WSR program and LSC management plan for BTSWSR. Government agencies (III,IV). Key actors: BTSWSR LSC (I) and Save The Waves (II).	Legal framework and general guidelines for the protection and management of surf breaks and coastal ecosystems. Implement formal mechanisms of protection. Authorize land use and concession. Establish geopolitical boundaries. Represent the interests of the local community and adopt a stewardship role. Identify unique targets for each Reserve, major threats to sites, causes of threats, and concrete measures to mitigate these threats.	To identify the most appropriate institutions or legal processes of the current environmental political and legislative framework in Mexico to protect each surf break.To promote local and regional institutional enforcement to preserve surf breaks. To develop a conservation and management plan to protect each surf break at BTSWSR.
Users: (V, VI, VII).	Users of the natural resources. Provide social pressure (activism) to address socio-ecological issues on each surf break.	To have an involved community and local leadership. To sustain public interest. To have new mechanisms that support local people to make decisions.
CSOs (VIII, IX, X, XI, XII, XIII).	Facilitate mechanisms for environmental protection and provide the necessary resources. Provide a link with the Government.	To establish collaboration, obtain support and resources to protect the surf breaks. To ensure the sustainable use and conservation of natural resources and coastal ecosystems for the benefit of people and the environment.
Academics (XIV).	Provide technical support and scientific knowledge to validate socio-ecological concerns regarding surf breaks.	To establish collaboration and develop joint programs with government, CSOs, the private sector, and the local community.
Coastal stakeholders (XV).	Play a role in the decision-making process related to coastal planning and development.	To include surf breaks in coastal management practices and planning.

Islands. This local initiative received the support of local volunteer divers and the international support of STW, Parley For The Oceans, and three environmental ambassadors from Chile, USA, and Puerto Rico. This cleanup activity opened a line of collaboration with CONANP to work on the Management Plan for the Pacific Islands Biosphere Reserve, and a monitoring program for the Islands of Todos Santos.

5.1.5. *Outcomes or responses of actors to the resource system*

The decisions that individuals or groups make, when combined with exogenous factors, affect the outcomes in a SES. In other words, social, institutional, and biophysical factors are inputs to the decisions that individuals make, and the outcomes of these decisions then feed back into the previous components in an iterative process (McGinnis and Ostrom, 2014). For our purposes, the SES framework enables us to understand these responses and outcomes better and organize this information to inform the more applied DPSIR framework. In Table 2, we identified the different individuals, groups and institutions that are involved in the decision-making process for BTSWSR, as well as their interactions, outcomes and desired responses to the SES.

5.2. *DPSIR indicators*

Identifying the appropriate categories, variables, and indicators to measure the sustainability of BTSWSR as a social-ecological system, is one of the challenges of this study. In this paper we used the SES framework to facilitate this process by integrating key elements of socio-environmental issues identified under the SES Framework for BTSWSR into the DPSIR general model shown in Fig. 5:

To develop the DPSIR schematic outline (Fig. 5) we used the information gathered from the participatory meetings with key actors, the conceptual model of the Reserve, and the SES framework developed for BTSWSR. We identified two primary driving forces behind impacts to surf breaks: a) unplanned and unsustainable urban development in coastal areas, and b) development and introduction of industrial and port infrastructure. Both of these activities contribute to trash and marine debris, coastal erosion, loss of access to the beach, loss of natural areas, and water pollution. In Fig. 6, we present a proposal of elements that can help measure the sustainability of surf breaks. The SES framework helped to identify four major activities pressuring BTSWSR: Land use change (privatization and concessions), the introduction of new coastal infrastructure, construction of houses and

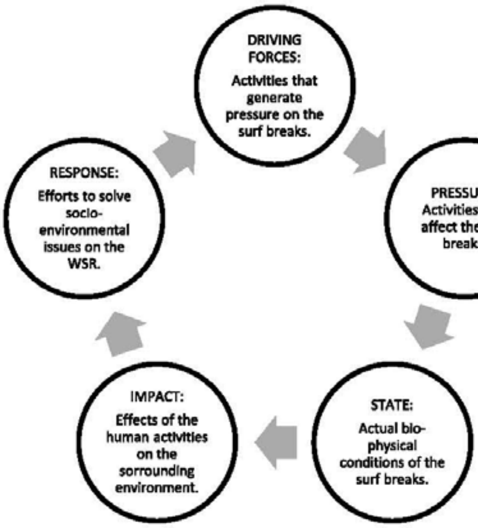

Fig. 5. Schematic outline for the DPSIR framework for BTSWSR.

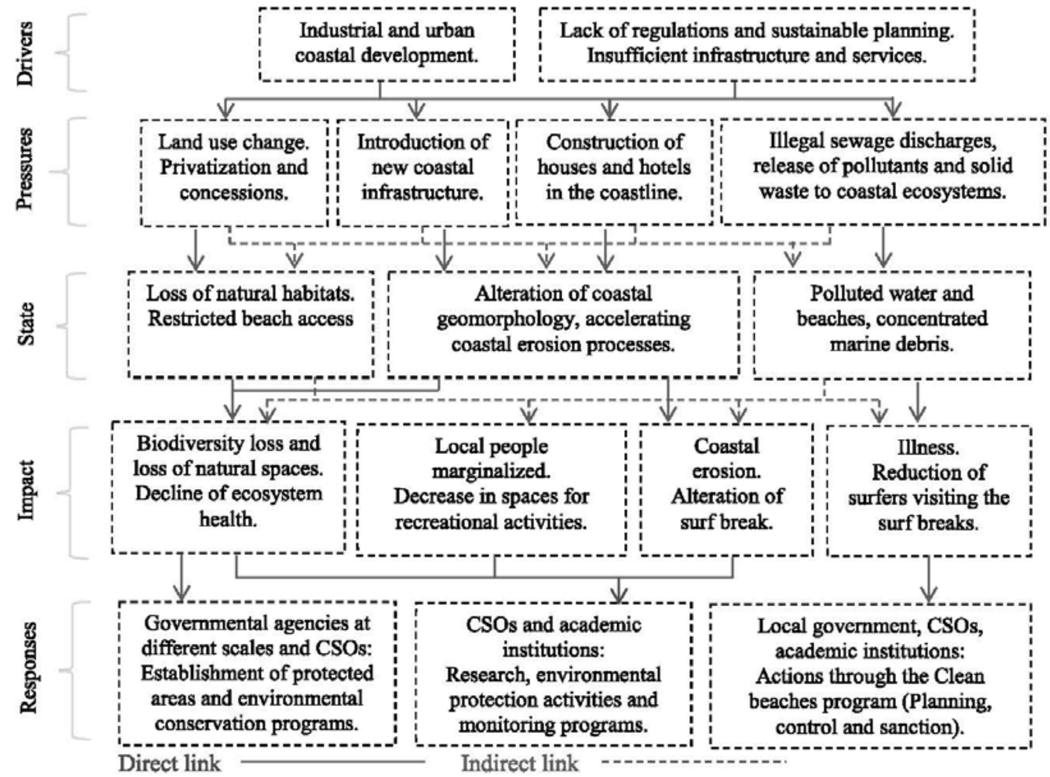

Fig. 6. Schematic outline for the DPSIR framework for BTSWSR.

hotels along the coastline, and the lack of regulations and sustainable planning (insufficient infrastructure and services). We also identified three potential elements that will help to measure the state of the surf breaks, and by analyzing the desired outcomes and responses from the SES framework, we present four elements that can help to determine the causal link between humans and their environments in surf breaks.

For coastal areas, DPSIR models have been used to support and develop a conceptual understanding of complex social-ecological systems and to identify drivers and pressures in the coastal realm (Baldwin et al., 2016). The DPSIR framework provides a useful tool to assess surf break conservation and management, as it allows the integration of scientific knowledge from different disciplines and placed based knowledge from other actors and policy makers. In a future publication we will present specific indicators to assess the state variables presented in the DPSIR framework. Further on our research we will define variables to measure the state of ecosystem health in BTSWSR, as well as parameters that can be measured to evaluate surf break protection, providing a systematic structure to evaluate and compare Surfing Reserves and surf breaks worldwide.

The information presented in this section allowed the identification of the different issues concerning surf breaks and an integrative perspective connecting actors and responses to mitigate these issues, providing a basis for an adaptive management proposal. In this paper we identify the following responses and outcomes for BTSWSR between 2014 and 2017:

1. BTSWSR has been able to provide key information for the technical studies of San Miguel's watershed and surf break to meet the requirements of the Secretary of Environmental Protection. It has also provided an essential connection with the local community and has been able to show the government how much cross-border support there is to make this State Park.
2. BTSWSR has provided the local community the necessary tools to protect Tres Emes beach from an industrial seawater intake and outfall system, together with the support of scientists from the UABC and CICESE, and different local environmental organizations.
3. BTSWSR introduced issues that are a concern to the local surfing community in the "Clean Beaches Program" for Ensenada, Baja California, Mexico.
4. BTSWSR is now part of a network of environmental organizations working towards sustainable and healthy beaches in Ensenada.
5. BTSWSR is collaborating with CONANP for the Management Plan for the Pacific Islands Biosphere Reserve and a monitoring program for the Islands of Todos Santos.

While guidelines for using the SES and DPSIR frameworks are laid out in the literature, the literature for engaging in adaptive co-management provides a less clear path. In the next section, we aim to provide a guideline for adaptive co-management based on the SES and DPSIR framework outcomes.

5.3. *Adaptive co-management*

Adaptive co-management is considered to be a transdisciplinary approach to managing complex SES, as it requires the participation of multiple actors to assess environmental problems and design approaches to solve such problems. It combines the learning function of adaptive management, and the linking function of co-management

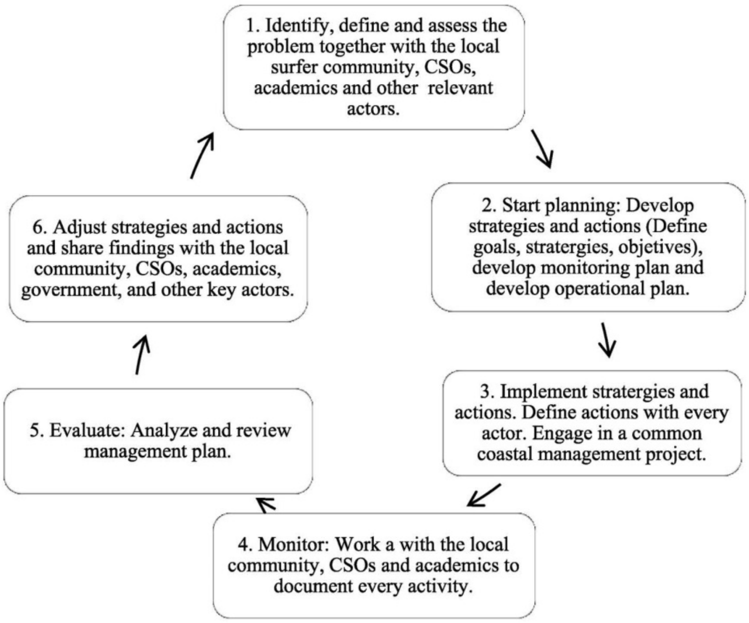

Fig. 7. Adaptive co-management cycle proposal for BTSWSR. Based on Olsson et al. (2004).

(Plummer et al., 2012). Adaptive co-management is fundamentally a participatory and iterative process in which actors help to implement and monitor activities and participate in the evaluation of results. We use adaptive co-management as the third step for implementation of surf break conservation and management in this study because it is an emergent governance approach for complex SES. Adaptive co-management provides the most appropriate applied approach to surf break management, especially for BTSWSR, because the strategies rely primarily on partnerships and the involvement of the community. The objective of using the adaptive co-management framework is to identify goals and objectives that reflect local stakeholder perceptions for coastal ecosystems in BTSWSR and guide interactions between society and nature within the complexity of the SES approach, where "the information provided by a single case study or individual respondent can yield rich and valuable insights" (Plummer et al., 2012). For surf break conservation and management planning we present the following cycle based on Olsson et al. (2004):

For BTSWSR, by using the SES framework outcomes, we were able to identify, define, and assess the system, including ecosystem and human dynamics and interactions. Next, following the adaptive co-management six-step cycle proposal (Fig. 7), and drawing from on Ehler (2003) and Plummer (2009), we identify who was engaged in managing and governing the WSR, as well as organized groups and institutions taking action to address environmental issues in coastal ecosystems within Bahía de Todos Santos. By identifying each actor and their connections we were able to define and asses' common issues in coastal ecosystems. Also, by engaging in a common coastal management project with other organizations, we were able to set goals and objectives for BTSWSR. These set of goals and objectives can be used to get the government, local community, CSOs, and other actors to commit on a common adaptive co-management plan (Van Putten et.al., 2016).

In pursuing an adaptive co-management plan for the BTSWSR, we make the following recommendations. First, identify key actors and their responses to the socio-environmental issues identified in the DPSIR framework. Start planning by analyzing the governance components of the SES and the DPSIR framework (especially the response components). Using the causal relationships (drivers, pressures, and impacts) formulated in the DPSIR framework, develop specific strategies and actions (responses) and a monitoring plan for key state and pressure variables. Define roles and responsibilities for actors involved in the WSR conservation and management plan among levels of governance, clearly identified in the SES framework, and build a common vision with national development, economic development, and environmental goals. Identify specific actors from the SES framework (individuals, organizations, agencies) who have specific assets and attributes that influence the adaptability of the SES. Attributes identified to strengthen adaptive co-management include leadership, emotions, capacity, experience, and interpersonal skills. We also recommend implementing strategies and actions (responses) through the appropriate actors identified in the SES framework and engaging actors in a common coastal management project. Look for appropriate funding available to implement activities.

Table 3 presents a summary of projects and programs implemented with an adaptive co-management approach in BTSWSR:

The next step for BTSWSR is to:

- Monitor the key state and pressure variables, identified as important to the social and ecological systems of the surf breaks. Involve the local community, CSOs and academics in monitoring activities.
- Evaluate outcomes through measured changes in indicators and system dynamics. Analyze and review the management plan. Use outcome indicators to evaluate the management plan's performance, either success or failure of management actions, and share findings with the local community, CSOs, academics, government, and other key actors.
- Use the results to adjust goals, objectives, management strategies, and desired outcomes. Ensure that appropriate indicators are being measured under the revised management plan.

In a future publication, we plan to present an adaptive co-management plan specific to the BTSWSR based on the outcomes of this paper, additional research, and community input.

Table 3
Projects implanted with an adaptive co-management approach in BTSWSR, including strategies, leadership, actors, goals, and objectives.

Project	Strategies	Leadership	Key actors involved	Goal	Objectives
San Miguel State Park proposal	To establish a natural protected area.	1)Pronatura Noroeste, A.C. 2)BTSWSR 3)Save The Waves Coalition 4)Secretary of Environmental Protection (SPA)	1)Faculty of Sciences of the Autonomous University of Baja California 2)The National Water Commission (CONAGUA)	To preserve one of the less altered watersheds in Baja California.	1) To protect the watershed and iconic wave at San Miguel. 2) To provide a public open space for the community of Ensenada. 3) To protect the San Miguel creek and aquifers.
Clean beaches program of Ensenada.	To integrate BTSWSR in the Beach management plan for Ensenada.	1)Municipal government authorities	1) CSOs. 2) The Autonomous University of Baja California.	To improve the environmental quality of local beaches and to protect the health of beach users.	1) To improve beach water quality. 2) To reduce solid waste pollution at the beaches and watersheds. 3) To eliminate the use of vehicles on beaches. 4)To regulate human activities on beaches,
Ensenada free of plastics campaign.	To promote a ban to eliminate the use of plastic bags and disposable utensils in commercial establishments of Ensenada.	1) A key member of the Ensenada City Council.	1) CSOs. 2) The Autonomous University of Baja California. 3) Representatives of the municipality.	To eliminate the use of plastic bags and disposable utensils in commercial establishments in Bahía de Todos Santos.	1) Create awareness about plastic pollution. 2) Empower local people to find sustainable strategies to live without single-use plastic. 3) Reduce the amount of plastic waste discharged into the World Surfing Reserve boundaries.
Management plan for the Biosphere Reserve of the Islands of the Pacific Ocean.	The strategies are now being developed together with local communities and key actors.	National Commission of Protected Natural Areas (CONANP)	1) CSOs 2) Secretary of Environmental Protection (SPA) 3) Local communities. 4) Users	To preserve natural resources, species, and ecosystems in the Mexican Islands of the Pacific Ocean.	1) To protect natural resources, species, and ecosystems. 2) To promote scientific research and monitoring. 3) To promote the sustainability of social and ecological systems.

6. Conclusions

The combined methodological and conceptual framework for surf break conservation and management presented in this paper is based on a transdisciplinary approach, where scientific and local knowledge combine and provide the elements for the analysis of BTSWSR (Semeoshenkova et al., 2016). Transdisciplinary approaches facilitate the synthesis of the theoretical and methodological approaches of different disciplines to better recognize complex problems (Baldwin et al., 2016). Although the SES, DPSIR and Adaptive Co-management frameworks have been individually applied for coastal environmental assessment, combining these three frameworks provides us with a more comprehensive understanding of WSRs, integrating scientific and theoretical perspectives with concrete local knowledge, and moving from describing and diagnosing the system to providing concrete strategies for adaptive co-management informed by direct engagement of local actors.

By combining the SES and DPSIR frameworks it was possible to gain a more comprehensive understanding of issues relating to environmental governance and sustainability that are relevant to a wide range of actors, including the local community, representatives of CSOs and academics. It was also possible to determine the specific activities that pressure surf breaks, their impact on the environment, and to identify actual or possible responses to those activities (Semeoshenkova et al., 2016). By using the SES framework, we were able to identify the components of the socio-ecological system and their articulation with BTSWSR surf breaks. We found it useful to use the SES framework prior to the DPSIR model in order to have a better understanding of the complex issues and actors involved in BTSWSR, thus facilitating a more complete assessment of the interactions between drivers, pressures, state, impact and response, facilitating the proposal of the co-adaptive management plan (Semeoshenkova et al., 2016). Coinciding with Baldwin et al. (2016), the DPSIR framework was useful to understand the complex socio-ecological interactions, providing a tool to communicate transdisciplinary systematic thinking, local expertise on threats, and build capacity among the participants. According to (Fontalvo-Herazo et al., 2007) DPSIR indicators should reflect people's concerns, and in doing so, they should be revised constantly to reflect a dynamic and complex socio-ecological system. Therefore, we need to conceptualize surf break management and conservation processes as a continuous cycle, involving repeated re-assessments of the social-ecological system, sustainability dynamics, and key issues for surf break protection.

The purpose of this paper was to contribute to knowledge accumulation regarding protection of surf breaks and their surrounding environments. In following contributions we plan to provide a common set of indicators under the DPSIR model to measure and evaluate WSRs and surf breaks around the world and, based on the outcomes of this first paper and application of the DPSIR model application, we will develop the adaptive co-management plan proposal for BTSWSR. While SES and DPSIR frameworks are essential to comprehensively understand the complex social-ecological system and dynamics at play at BTSWSR, adaptive co-management will serve an applied approach to plan actions for improved surf break management and to address resources management issues by promoting partnerships and a community-based, 'bottom-top,' and iterative approach.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.electacta.2018.11.083.

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3. RESULTADOS Y DISCUSIÓN.

3.1 Artículo 3: Indicators to assess pressure, state, impact and responses of surf breaks. The case of Bahía de Todos Santos World Surfing Reserve

.

Indicators to assess pressure, state, impact and responses of surf breaks. The case of Bahía de Todos Santos World Surfing Reserve.

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Abstract.

Using the Driving Forces-Pressure-State-Impact-Response (DPSIR) framework, this paper presents a set of indicators to measure human activities affecting the sustainability of three surf breaks located within Bahía de Todos Santos World Surfing Reserve, in Ensenada, Baja California, Mexico. Addressing issues facing surf breaks and the actual or potential responses of the reserve could provide new strategies for conservation and management of other surf zones and contribute to global marine conservation efforts. For the general DPSIR indicators proposal, we gathered information through a literature review and an analysis of activities, projects, and actions undertaken by the Bahía de Todos Santos World Surfing Reserve Local Stewardship Council, between 2015 and 2018. To define the parameters and criteria for the assessment of surf breaks and to measure each indicator, we used qualitative data from six informal interviews, four semi-structured interviews and five transect walks, and quantitative data from various sources: undergraduate and postgraduate theses, satellite images from Google Earth and on-site data collection such as the collection and classification of solid waste, and water quality sampling. Using the DPSIR framework allowed us to estimate specific anthropogenic activities affecting surf breaks, their impact on the environment, and actual or possible responses to human activities. The visual results will facilitate the development of specific strategies for an Adaptive Co-management plan at BTSWSR.

Keywords.
Coastal management, Sustainability indicators, Surf breaks, World Surfing Reserves.

1. Introduction.

Surf breaks are a natural resource that provide both a source of recreation as well as aesthetic benefits for people. Unfortunately, surf breaks and coastal-marine ecosystems worldwide are under threat, either from global impacts of climate change, such as sea level rise, ocean acidification and ocean warming (Scavia, *et al.,* 2002; Harley, *et al.,* 2006; Caldwell and Segall, 2007; Hoegh-Guldberg and Bruno, 2010; Caldwell *et al.,* 2013; Hemer *et al.*, 2013; Reguero *et al.,* 2013; Espejo *et al.,* 2014; Reineman *et al.,* 2017), or from the impacts of nearby human activities that cause habitat deterioration and reduce water quality, such as coastal development, sewage, marine debris, solid waste, oil spills, coastal erosion, and restricted access (Corne, 2009; Caldwell *et al.,* 2013). To promote surf break sustainability in specific locations and at the same time to contribute to costal and marine conservation (Scheske C, Arroyo, Buttazzoni JE, *et al.*, 2019), it is critical to both identify threats and develop indicators to monitor progress in addressing these threats. In this paper, we use the DPSIR framework as part of a surf break conservation and management plan at Bahia Todos Santos World Surfing Reserve (BTWSR) to identify and measure anthropogenic activities affecting surf breaks and their surrounding ecosystem.

This paper is part of a larger research project on surf break conservation and management that combines the Social-Ecological System (SES), the Driving Forces-Pressure-State-Impact-Response (DPSIR), and Adaptive Co-management frameworks (Arroyo *et al.,* 2019) as an integrative and more effective way to protect and manage surf breaks. Using the SES framework, we were able to conceptualize the social, ecological, and governance components of the BTSWSR, their interactions, and the outcomes of these interactions through describing the resource system, the resource units, the actors influencing the system, and the governance system that sets the rules for the diverse actors interacting with the World Surfing Reserve (Arroyo *et al.,* 2019). By using the DPSIR framework, we determined specific links between human activities affecting the ecosystem. In this paper, we selected indicators and its metrics of sustainability at BTSWSR and address actual responses and actions to protect these three surf breaks in BTSWSR. Finally, we provide a grounded and practical approach to address the process of knowledge generation, organization, and problem-solving for the development of a conservation and management plan for surf breaks at BTSWSR under the Adaptive Co-management framework, and we suggest that this model can be used and adapted to evaluate and monitor other surfing areas around the world.

2. Case study area.

Bahía de Todos Santos is located at the north end of the city of Ensenada, on the Pacific side of the Baja peninsula in Mexico, approximately 68 miles south of the Mexico-United States border. This region was officially designated as a World Surfing Reserve on June 21 of 2014 (Figure 1). It is one of the main surf destinations in Mexico and is known for its high-quality waves for surfing and a landscape with towering cliffs and headlands, islands, natural bays, and points and Mediterranean climate (Nájera, 2014). San Miguel, Tres Emes, and Stacks are three of the five surf breaks that integrate BTSWSR. These surf breaks are located on the northern part of Bahía de Todos Santos, in a small community with a fishing harbor called El Sauzal de Rodriguez (Figure 2). In this paper we focused on these three surf breaks because i) they share similar geomorphological characteristics, ii) they are located in an urban area with a high percentage of industrial land use and iii) they are all vulnerable to the pressure of human activities such as privatization and concessions, introduction of new coastal infrastructure, illegal sewage discharges, and the release of pollutants and solid waste to the coastal ecosystems. Although biodiversity is of partial relevance when designating a world surfing reserve, the strategies to protect the surf breaks contributes to the conservation of the flora and fauna, since the objectives and actions to protect surf breaks are mainly focused in regulating activities that can impact on a coastal or marine ecosystems, such as infrastructure development, wastewater discharges, pollution by solids, change of land use, among others.

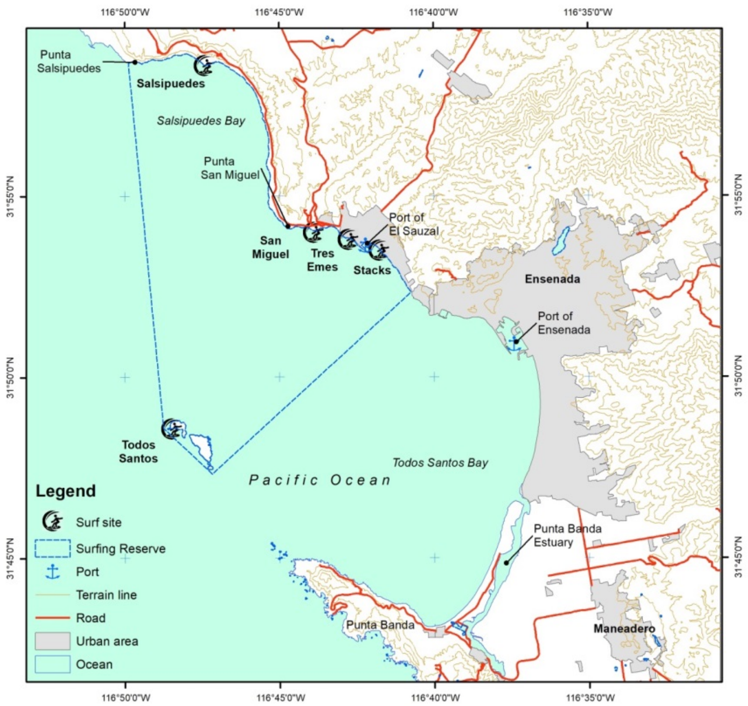


Figure 2. Ensenada, Baja California and Bahía de Todos Santos World Surfing Reserve map.

Figure 2. Location of three surf breaks in Bahía de Todos Santos in Ensenada, Baja California, México.

The northern coastline of the municipality of Ensenada is characterized by a combination of sand, cobblestones and rocky beaches surrounded by rocky cliffs (Gastil *et al.*, 1975, Cruz-Colín, M.E. & Cupul-

Magaña, L.A. 1997, Ledesma-Vázquez, J. y Huerta-Santana, D. M. 1993). Along the coastline of the community of El Sauzal there are vast tide pools and kelp forests (API, 2010; 2011). Small-scale fishing plays a significant role in this area (API, 2010; 2011). The rocky intertidal area is an important site for a large number of organisms of different species that live, feed and seek protection between rocks (Ruíz-Campos and Hammann, (1987). This favorable habitat is important for fish spawning and growth. The tide pools are hatcheries for juvenile's specimens of the marine fauna and flora (API, 2010). Researchers at the local university (Autonomous University of Baja California-UABC) monitor these sites looking into the effects of natural and anthropogenic disturbances on populations and communities. With the information from monitoring activities, it is possible to identify changes in these important ecosystems in the medium and long-term and to make suggestions for their use and conservation.

Surfing was introduced to Mexico by foreigners (mainly from California, USA) in the late 1950s, and first practiced by locals in the early 1960s (Félix, 2011). San Miguel is one of Mexico's most iconic surf spots and is considered the birthplace of Mexican surfing. The Baja Surf Club was founded in San Miguel in 1965 by Mexico's first surfers, with the support of the Windnsea Surf Club (Félix, 2011). Tres Emes was also an iconic surf break in the 1960s and the venue for the first National Surf Contest in Mexico in 1967. Since then, San Miguel, Tres Emes, and Stacks have been visited by renowned professional surfers.

Especially in the last decade, the surfing community of Ensenada continues to grow. Every year in San Miguel and Tres Emes several local, national and international surfing contest take place. For recent generations of surfers, San Miguel and Tres Emes are preferred surfing locations to train and prepare for national and international competitions, such as the ISA World Junior Surfing Championship. In December of 2018, the Mexican National Surfing Games were held in San Miguel with the participation of surfers from all over Mexico.

Surf breaks in Bahía de Todos Santos are of great importance and value for the local and international surfing community, and the need to protect the key environmental, cultural, economic and community attributes of surfing areas motivated the petition to designate Bahía de Todos Santos as a World Surfing Reserve in 2014 (Puig, 2014). The designation of a World Surfing Reserve is largely symbolic, but when this international recognition is obtained, the local community commits itself to protect the coastal and marine resources of the Reserve. This program, created by Save The Waves Coalition (STW) promotes the work of local communities, government, academics, and other key stakeholders to protect surf zones and surrounding environments around the world. In BTSWSR's case, this designation recognizes the need to protect Salsipuedes, San Miguel, Tres Emes, Stacks and Todos Santos surf breaks for their historical, cultural and ecological value, and support initiatives such as the process to denominate Arroyo de San Miguel as a State Park (http://www.arroyosanmiguel.org).

3. Conceptual approach.

Diverse ecological problems have challenged scientists, environmental activists, and decision makers, creating the need to develop effective strategies and flexible and practical approaches to understand complex social-ecological systems (Mateus and Campuzano, 2008). In this sense, the DPSIR framework (Eurostat 1999, Carr *et al.,* 2007, Svarstad *et al.,* 2008), developed by the Organization of Economic Cooperation and Development (OECD, 1993) and the European Environment Agency (EEA, 1995), has become one of the most popular tools for adaptive management of social-ecological systems (Gari *et al.,* 2015). The DPSIR is a practical tool to analyze the relationship between the environment and anthropogenic activities, using an interdisciplinary approach, to enable responsive and effective -management strategies. It assumes that human activities (drivers) exert pressure on a particular part of the environment, which causes the state of the environmental system to change. The outcome is an ecological impact that then results in a response by society to prevent or control the impact itself, or ideally the fundamental drivers of the impact (Mateus and Campuzano, 2008). This framework has been widely used, especially in Integrated Coastal Zone Management (ICZM), as it integrates broad ranges of stakeholder perspectives and values and establishes multi cause-effect relations between anthropogenic activities and their ecological consequences (Ojeda Martínez *et al.,* 2008; Gari *et al.*, 2015).

However, the DPSIR approach has been criticized primarily for four reasons: i) its analysis is based on static indicators, without taking into account the dynamic nature of social-ecological systems; ii) to identify trends one must repeat the study with the same indicators at regular intervals; iii) it suggests that there is a linear unidirectional cause and effect dynamic in complex environmental problems i) it ignores synergies between categories (Gari *et al.,* 2015). Nevertheless, its reductionist and simplicity characteristics help to capture key relationships between humans and nature; and it can be an effective tool for identifying solutions and making informed decisions to address real problems in complex social-ecological systems. DPSIR is a well-known and widely used tool in OCDE countries, where it is currently being used to estimate current sustainability as well as measure and monitor progress toward the 2030 sustainable development goals (https://sustainabledevelopment.un.org/?menu=1300).

DIPSIR helps to simplify the complex connections between humans and the environment and facilitates communication between scientists, stakeholders, and policymakers (Mateus and Campuzano, 2008). For coastal areas, DPSIR models have been used to support and develop a conceptual understanding of complex social-ecological systems and to identify drivers and pressures in the coastal realm (Baldwin *et al.,* 2016). This framework provides a useful tool to assess surf break conservation and management, as it allows the integration of scientific knowledge from different disciplines and placed based knowledge from other actors and policymakers. We argue that is also helps to assess the sustainability of surf breaks by facilitating the learning process of stakeholders as part of the adaptive co-management cycle. Based on the outcomes of the SES analysis developed in a previous paper (M Arroyo *et al.*, 2018), we present specific indicators to measure the state of the ecosystem in BTSWSR, as well as parameters that can be measured to evaluate activities affecting surf breaks. The application in this case study provides a systematic scheme that could be useful to evaluate and compare pressures, state and impact of human activities in World Surfing Reserves and surf breaks worldwide.

4. Methodology.

4.1. Participatory selection process for indicators.

Participation of stakeholders has become a useful tool in the development of indicators to evaluate, monitor and manage social-ecological systems, especially when aiming to develop and improve adaptive co-management (Ehrhart and Schram, 2018; Trimble and Berkes, 2013). Community involvement in the process of identifying indicators of sustainability can help to ensure that indicators are relevant to local situations and to build community capacity to address socio-environmental issues (Frase *et al.,* 2006; Reed *et al.,* 2006). Integrating findings from participatory methods is a critical component of adaptive co-management (Trimble and Plummer, 2018).

In order to select appropriate indicators, we integrated multiple methods, including participatory methodology as well as analysis of secondary sources. Participatory methods included five transect walks, two participatory focus groups, and participant observation between 2016 and 2018. The transect walks were a helpful tool for onsite observations and to identify issues of interest for the local surfing community. During the transect walks we were able to observe and identify physical and biological attributes of the surf breaks and their surrounding environment, observe local practices, and identify relationships between the natural resources and users. Transect walks also allowed us to have informal interviews with key stakeholders and facilitated communication with members of the local surfing community. After gaining a broader contextual perspective through transect walks, we carried out two focus groups. The focus groups enabled deeper discussions with key stakeholders and allowed us to gather information about specific issues relevant to the surf breaks. We also engaged in participant observation of 10 formal meetings with representatives of different environmental Civil Society Organizations. The data obtained from participant observation helped to identify key information provided by other stakeholders participating in events and activities related to BTSWSR. The information collected through participatory methods was then triangulated with an analysis of relevant documents, including internal BTSWSR reports and minutes from the LSC meetings held between 2014 and 2018. Each of these methods for this study is detailed below.

Transect walks.

Transect walks are a practical tool commonly used in Participatory Rural Appraisal (Chambers, 2011; Anyaegbunam *et al.*, 2004; Scoones, 2009; Corbett, 2009). A transect walk consists of systematically walking with key informants (local people and visiting professionals) through an area while observing, asking questions, listening, discussing, identifying different zones, seeking problems, solutions, and opportunities, and being open to new information (Chambers, 2011). It is important to previously identify key members of the community and other stakeholders who can make contributions and collaborate on the project. In this study we carried out a total of five transect walks. Three were conducted in San Miguel: one with biologists and oceanographers from the regional environmental organization Pronatura Noroeste A.C., a second walk with three local surfers, four visiting surfers and three members of Save The Waves Coalition, and a third transect walk with four biologists from the UABC and from Inpacvi, A.C., a local environmental organization. In Tres Emes we conducted one transect walk with four local surfers, four members of the LSC and two members of Save The Waves Coalition. In Stacks we participated in one transect walk with six local surfers.

Focus groups.

The proposal and evaluation of the general topics for the DIPSIR framework was carried out through two participatory focus groups that involved diverse stakeholders. The aim of these sessions was to identify key issues and desired outcomes for BTSWSR. The first focus group was held with the Local Stewardship Council (LSC) representatives from three local nonprofit organizations (SurfEns, Costasalvaje, and Pronatura Noroeste, and the BTSWSR manager in 2016. A second focus group was held with representatives of the local surfing community. In each focus group we used Participatory Rural Appraisal tools, such as participatory mapping, problem tree, and social mapping (Anyaegbunam *et al.*, 2004; Scoones, 2009; Corbett, 2009). Participatory Rural Appraisal methodology is most commonly used by non-governmental organizations and other organizations that work in development fields, as it aims to incorporate knowledge and perceptions of the local surfing community in the planning and management of projects and programs.

In 2018 the first author also participated in a meeting with Save The Waves Coalition members, where one of the exercises was to work on a general framework proposal to evaluate World Surfing Reserves.

Participant observation.

Between 2017 and 2018, the first author, who is also the BTSWSR manager, participated in 10 formal meetings with representatives of different environmental Civil Society Organizations with the aim of discussing environmental issues in local beaches in the municipality of Ensenada, B.C., Mexico. Input from these meetings, enabled us to develop a general problem tree and an objective tree for all the beaches within Bahia de Todos Santos, including the WSR surf breaks. With the problem tree tool, we were able to identify and understand what stakeholders considered to be the causes of key problems in the BTS area and with the objective tree tool we were able to transform the problems into desired conservation outcomes.

Document analysis.

We reviewed internal BTSWSR reports and minutes from LSC meetings held between 2014 and 2018, including the conceptual model of the Reserve, developed by Save The Waves and the local committee in 2014 and revised in 2015 and 2016. We classified the information into four main topics: i) projects carried out by the LSC, ii) projects in which the LSC participates, iii) issues that the LSC has identified for BTSWSR and iv) conservation outcomes for BTSWSR between 2014 and 2018.

a. Indicators selection.

The development of initial indicators for BTSWSR was based on the outcomes of focus groups. The selection of the indicators for each category was based on the following criteria: a) relevance, b) ease of understanding, c) reliability, d) data availability and, e) multidimensionality. First we selected the parameters that could be measured to evaluate surf break protection; if indicators are adapted to each site's characteristics, this framework can provide a systematic scheme useful to evaluate and compare Surfing Reserves and surf breaks worldwide. Second, we revised the first list of desirable indicators to see if the data required to asses each indicator was available and was appropriate to what we wanted to measure. We then refined the indicators to the list presented in Table 1.

	Topic	Indicators	1	2	3	4	5
Drivers (D)	1. International industrial development (manufacturing and fishing companies)	a. International investment in Ensenada between 2000 and 2010. Fuente CODEEN, 2011.	Decreased	Stayed the same	Less than 20% growth	Less than 50% growth	More than 50% growth
	2. Binational and national urban coastal developments.	a. Real estate growth in Tijuana-Rosarito-Ensenada corridor between 2010 and 2018.	Decreased	Stayed the same	Less than 50% growth	Between 50% and 100% growth	More than 100% growth
Pressures (P)	1. Land use change affecting surf breaks.	a. Land use change % Google earth images from 2004 to 20017	No perceivable change		Partial		Total
		b. Number of constructions affecting surf breaks	No constructions near the coastline		Presence of constructions along the coastline		Constructions along all the coastline
		c. Predominant land use in urban plan (policy)	Conservation		Touristic and recreational-Habitational		Industrial, infrastructure
	2. Privatization and concessions.	a. ZOFEMAT and marine zone concessions	Protection, research.	None	Touristic and recreational	Habitational and commercial	Nautical development
	3. Introduction of new coastal infrastructure.	a. New infrastructure affecting surf breaks since 2000.	None		Presence of pipelines, retaining walls.		Presence of Breakwaters, jetty.
	4. Illegal sewage discharges, release of pollutants and solid waste to coastal ecosystems.	a. Number of sewage discharges.	None				Present
State (S)	1. Loss of natural habitats.	a. Loss of natural areas Google earth images from 2004 to 20017	No perceivable change		Partial		Total
	2. Restricted beach access.	a. Type of access	Public-free	Controlled	Restricted	Private	Closed
	3. Alteration of coastal geomorphology.	a. Retaining walls	None		Presence		Along most of the coastline
		b. Coastal infrastructure	None	Pipelines (intake and outfall)	Land reclamation	Jetty	Breakwaters
	4. Polluted water and beaches, concentrated marine debris.	a. Most probably number of Enterococcus per 100 ML of water	No bacteria identified	Under 25 Most probably number of Enterococcus per 100 ML of water	Between 50 Most probably number of Enterococcus per 100 ML of water	Between 100 and 200 Most probably number of Enterococcus per 100 ML of water	More than 200 Most probably number of Enterococcus per 100 ML of water
		b. Smells.	Absence		Perceptible		Strong
		c. Volume of solid waste kg per 100 mts of linear coast.	None	Less than 20 kg	Between 20 and 50 kg	Between 50 and 100 kg	More than 100 kg
Impact (I)	1. Biodiversity loss	a. Marine species	No changes perceived		Perceivable decrease in population size		Decrease in population size
	2. Decline of ecosystem health.	a. Ecosystem health	No changes perceived		Perceivable decrease		Decrease
	3. Seascape loss affecting sea recreational	a. Absence of parks, recreational areas	Public recreational areas		Restricted recreational areas		Absence of recreational areas.

	activities.	and clean beaches					
	4. Coastal erosion.	a. Degree of erosion	No change		Perceptible.		Considerable change
	5. Alteration of surf break.	a. Reduction of surfers using the break.	Daily visitors		Occasionally visited		Barely surfed
		b. Perception of the local surfers of the quality of the wave	No change		Perceptible		Considerable change
Responses (R)	1. Establishment of protected areas and environmental conservation programs.	a. Establishment of protected areas	Not suitable for a Natural Protected area.		Suitable for a Natural Protected area.		Natural Protected area.
		b. Management plan	Non existing management plan		Developed management plan		Implemented management plan
	2. Research, environmental protection activities and monitoring programs regarding coastal management.	a. Area used for scientific research	No research available for this area.		Uused for postgraduate research.		Area under concession for research.
	3. Actions through the Clean beaches program (Planning, control and sanction).	a. water quality monitoring programs	No monitoring at all		Independent monitoring.		Part of a monitoring program.
		b. Beach regulations	None		Proposal for a beach regulation document.		Effective Beach regulations.
	4. Community involvement.	a. Number of active community members present at local events.	None		Less than 50 persons.		More than 50 persons

Table 1. Indicator parameters for sustainability assessment of surf breaks under the DPSIR framework.

b. Indicators estimations or measurements

To assign a numeric value to the 16 qualitative indicators and 11 quantitative indicators (see Table 1) we used a combination of techniques drawn from literature that details social science methodologies for conservation and ecosystems management (Li and Heap, 2011, Newing *et al.*, 2011, Bennet, 2016).

Qualitative data.

Qualitative data to inform indicators S4b, I5a, I5b was obtained from four informal interviews (three with local surfers, one with a local fisherman, and one with a local diver) and four semi-structured interviews with key actors who were selected because of their local knowledge, participation and commitment with the BTSWSR projects (two oceanographers that are also surfers, a local pioneer surfer, and one professional local surfer). Data to assess indicators I1a and I2a was obtained through other informal interviews and the previously mentioned transect walks. The informal interviews were held during field trips with students and professors from the Faculty of Marine Science of the Autonomous University of Baja California studying marine biodiversity in the Pacific coast of the peninsula. The transect walks included biologists, oceanographers, local surfers, visiting surfers and members of Save The Waves Coalition. From these informal interviews and transect walks, assessments of biodiversity loss, ecosystem health, coastal erosion and alteration of the surf breaks were determined. The response indicators (R1a, R1b, R2a, R3a, R3b, R4a) were estimated by document analysis. We reviewed BTSWSR projects and outcomes between 2014 to 2018 from reports and minutes of the LSC.

Quantitative data.

Indicators for land use change (P1a), ZOFEMAT and marine concessions (P2a), land use (P1c), loss of natural areas (S1a), coastal erosion (I4a), number of constructions and presence of infrastructure affecting the surf breaks (P1b, P3a), type of access (S2a), retaining walls (S3a), and coastal infrastructure S3b), absence of parks and recreational areas (I3a), were estimated by comparing Google Earth images from 2004 to 2017, by analyzing the urban plan of the Municipal Institute of Research and Planning of Ensenada, and verified with onsite observations. For indicators P4a, S2a and I4a we also used quantitative data from eight undergrad and postgraduate theses from UABC that addressed topics such as beach management, coastal erosion, coastal currents, coastal dynamics changes, beach access and sewage discharges at the research area. To assess water quality (S4a), we hired a certified private laboratory specialized in residual water, natural water and fresh water analyses, and approved by the Commission of National Waters (CONAGUA) and the Secretariat of Environmental Protection of Baja California (see appendix1 and 2). For indicator related to solid waste collection and classification (S4c) we used the Ocean Conservancy methodology and registration forms that are used worldwide for The International Coastal Cleanup (see appendix 3 and 4).



Photo 1 Water quality sampling San Miguel, 2017; photo 2 Solid waste classification, San Miguel, 2018; photo Tres Emes intertidal zone monitoring, UABC, 2018.

c. Integrating indicators

After analyzing the qualitative and quantitative data, the information was converted into values from 1 to 5, according to the weight of the activity affecting the surf break (Table 2). For Driving Forces, Pressures, State and Impacts, a value of 1 represents the desirable condition for the surf break (1= low value for Driving forces, low pressure, low negative state of the ecosystem, and low impact), while 5 represents the worst condition for the surf break (5= high value for Driving Forces, high pressure, high negative state of the ecosystem, and high impact). Indicators for Responses are in reverse order of desirability: 1 represents a low response and 5 the best human actions aimed to address activities affecting the surf break and its surrounding environment (1=/lowest, 2=very bad, 3=bad, 4=good, 5=best) (see table 2). The visual tool to show the performance for indicators in each category was a radial graph.

	Topic	Indicators	San Miguel	Tres Emes	Stacks
Drivers	International industrial development (manufacturing and fishing companies)	International investment in Ensenada between 2000 and 2010. Fuente CODEEN, 2011.	1	1	1
	Binational and national urban coastal developments.	Real estate growth in Tijuana-Rosarito-Ensenada corridor between 2010 and 2018.	5	5	5
Pressures	Land use change affecting surf breaks.	Land use change % Google earth images from 2004 to 2017	1	3	3
		Number of constructions affecting surf breaks	3	5	5
		Predominant land use in urban plan (policy)	3	5	5
	Privatization and concessions.	ZOFEMAT and marine zone concessions	2	5	5
	Introduction of new coastal infrastructure.	New infrastructure affecting surf breaks since 2000.	1	3	1
	Illegal sewage discharges, release of pollutants and solid waste to coastal ecosystems.	Number of sewage discharges.	1	5	5
State	Loss of natural habitats.	Loss of natural areas Google earth images from 2004 to 20017	1	3	1
	Restricted beach access.	Type of access	2	4	4
	Alteration of coastal geomorphology.	Retaining walls	1	3	5
		Coastal infrastructure	1	2	5
	Polluted water and beaches, concentrated marine debris.	Most probably number of Enterococcus per 100 ML of water	1	2	2
		Smells.	1	3	3
		Volume of solid waste kg per 100 mts of linear coast.	3	2	4
Impact	Biodiversity loss	Marine species	1	3	3
	Decline of ecosystem health.	Ecosystem health	1	3	3
	Seascape loss affecting sea recreational activities.	Absence of parks, recreational areas and clean beaches	1	3	5
	Coastal erosion.	Degree of erosion	1	3	3
	Alteration of surf break.	Reduction of surfers using the break.	1	1	1

		Perception of the local surfers of the quality of the wave	3	1	3
Responses	Establishment of protected areas and environmental conservation programs.	Establishment of protected areas	3	1	1
		Management plan	1	1	1
	Research, environmental protection activities and monitoring programs regarding coastal management.	Area used for scientific research	5	5	3
	Actions through the Clean beaches program (Planning, control and sanction).	Water quality monitoring programs	1	1	1
		Beach regulations	1	1	1
	Community involvement.	Number of active community members present at local events.	5	5	3

Table 2. Indicators for sustainability assessment of surf breaks under the DPSIR framework.

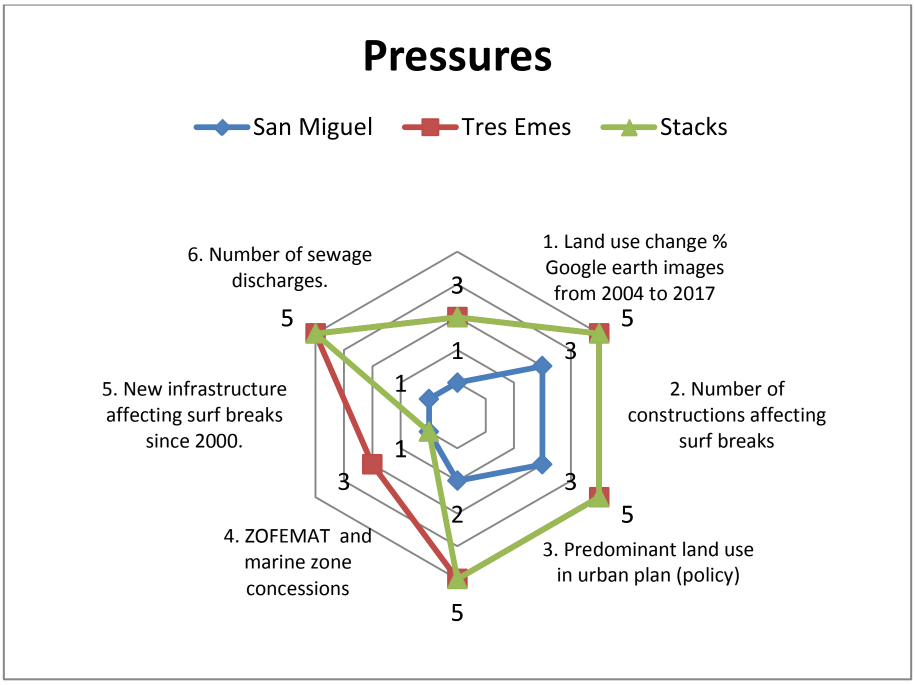
4. Results and discussion

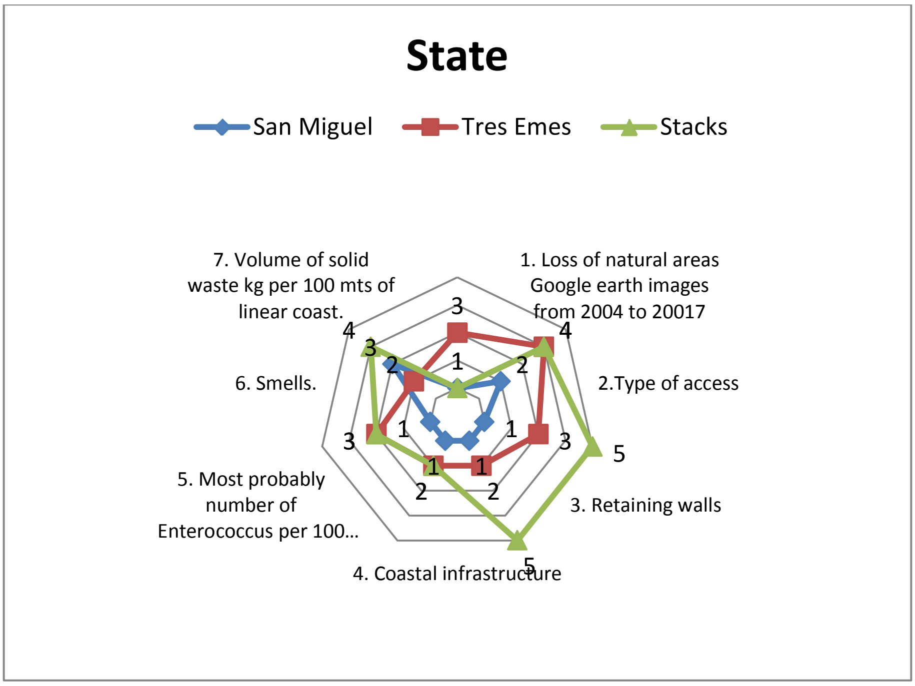
5.1 Visualizing indicators for BTSWSR using the DPSIR framework

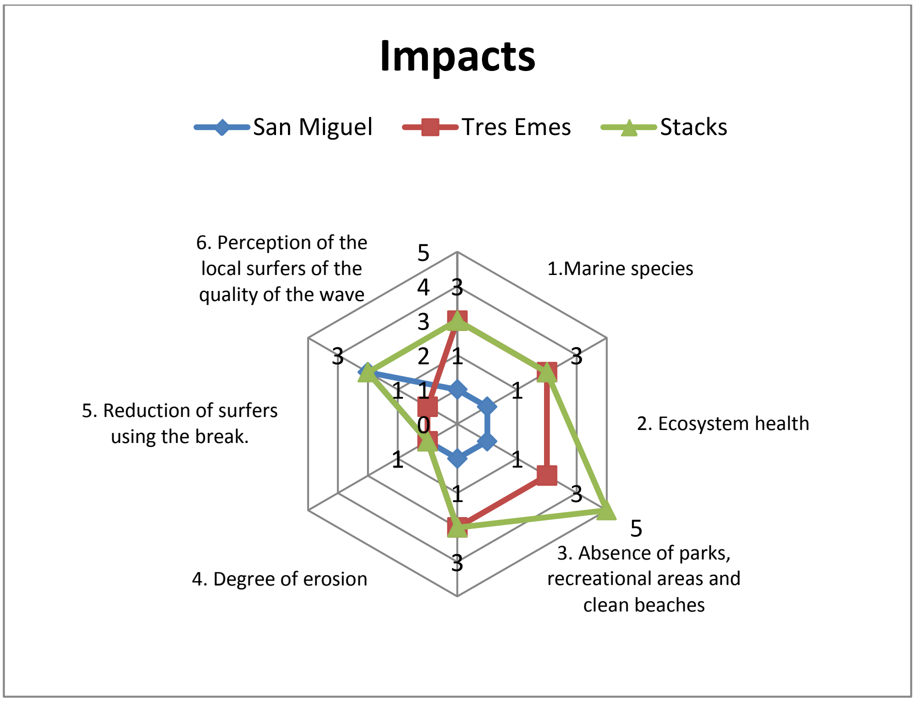
Using the methods detailed above, we were able to collect data to assess each indicator in the DPSIR framework relevant to the sustainable development of each surfing site of the BTSWSR. We identified two primary driving forces affecting BTSWSR surf breaks and their surrounding environment: 1) binational and national urban coastal developments and 2) international industrial development (manufacturing and fisheries). Urban development growth has become a major concern when looking into protecting coastal environments. As the population density and economic activity in the coastal zone increases, pressures on coastal ecosystems increases. Human population is projected to increase to more than 9 billion people by 2050, bringing increasing pressure marine and coastal resources (UN, 2017). In addition, international industrial development linked to coastal areas has also altered and destroyed coastal ecosystems. The impact of industrial development is especially related to issues such as introduction of infrastructure that causes the alteration of coastal morphology, land use change that causes biodiversity loss, or wastewaters that cause water pollution.

Both of these forces are linked to activities that have direct pressure on BTSWSR: i) land use change, ii) privatization and concessions, iii) introduction of new coastal infrastructure and iv) illegal sewage discharges, the release of pollutants and solid waste to coastal ecosystems (M Arroyo *et al.*, 2019). In this research we found that by measuring i) biodiversity loss, ii) decline of ecosystem health, iii) lack of spaces in coastal areas for recreational activities, iv) coastal erosion, and v) alteration of surf break, it is possible to determine the causal link between humans and their impact on the environments in surf breaks.

The indicator values assessed for each DPSIR component (except driving forces) at each surf location are shown in spider graphs in Figures 1a-d. We chose not to show graphs for driving forces indicators, as these indicators are external to the sites and related to national-international agreements or global phenomena which are impossible to address directly through local co-management actions and are constant for the three sites. Nevertheless, driving forces indicators are useful to recognize the origin of pressures causing coastal use changes or to adapt local policies. Indicators graphs, as shown in Figures 1a-d below, provide a practical visual tool to identify, monitor and compare states or trends in various sites across time and space, and to evaluate sustainability in complex social-ecological systems. Visualizing indicators in this way allows BTSWSR co-managers to focus on critical issues in need of attention at each surf break. The selected indicators cover key properties of coastal ecosystems linked to surf breaks and as the assessment and monitoring of coastal co-management practices.




State
San Miguel
Tres Emes
Stacks
1. Loss of natural areas Google earth images from 2004 to 20017
2.Type of access
3. Retaining walls
4. Coastal infrastructure
5. Most probably number of Enterococcus per 100...
6. Smells.
7. Volume of solid waste kg per 100 mts of linear coast.


Impacts
San Miguel
Tres Emes
Stacks
1.Marine species
2. Ecosystem health
3. Absence of parks, recreational areas and clean beaches
4. Degree of erosion
5. Reduction of surfers using the break.
6. Perception of the local surfers of the quality of the wave

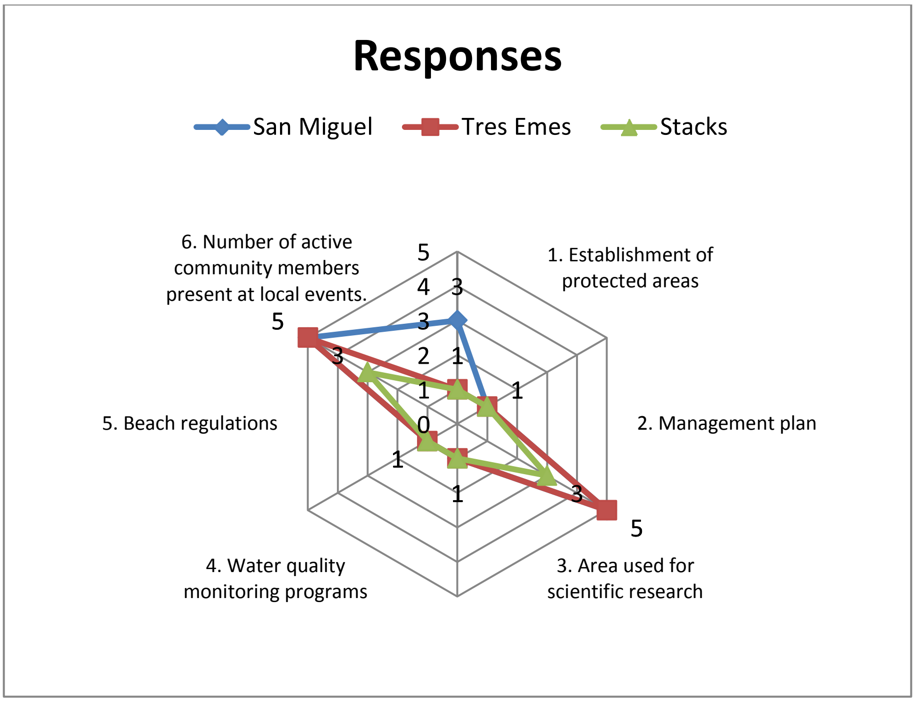


Figure 3. DPSIR radar charts to compare three surf break sites in Bahia Todos Santos World Surfing Reserve (BTSSBR) a) pressure indicators, b) state indicators, c) impact indicators and d) response indicators. Note that indicator scores go from lowest (best) level of pressure, state, or impact (1) to highest (worst) level of pressure, state, or impact (5). For responses, a score of 1 indicates the lowest (worst) level of response, while 5 indicates the highest (best) level of response.

5. Management strategies with regard to DIPSIR indicators.

The radar charts (Figure 3) allowed us to compare pressure exerted on each of the three case study sites and prioritize actions directed to protect surf breaks in BTSWSR. Although the three case study areas show evidence of activities that exert pressure on the environment, the first case study (San Miguel) is currently experiencing the lowest degree of pressures or impacts. This is mainly related to the fact that San Miguel beach is located in an area were the land use is mainly habitational, touristic, recreational and mixed commercial-habitational. Tres Emes and Stacks in the other hand are located inside an industrial zone and the Port Administration has the concession of the coastal and marine area. State and Impact charts show that Stacks and Tres Emes are in need of immediate actions to address issues such as loss of natural habitat, beach access restrictions, water quality, coastal erosion and introduction of coastal infrastructure. All three surf breaks have a solid waste problem that needs immediate attention.

In the last four years, BTSWSR local stewardship council has been leading efforts alongside regional civil society organizations, key stakeholders, academic institutions and the local government to solve issues on

Ensenada's local beaches. Between 2014 and 2018 according to responses using the DPSIR framework, we identified the following main projects for BTSWSRs:

a. San Miguel State park proposal.
b. Inclusion of BTSWSR into the Clean beaches program of the Municipally of Ensenada, B.C., Mexico.
c. The establishment of a network of local environmental organizations working with local authorities towards the same goal: to protect the coastline (eg. Ensenada Free of plastic law and campaign).
d. A direct collaboration with governmental agencies such as Conanp, Federal Maritime and Terrestrial Zone (ZOFEMAT), the Secretariat of Environmental Protection and representatives of the municipality to promote, manage and monitor natural protected areas.
e. Baja King Tides project to visualize and record changes on our coast from sea level rise by observing the tides of today.
f. The development of a civil association that aims to protect surf zones in different regions in Mexico.

Current responses to activities affecting all three surf breaks arise mainly from the local stewardship council of BTSWSR, and programs together with other local civil society organizations. There is an urgent need to provide legal protection for coastal ecosystems and promote sustainable development in areas where surfing and priority coastal ecosystems overlap (Scheske *et al.,* 2019).

6.1 Planning for Adaptive Co-Management.

The DPSIR indicators allowed us to measure and compare different issues concerning surf breaks and to have an integrative perspective connecting actors and responses to mitigate these issues. In this section we aim to provide a guideline for adaptive co-management based on the proposed indicators outcomes. Adaptive co-management can help to improve adaptability and resilience and develop specific strategies for sustainable management of surf breaks and their surrounding environments. Bridging knowledge between case studies, management, stakeholders and scientists can assist in the development of adaptive co-management approaches (Ehrhart and Schraml, 2018). For BTSWSR we identified the following responses and outcomes between 2015 and 2018:

1. BTSWSR has been able to provide key information for the technical studies of San Miguel's watershed and surf break to meet the requirements of the Secretary of Environmental Protection. It has also provided an essential connection with the local community and has been able to show the government how much cross-border support there is to make this State Park.
2. BTSWSR has provided the local community with the necessary tools to protect Tres Emes beach from an industrial seawater intake and outfall system, together with the support of scientists from the UABC and CICESE, and different local environmental organizations.
3. BTSWSR introduced issues that are a concern to the local surfing community in the "Clean Beaches Program" for Ensenada, Baja California, Mexico.
4. BTSWSR is now part of a network of environmental organizations working towards sustainable and healthy beaches in Ensenada.
5. BTSWSR is collaborating with CONANP for the Management Plan for the Pacific Islands Biosphere Reserve and a monitoring program for the Islands of Todos Santos.
6. Members of the local stewardship council of BTSWSR created Reservas de Surf Mexico, A.C., a nonprofit that will support the reserve and will provide mechanisms under the current legal framework, to protect and monitor surf ecosystems in different parts of the country.

With the previous outcomes of the DPSIR indicators, the next step is to use adaptive co-management as an applied approach to plan actions for improved surf break management and to address resource management issues by promoting partnerships and a community-based, 'bottom-top,' and iterative approach. An adaptive co-management framework is a promising tool for surf break management due to its inclusive and adaptive approach to addressing resource management problems that are specific to a local area and may be approached from multiple perspectives. Adaptive co-management provides the most appropriate applied approach to surf break management, especially for BTSWSR, because the strategies rely primarily on partnerships and the involvement of the community. In developing an adaptive co-management plan, it is important to consider the responses in the DIPSIR framework that seek to eliminate, control, or reduce pressures, either through regulations or technology or direct actions. As part of the Adaptive co-management plan for BTSWSR, in table 3 we present 5 main issues in San Miguel, Tres Emes and Stacks surf breaks, as well as goals and actual and desired responses to address this issues.

Issues	**Goals**	**Plan actions**
Unmitigated coastal development threatening coastal environments and surf breaks.	To have legal mechanisms and tools to protect surf breaks.	Creation of Surf Protected Areas.

Water quality.	To improve water quality and ensure users safety in local surf zones.	Water Quality monitoring program.
Solid waste pollution.	To reduce solid waste pollution on local coastal areas.	Plastic program.
Beach access	To ensure free beach access.	To include surf breaks in coastal management practices and planning.
Decline of ecosystem health and biodiversity loss	To ensure the sustainable use and conservation of natural resources and coastal ecosystems for the benefit of people and the environment in Ensenada.	Promote the creation of Natural Protected Areas in coastal environments.

Table 3. Co-management ideas to be implemented in Bahia Todos Santos World Surfing Reserve BTSWSR

In order to foster conservation actions for BTSWSR there is a need for a political framework that supports the protection of surf breaks and their surrounding environment. Although there are no marine protected areas created with the principal purpose of protecting a surf break, there are examples of surf breaks located within protected areas created for other conservation purposes (Scheske *et al.,* 2019). For example, the surf break of Killers, located at Todos Santos Islands, that is now part of the Biosphere Reserve of the Islands of the Pacific Ocean, and the draft management plan specifically includes surfing.

Currently, the nonprofit Reservas de Surf Mexico is working on the legal framework analysis, and a surf break inventory based on a national survey applied to key local actors from different surf regions in Mexico. The inventory for surf breaks was designed to be used as a practical tool for introducing environmental assessment and monitoring in surf zones and their surrounding environments. Together with Save The Waves, this nonprofit will develop a central database of high value surf breaks. This database will include technical studies for surf break protection in Mexico, based on the requirements to establish natural protected areas of the General Law of Ecological Balance and Environmental Protection, which is the primary environmental legislation.

7. Conclusion

The DIPSIR framework and associated indicators provide a useful tool to improve surf break management and to address resource management issues. The system presented here can also be adapted for use in monitoring programs for surf breaks around the world. We found it highly useful to combine qualitative and quantitative assessments of indicators to estimate the sustainability of surfing sites. As well, the use of spider graphs to illustrate indicator values for each DPSIR component (except driving forces) allowed us to compare different sites and to recommend focal areas for co-management actions.

Although perceptions and estimations are an important and practical tool to assess indicators in a data-limited context, we also strongly recommend the development of more precise quantitative methods to evaluate and monitor surf breaks and their surrounding environments, to identify specific aspects of how they are affected by anthropogenic activities (pressures, state, impacts), and the conservation outcomes. We envision that the use of aerial vehicles such as drones, combined with remote sensing data (satellites), and in-situ oceanographic observations will provide invaluable data to support future assessments, facilitating the preservation and sustainable development of surf breaks and coastal ecosystems. Coastal participatory observation through citizen science (Engelken *et al.*, 2014 Craglia & Granell, 2014) could also provide a useful information gathering tool because the city of Ensenada has many scientists and students motivated to take action to turn it to an exemplar sustainable city.

Particularly in Ensenada, there has been an important local planning agenda to protect the region's natural resources, based on interactive processes between community, environmental, and government actors. For instance, the need to protect Ensenada's remaining natural coastal environments, together with the desire to have recreational areas for the local community, has encouraged diverse CSOs to promote the creation of Natural Protected Areas in the region. Bridging organizations and networking have allowed different stakeholders to develop appropriate strategies to address common issues. For instance, water quality and solid waste pollution in beaches are being addressed through the Clean Beaches program together with local government authorities and different CSOs; the "Libre de Plásticos" (Free of Plastics) campaign, led by a member of the Ensenada City Council, is tackling plastic pollution; marine debris removal is taking place through a common project with The National Commission of Natural Protected Areas (CONANP); and the lack of laws or regulations directed to promote the sustainable use of coastal ecosystems is being addressed together with the Federal Maritime Terrestrial Zone (ZOFEMAT). The assessment tools presented in this paper helped monitor the outcomes of these multi-stakeholder efforts, as well as suggest future directions for actions to promote surf break sustainability in the BTSWSR region and to coordinate actions taken by different actors.

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3.2 Bahía de Todos Santos World Surfing Reserve technical report and guidelines for a conservation and adaptive co-management plan for Surf breaks in Mexico.

Surfing was introduced to Mexico in the late 1950s, and first practiced by locals in the early 1960s. Since then Mexico's has been the home to some of the most iconic surf spots in the Pacific Coast. Especially in the last decade, the Mexican surfing community continues to grow and awaken the interest of new generations to protect the key environmental, cultural, and economic attributes of surfing areas. After Bahia de Todos Santos, located in Baja California, was declared as a World Surfing Reserve, there is a noticeable increase of interest to protect surf ecosystems in Mexico.

i. Bahia de Todos Santos World Surfing Reserve technical report.

In this section I present a technical report that describes anthropogenic activities affecting three surf breaks at BTSWSR, the impacts on their environment and actual responses to those activities.

1. Driver forces.

We identified two primary driving forces affecting BTSWSR surf breaks and their surrounding environment: 1) binational and national urban coastal developments and 2) international industrial development (manufacturing and fisheries). Both of these forces are linked to the activities that have direct pressure on BTSWSR: i) land use change, ii) privatization and concessions, iii) introduction of new coastal infrastructure iv) illegal sewage discharges, the release of pollutants and solid waste to coastal ecosystems.

First, urban development growth has become a major concern when looking into protecting coastal environments. Around 10 % of the world's population lives in coastal areas that are less than 10 meters above sea level, and about 40 % of the world's population lives within 100 km of the coast. As the population density and economic activity in the coastal zone increases, pressures on coastal ecosystems increases. Human population is projected to increase to more than 9 billion people by 2050, bringing increasing pressure marine and coastal resources (UN, 2017). Second, international industrial development linked to coastal areas has also altered and destroyed coastal ecosystems. The impact of industrial development is especially related to issues such as the introduction of infrastructure that causes the alteration of coastal morphology, land use change that causes biodiversity loss, or wastewaters that cause water pollution. Industries are attracted to the coastal zones for several reasons: 1) they have access to low-cost marine and inland transportation systems, 2) use seawater for industrial process, 3) direct access to the marine environment for raw material, such is the case of the port of El Sauzal in Ensenada, B.C., México. In Mexico, although between 2000 and 2010 the international investment on industrial sector decrease during the first global recession, the Mexico-United States border zone kept as an attractive area for foreign projects. Such is the case of Sempra Energy, a Liquefied Natural Gas Terminal based on the north end of Salsipuedes bay, Ensenada, and other small companies based in the community of El Sauzal.

2. Pressures.

The community of El Sauzal is characterized by its fishing industry. Since the 1950's and until 1980's fishing was the main activity of Ensenada, but in 1993 the United States imposed an embargo on tuna-fishing, affecting the fishing industry in Ensenada. As a consequence, many industrial buildings in El Sauzal were abandoned, such is the case of the Zapata fishing company, a large industrial complex located just in front of Tres Emes surf break. Since then, the industry has slowly recovered and many fishing and aquaculture companies are now based in the community of El Sauzal. Today there are two major project proposals for the El Sauzal area: the project called "Puerto El Sauzal II" and a railway that will connect El Sauzal with Tecate. These projects include the extension of the port El Sauzal, a project that would affect the waves, beach access and near-shore coastal and marine ecosystems, and the construction of a railway that will go through residential areas and the Guadalupe wine valley.

a. Land use change, privatization and concessions.

At the northern extension of El Sauzal, were the San Miguel beach is located, the land use is mainly habitational, touristic, recreational and mixed commercial-habitational. At the southern part of the beach, locally known as "la playita" the land use is destined for mixed habitational and commercial purposes. The watershed is destined for ecological conservation and is in the process to become the first State Park in Baja California.

Tres Emes is located inside an industrial zone. Although in Tres Emes the Port Administration has the concession of the road, reef and marine area, and controls the access, access to the beach is currently permissible. This beach is frequented also by non-surfing users. To ensure the recreational use of the beach is a difficult task, as the land use is mainly industrial and destined for urban infrastructure. Only a small part of the northern part of the coastline is destined for touristic use.

Stacks is also located within the Port Administration concession area. The northern part of the coastline is for urban infrastructure, and is where the breakwater of the port of El Sauzal is located. The rest of the coastline is for habitational and commercial use. The main beach access is through a private property that is currently for sale. The property has a fence but is usually open for surfers visiting the beach.

b. Infrastructure that affects the surf break.

In San Miguel there are the remains of a boat landing and a jetty that appears in pictures from 1966. The boat landing consisted of a jetty that protected a boat ramp located at the southern end of the main point break. Throughout the years, the jetty disappeared due to high surf and strong current and the boat ramp was covered with a mixture of sand and rocks. In the early 80, the outflow into the ocean of the watershed was diverted to mitigate the flooding risk of a new habitational complex on the northern end of the beach. This diversion of the outflow modified the wave. In 2009, due to a strong flash flooding event, with the help of heavy machinery the watershed outflow was returned to its original outflow path.

In Tres Emes, there is an industrial seawater intake and outfall system near the surf break. This system was installed on 2017, during that time, the LSC of BTSWSR provided to the Port Administration and the company involved in the project, a technical opinion about the location and possible consequences of the proposed pipes before construction began. Unfortunately, they did not take into account the proposed recommendations. The location and size of the pipelines, as well as the aggressive construction system, anchoring the pipelines permanently into the reef, are a significant concern for the local and international surfing community and the World Surfing Reserve. The presence of these pipes and concrete structures present a considerable danger for the users, especially during bigger swells due to the strong lateral currents from north to south over the area where the pipelines where installed. The pipeline is located on the inside section of the wave, the traditionally safe paddle out channel during big swells. There is also a considerable concern about the long-term effects of the pipe on the nearshore dynamics and the durability of the pipeline, fearing it will become inoperative and left as marine debris.

In Stacks, the extension of the port’s pier behind the port’s main breakwall seems to have had an effect on the wave’s quality, according to the local surfers. Further studies are required to confirm this assertion.

c. Illegal sewage discharges.

One of the consequences of population growth in coastal areas is discharge of sewage and industrial wastewater into the ocean. When wastewater is not properly treated diverse pollutants are introduced into the marine ecosystem. The coastline of Tijuana, Rosarito and Ensenada receive wastewater from different treatment plants, which have caused pollution problems over the years, even causing binational conflicts between Mexico and the USA, such is the case of the Tijuana River valley watershed (Einstein, 2017; Johnsen, 2018).

Two concerns of the main challenges in Ensenada are to have a continuous control of the quality of the water discharged to the ocean and the occasional inadequate functioning of the treatment plants (Sánchez García, 2012). In Tres Emes there are several outtake and intake pipelines that use ocean water for diverse industrial process, mostly related to seafood processing. Those waters are returned into the ocean as "clean sea water" even after becoming residual industrial water. Another significant contributor to coastal pollution in the area is storm drain discharges along the coastline As Ensenada has a very short rainy season, characterized by either small rain events and occasional strong rainy storms, pollution from different sources (industrial and urban waste) is accumulated throughout the year on the storm drains. When the strong rain events occur the accumulated waste is washed away directly into the ocean. In Stacks there are runoffs and direct discharges of sewage from houses along the coastline. There are also discharges of industrial water by companies operating within the port of El Sauzal and discharges of brine as a byproduct of seafood processing. Users have often identified oil spots in the sea (discharges from the ports boats operations), garbage and debris.

3. State.

In this paper, we identified four potential elements that will help to measure the state of the surf breaks: i) loss of natural habitats, ii) restricted beach access, iii) alteration of coastal geomorphology, and iv) polluted water and beaches, and concentrated marine debris.

a. Loss of natural habitat.

San Miguel has a well preserved coastal environment that has not changed much over time. Google Earth photos show that main changes between 2004 and 2017 have occurred on the outflow of the watershed. The river mouth of San Miguel watershed was diverted in the 80's to protect the houses located north of the surf break, and redirected to its original outflow path in 2009. These changes had an effect on the surf break and coastline, but further studies need to be carried out. In Tres Emes, the construction of several industrial buildings has considerably diminished the natural habitats. Almost all the natural habitat has been replaced by industrial complexes. Google Earth images show that the coastline of Stacks shows a considerable increase of constructions, with a mixture of new houses and industrial buildings.

b. Beach access.

Beach access is a major issue along Ensenada's coastline. The urban growth along the corridor from Tijuana to Ensenada has promoted the urbanization of spaces with waterfront, which has resulted in the closure of public accesses to the beach. In 2004, 75% of the Federal Maritime Terrestrial Zone (ZOFEMAT) from El Sauzal to the port of Ensenada was not accessible and used as private property. Díaz De León (2013) compared beach access in 2004 with 2012 in the northern part of Ensenada, and analyzed 25 access stations from El Sauzal to Ensenada's Port area. 80% of the analyzed accesses were private, and half of the accesses identified in 2004 were no longer present in 2012; 24% of the accesses present in 2012 had restriction to vehicles.

San Miguel beach is inside a private residential area with controlled access and parking. The access to pedestrians is free. The road to enter Tres Emes belongs to the Port Administration. There is a fence at the entrance that opens at sunrise and closes at night for security purposes. The access to Stacks is mainly through a private property that is currently for sale. The property is fenced but the gate is usually opened. Another access is through a ramp on the property of the Port Administration. The third access is through another private property that does not have a gate.

c. Alteration of coastal geomorphology.

The changes on the coastline and the bathymetry in San Miguel surf break have been affected mainly by human intervention on the watershed outflow. When the outflow of the river was returned to its original path in 2009, the geomorphology of the coastline was affected by the flow of sand and cobblestones during strong rain events. As the mouth of the watershed is now directly in front of the surf break, the wave was affected. The interactions of the modified bathymetry with the currents and tides have had an effect on the coastline, but it is necessary to develop further research studies to determine how the quality of the wave has being affected.

Over the years Tres Emes coastline does not present major perceivable changes besides natural erosion of the cliff due to strong winds, big swells, high tides and strong currents. However, the intake and outflow pipelines for a lobster processing plant permanently installed in 2017 near the surf break, has had a serious effect on the stability of the coastline cliffs. The introduction of heavy machinery and the digging over the cliff and on the cliff walls have seriously affected the natural stability of cliff and accelerated its erosion process. It is evident how the width of the access road has reduced since the installation of the new lobster processing plant pipelines.

In Stacks the construction of retaining walls of houses along the beach has had an effect along the shore sand transport and on the cliffs erosion processes (ref). Occasional observations of the cliff together with the analysis of Google Earth images have highlighted the presence of several landslides, increasing amount of runoff and sewage discharges (from the new house and industrial buildings), widening of storm drains (natural and manmade) and cracks on the cliffs, summing into the acceleration of the cliff and coastline natural erosion processes.

d. Polluted water and beaches, and concentrated marine debris.

The results of the water samples at San Miguel, Tres Emes and Stacks show no significant indicators of enterococcus and coliforms. The Mexican government standard for recreational beaches specifies that when a beach has under 200 NMP (most probably number of Enterococcus per 100 ML of water) is suitable for swimming. Our results for the three surf breaks were: no enterococcus and no fecal coliform bacteria identified in San Miguel; less than 2 NMP enterococcus and no fecal coliform bacteria identified in Tres Emes; and 5 NMP fecal coliform bacteria and less than 2 NMP enterococcus in Stacks. Although the water samples did not show major presence of bacteria, during the interviews with local users we found that most surfers have suffered a skin condition, infection or illness from surfing in Tres Emes and Stacks. Surfers are often exposed to viruses, bacteria, and parasites in contaminated water (Kapono, 2018). Also they usually perceive strange smells from the water, especially at Stacks and sometimes Tres Emes.

For the solid waste collection and classification we used the Ocean Conservancy methodology and registration forms. In San Miguel beach and the mouth of the watershed we collected a total of 44.5 kg of solid waste per 100 linear meters of coastline, in Tres Emes a total of 18.66 kg, and in Stacks, 50.4 kg of solid waste per 100 linear meters of coastline. In San Miguel we registered a total of 5,403 cigarette butts and 3,131 metal bottle caps, 544 plastic bottle caps and 344 food containers (for other objects and material see annex no.). In Tres Emes we registered 223 cigarette butts, 202 feminine hygiene products, 533 small foam pieces, 212 small glass pieces and 282 plastic pieces. In Stacks 160 cigarette butts, 115 plastic bottle caps, 617 plastic bottles and 1,000 small pieces of unicel.

4. Impact.

We state that by measuring i) biodiversity loss, ii) decline of ecosystem health, iii) lack of spaces in coastal areas for recreational activities, iv) coastal erosion, and v) alteration of surf break, it's possible to determine the causal link between humans and their impact on the environments in surf breaks.

a. Biodiversity loss.

San Miguel beach is located at the mouth of one of the best-preserved watersheds in Ensenada. Most of the coastal ecosystem in San Miguel preserves its natural condition, but there are different issues that need to be addressed, such as invasive flora, sand extraction and dumping of urban solid waste. Tres Emes, is a traditional small-scale fishing ground for the El Sauzal community, although some occasional fisherman are using damaging products (such as chlorine) as a fishing technique with serious impacts on the ecosystem.

b. Coastal erosion.

The cliffs located on the southern area of San Miguel beach have being affected by water runoffs from the houses and touristic complex build on top of the cliffs. These have created notable cliff landslides that have been occurring more frequently in the last years. The coastline along the surfbreak has eroded by natural processes, influenced by the changes on the location of the watershed outflow. The main noticeable effects of erosion in Tres Emes are related to the coastal cliffs. Industrial pipelines installed on 2017 have seriously impacted the stability of the cliffs, accelerating the natural erosion processes (some areas of the cliffs are collapsing). The coastline of Stacks has being affected mainly due to the construction of retaining walls of houses and industrial buildings along the cliff, although the coastline doesn't have major perceivable modifications.

c. Alteration of surf break.

San Miguel surf break has changed due to the location of the river mouth, strong stream flows, and significant storm surf. The surf crowds have fluctuated during the last few years due to different factors, such as: the swine flu epidemic, the perception of security in Mexico by visiting surfers, the increase of local surfers by newer generations, changes in the local and U.S. economy, accessibility to equipment by local surfers, among other things. San Miguel has been the venue for diverse local and International competitions;

is the venue for the Baja Surf Club Invitational, one of the first surf contests in Mexico, as well as for the Mexican National Championship and Baja California State Surfing Championship. Also, is one of the stops for a bi-national surfing contest tour held between California and Baja California. It is a proven training ground for the national and state junior surfing teams, due to the good quality of surf break.

Tres Emes wave has maintained its quality throughout the years due to the fact that the reef has not being modified. There was a serious threat to the surf break as the initial plan to install an industrial pipeline through the surf break. Thanks to the actions of the BTSWSR and the pressure of the local community, the pipe was relocated a few hundred meters to the south. However, this new location represents a serious threat to the safety of the surfers, especially beginners.

5. Responses.

In the last four years, BTSWSR LSC has been leading the efforts alongside regional CSOs, key stakeholders, academic institutions and local government to solve issues on Ensenada's local beaches. One of the first initiatives of BTSWSR was to work with ProNatura Noreste and the Secretariat of Environmental Protection to achieve the approval of San Miguel Watershed as the first State Park in Baja California. This effort stemmed directly from members of the community of El Sauzal, to preserve public open space for future generations. Protecting San Miguel as a State Park, will guarantee that activities such as sand mining, industrial development, and dumping be prevented by legal decree. This project will also help to preserve and protect biodiversity and maintain the natural conditions of the surf break. San Miguel is a case of successful alliances of civil society organizations academic institutions and with governmental agencies working together to protect a coastal ecosystem. BTSWSR LSC is also directly involved in the Clean beaches program, working with local environmental organizations and representatives of diverse agencies of the government, to monitor and regulate activities that affect local beaches. We identified the following main projects for BTSWSRs:

g. San Miguel State park proposal.
h. Inclusion of BTSWSR into the Clean beaches program addressing issues such as water quality and sewage discharges into the ocean.
i. The establishment of a network of local environmental organizations working with local authorities towards the same goal: to protect the coastline and developing common projects (eg. Ensenada Free of plastic campaign and law, program to design and install signage in every beach of Ensenada).

j. A direct collaboration with governmental agencies such as Conanp, Federal Maritime and Terrestrial Zone (ZOFEMAT), the Secretariat of Environmental Protection and representatives of the municipality to promote, manage and monitor natural protected areas.
k. Baja King Tides project to visualize and record changes on our coast from sea level rise by observing the tides of today.
l. The development of a civil association that aims to protect surf zones in different regions in Mexico.

ii. SURF PROTECTED AREA NETWORK FOR MEXICO

To protect Mexico's surf ecosystems, members of the Local Stewardship for Bahía de Todos Santos World Surfing Reserve created Reservas de Surf México, a non-profit organization that will support the World Surfing Reserve and will provide mechanisms under the current legal framework, to protect and monitor surf ecosystems in different parts of the country. Currently, Reservas de Surf Mexico is working on the legal framework analysis, and a surf break inventory based on a national survey applied to key local actors from different surf regions in Mexico. The inventory for surf breaks was designed to be used as a practical tool for introducing environmental assessment and monitoring in surf zones and their surrounding environments.

Together with Save The Waves, Mexico will develop a central database of high value surf breaks. This database will include technical studies for surf break protection in Mexico, based on the requirements to establish natural protected areas of the General Law of Ecological Equilibrium and Environmental Protection, which is the primary environmental legislation. These studies will provide invaluable data to support the assessment, preservation and sustainable development of surf breaks and coastal ecosystems. The following figure represents a proposal for a surf protected area network plan and a proposal for technical studies for surf break protection in México, based on the requirements to establish natural protected areas in México.

SURF PROTECTED AREA NETWORK FOR MEXICO.

1. Conceptualize / Inform.

a) Define project's vision, concepts and objectives.

b) Define initial team and partners.

2. Identify and prioritize sites.

a) Surf break inventory for Mexico.

b) Surf ecosystem profile.

c) Prioritization of sites.

3. Legal framework analysis.

a) Ley general del equilibrio ecologico y la proteccion al ambiente (categories):

Reservas de la biosfera;

Parques nacionales;

Monumentos naturales;

Áreas de protección de recursos naturales;

Áreas de protección de flora y fauna;

Santuarios;

Parques y Reservas Estatales, así como las demás categorías que establezcan las legislaciones locales;

Zonas de conservación ecológica municipales, así como las demás categorías que establezcan las legislaciones locales

Áreas destinadas voluntariamente a la conservación.

2. **Technical studies, problem assessment and management plan.**

a) Develop technical studies (based on the requriments to establish natural protected areas in Mexico).

b) Develop GIS.

c) Assess problem.

d) Define goals, objectives, strategies and actions.

Develop a management plan.

3. Implement actions.

a) Develop plan , budget and timeline.

b) Define actions with every actor.

b) Engage in a common coastal management project.

4. Monitor.

a) Establish a monitoring program.

b) Select locally relevant indicators from the base set (from DIPSIR framework for surf breaks).

c) Adjust and apply performance indicators.

d) Work a with the local community, CSOs and academics to generate and analyze data.

5. **Evaluate**.

Analyze and review management plan.

6. **Adjust** strategies and actions and share findings with the local community, CSOs, academics, government, and other key actors.

PROPOSAL FOR TECHNICAL STUDIES FOR SURF BREAK PROTECTION IN MEXICO

(Based on the requirements to establish natural protected areas in Mexico).

1. **Geographical location.**
2. **Area or sites included in the proposal.**
3. **Ecological description.**
    - 3.1 Resource unit (Surf break)-Quality, Consistency.
    - 3.2 Resource system (surf ecosystem):
        - 4.2.1. Geophysical attributes (topography and bathymetry, physical and historical geology, type of soil, hydrology, climate)
        - 4.2.2 Biodiversity and Ecosystems (flora and fauna, general ecosystem description).
4. **Socio-economical description.**
    - 4.1 Economy (main economic sectors).
    - 4.2 Demographic aspects.
5. **Historical overview.**
6. **Legal aspects.**
    - 6.1 Jurisdictional land status.
    - 6.2 Conflicts.
7. **Conservation background.**
    - 7.1 Research projects.
    - 7.2 Conservation projects (pre-existing conservation regimes).
    - 7.3 Conservation regimen proposal (applicable Legal Framework).
8. **Environmental issues** (Development, Tourism Impacts, Water Quality, Trash/Marine Debris, Coastal Erosion / SLR vulnerability, Coral Reef Degradation, Coastal Access)
9. **Management and operational plan.**
   Responses to que questions what?, how? when? where?, who?, how much? with indicators to measure success like those presented in 1.2.2
10. **Funding Potential and sustainable Financing.**

4. DISCUSIÓN GENERAL.

En las últimas décadas, la preocupación por la preservación de la naturaleza, ha generado el surgimiento de nuevas comunidades y discursos en los que se expresan y confrontan diferentes visiones sobre la relación sociedad-naturaleza (grados de uso, incorporando el no uso). La creciente preocupación por la pérdida y deterioro de los ecosistemas se ha traducido en la búsqueda de sitios con gran biodiversidad amenazados por el desarrollo de actividades humanas (*hotspots*); este enfoque ha sido criticado porque excluye las zonas con menor riqueza de especies o belleza escénica, dejando de lado las zonas sin especies carismáticas o baja diversidad pero que están experimentando una rápida transformación del ecosistema. La estrategia para proteger sitios con valores especiales para la biodiversidad está basado en el sistema mundial de áreas protegidas el cual ha crecido exponencialmente en los últimos 25 años, especialmente en los países en vías de desarrollo, donde es mayor la biodiversidad, según lo señalado y definido por las organizaciones y acuerdos internacionales (Naughton -Treves *et al.*, 2005). El esquema ha cambiado para ampliarse e incorporar como valor especial la geomorfología, el suelo y a las comunidades que habitan sitios geo y biodiversos (Nowlan *et al.*, 2004; Henriques & Brilha 2017; Hose 2011), como se verá más adelante.

En el panorama internacional, las áreas protegidas cubren el 14.7% de las tierras del planeta y el 10% de sus aguas territoriales (IUCN, 2016). Durante el período 1980-2000 estas actividades de conservación comenzaron, y crecieron, a través de instituciones internacionales como las Naciones Unidas (PNUMA y UNESCO) y la Unión Internacional para la Conservación de la Naturaleza (UICN), así como organizaciones no gubernamentales internacionales ambientales con influencia en diversas partes del mundo (Zimmerer *et al.*, 2004), tales como The Nature Conservancy, World Wildlife Fund for Nature, The Ocean Conservancy, Greenpeace y Conservation International. Especialmente durante este periodo (1980-2000), se han realizado intentos para reconciliar el manejo de recursos naturales dentro de las áreas naturales protegidas con las necesidades y aspiraciones locales, pero en muchas ocasiones los resultados no han sido los esperados, ya que poner en práctica esta visión ha demostrado ser difícil (Wells y McShane, 2004). A través de programas como el Hombre y la Biosfera UNs, las áreas protegidas no sólo tienen la misión de conservar la biodiversidad, sino también mejorar los medios de vida de la población local. El Programa de la Biosfera fue un modelo teórico útil en la década de los años 80 que sirvió como un primer paso para reconciliar el manejo de áreas protegidas con las necesidades y aspiraciones locales (Wells y McShane, 2004).

Figueroa y Sánchez-Cordero (2008) en el estudio de Áreas Naturales Protegidas en México muestran que fueron efectivos más del 54% de las reservas de la biosfera, áreas de protección de flora y fauna y parques nacionales, 23% ligeramente efectivos y el 23% no efectivos. Aunque este estudio fue desarrollado utilizando un enfoque cuantitativo y se centra en la eficiencia de la conservación de la biodiversidad, es importante tener en cuenta que las reservas de biosfera son la categoría de ANP que mostraron ser más efectivas. En general, las ANP integran la participación local en términos de desarrollo de proyectos de gestión de recursos, sin embrago, la participación local y la distribución de beneficios no son los mismos que el empoderamiento local para controlar el uso y acceso de los recursos y las tierras, lo que finalmente buscan muchas comunidades (Neumann, 1997).

En la península de Baja California el tema de protección del ambiente es de suma importancia ya que, por la calidad de sus ecosistemas, ausencia de agua dulce y aislamiento, es un espacio prioritario para la conservación a nivel nacional. Por sus características socio-ambientales, en esta región se ha desarrollado una extensa red de Áreas Naturales Protegidas (ANP) que cubren aproximadamente el 29% del territorio bajo protección federal con la participación de reconocidas organizaciones civiles e instituciones académicas, tal es el caso de Pronatura Noroeste, Costasalvaje, Terra Peninsular, el Centro de Investigación Científica y Estudios Superiores de Ensenada (CICESE) y la Universidad Autónoma de Baja California (Martínez *et al.*, 2015). En Baja California, a pesar de que en 1996 en México se modificó la Ley de Protección al Ambiente para permitir la conformación de áreas privadas y comunitarias para la conservación voluntaria y legitimización de actores sociales para participar en los procesos de gestión ambiental, en algunos casos hay relaciones de conflicto entre gobierno y sociedad, y en la práctica los activistas comunitarios tienen una participación principalmente informativa con poca influencia en el proceso de gestión (Martínez *et al.*, 2015).

En este sentido, las áreas protegidas como las mexicanas, tienen una tarea mucho mayor que conservar la biodiversidad. Tienen también como objetivos mejorar el bienestar de la población, salvaguardar la seguridad local y proporcionar beneficios económicos a través de múltiples escalas, objetivos que tradicionalmente correspondían al sector del desarrollo (Naughton - Treves *et al.*, 2005). Sin embargo, es importante reconocer que los aspectos sociales no siempre están alineados con los aspectos de conservación. En las ANP, más que una decisión con respecto a los problemas ambientales, hay una necesidad de tomar una secuencia de decisiones desde diferentes enfoques que ayuden a identificar y relacionar los problemas ambientales a nivel global con los problemas locales. Por tanto, los enfoques transdisciplinarios integrativos cobran importancia para entender las conexiones existentes entre los subsistemas naturales y los sociales (Díaz *et al.*, 2011).

En esta tesis se plantea que el modelo de Reservas Mundiales de Surf (RMS) y la protección de zonas de rompientes abre la posibilidad de vincular la conservación con agentes territoriales heterogéneos, el paisaje natural y paisaje simbólico, el marco jurídico y las instituciones políticas multiescalares. En esta investigación, se aprovechó una de las metas de la Reserva Mundial de Surf Bahía Todos Santos (RMSBTS) y que se refiere a un elemneto clave: ser ejemplar y pionera organizando un movimiento regional hacia la conservación de zonas de rompientes y la protección de zonas costeras. Para ello, se han planteado utilizar tres acciones fundamentales: a) gestión ambiental y manejo de recursos naturales, b) fortalecimiento de lazos de cooperación institucional en diferentes niveles y c) otorgar nuevos mecanismos de apoyo a la población local para fomentar la participación y la toma de decisiones en los procesos y proyectos de conservación ambiental. En el caso de la RMSBTS, con esta tesis se logró que los actores involucrados en la protección de las zonas de rompientes recibieran el apoyo de organizaciones de la sociedad civil y utilizaran bases de datos existentes para generar nuevas estrategias de conservación ambiental diversificadas. La creatividad de los participantes y de la autora de esta tesis, se logró a partir de múltiples asesoría y un intenso trabajo en conjunto con un equipo de investigadores interdisciplinarios pensando desde la perspectiva social y ecológica.

A partir de este contexto inter y transdisciplinario y sobretodo, participativo, y con el fin de reforzar las actividades de conservación en México y explorar nuevas herramientas para la protección legal de zonas de rompientes en el plano internacional, la autora de esta tesis participó como parte de una colaboración entre Save The Waves Coalition y las organizaciones Conservamos Por Naturaleza en Perú (www.conservamospornaturaleza.org) y Fundación Rompientes en Chile (www.rompientes.org) en un proceso metodológico conocido como investigación-acción. En este estudio se exploró la posibilidad de conjuntar estrategias de protección en zonas de rompientes y la conservación de ecosistemas marinos bajo las categorías de manejo de áreas protegidas de La Unión Internacional para la UICN (Scheske *et al.,* 2019).

Las áreas protegidas tienen la finalidad de conservar la biodiversidad natural y cultural y los bienes y servicios ambientales, y son definidas como "Un espacio geográfico claramente definido, reconocido, dedicado y gestionado, mediante medios legales u otros tipos de medios eficaces para conseguir la conservación de la naturaleza, de sus servicios ecosistémicos y sus valores culturales asociados a largo plazo" (Dudley, 2008). De acuerdo a Scheske *et al.* (2019), donde los intereses de conservación de zonas de rompientes y conservación de ecosistemas marinos coinciden, las zonas de rompientes deberían integrarse en la planificación de ANP. La UICN considera seis categorías de gestión de áreas protegidas:

I. Protección estricta.
II. Conservación y protección del ecosistema.
III. Conservación de los rasgos naturales.
IV. Conservación mediante manejo activo.
V. Conservación de paisajes terrestres y marinos y recreación.
VI. Uso sostenible de los recursos naturales.

De las seis categorías de la UICN se encontró que cuatro de ellas son afines para la protección de zonas de rompientes y por ello, se propone explorarla en los países donde se vayan a establecer áreas que protejan rompientes:

II. Conservación y protección del ecosistema: parque nacional.
III. Conservación de rasgos naturales: Monumento natural.
V. Conservación de paisajes terrestres y marinos y recreación: Paisaje terrestre y marino protegido.
VI. Uso sostenible de los recursos naturales: Área protegida manejada.

La elección de la categoría más apropiada dependería de cada caso, de cada país y de las características ecológicas de la zona, pero se encontró que en estas cuatro categorías existe la posibilidad de integrar la protección de zonas de rompientes y ecosistemas marinos. Asimismo, Scheske *et al.* (2019) mencionan que la protección de zonas de rompientes es compatible con un programa de la UICN que ofrece medidas alternativas para la conservación denominado "Otras Medidas Eficaces de Conservación basadas en el Área" (OECM, por sus siglas en inglés). De los 10 criterios que se consideran para definir una OECM, el programa de RMS cumple con nueve criterios. Los 10 criterios son: i) área geográfica definida, ii) no ser área protegida, iii) gobierno, iv) manejo, v) visión a largo plazo, vi) efectiva, vii) conservación *in-situ*, viii) biodiversidad, xix) servicios eco sistémicos y x) valores culturales y espirituales. Para el caso de las RMS, solo el criterio de biodiversidad es de relevancia parcial para la creación de una reserva, pero las estrategias para proteger las zonas de rompientes contribuyen a la conservación de la flora y fauna, ya que los objetivos y acciones se centran principalmente en la regulación de actividades antropogénicas que impactan los ecosistemas costeros, tales como desarrollo de infraestructura, descargas de aguas residuales, contaminación por sólidos, cambio de uso de suelo, entre otros.

En este estudio se plantea que la protección de zonas de rompientes puede contribuir a alcanzar algunas de las metas internacionales para la conservación marina y auxiliar a regular las actividades recreativas del área y asegurar el uso sostenible de los ecosistemas costeros. Proteger las zonas de rompientes es cuidar las características físicas y los componentes biológicos de un ecosistema costero, aunque estos sean cambiantes ante los efectos del Cambio Climático. En este sentido, en el año 2018 se estableció una alianza entre Conservation International y Save The Waves Coalition para la creación de una Red de Áreas de Surf Protegidas en distintas regiones del mundo, representando la posibilidad de conjuntar la protección de zonas de rompientes y la conservación de ecosistemas marinos, donde surfistas y la comunidad de conservación ambiental trabajan por objetivos comunes (Scheske *et al.*, 2019).

A partir de este estudio, se plantean tres líneas principales para la protección de zonas de rompientes en el mundo:

1) Integrar el deporte del surf y las zonas de rompientes a planes de manejo de áreas naturales protegidas existentes. Por ejemplo, el plan de manejo de la Reserva de la Biosfera de las Islas del Pacífico ahora incluye al deporte del surf y la zona de rompiente de Killers en la Isla de Todos Santos, BC. Otro ejemplo es la propuesta para integrar zonas de rompientes en la política de Derechos de Uso Territorial para la Pesca (DUTP) o TURF en Chile (Scheske *et al.*, 2019).
2) Proteger las zonas de rompientes bajo categorías de áreas protegidas existentes. Por ejemplo, utilizar las categorías de áreas protegidas de la UICN o explorar categorías relacionados con la protección del patrimonio histórico y cultural, como fue el caso de Malibu Surfing Area, la cual fue integrada en el Registro nacional de sitios históricos en Estados Unidos.
3) Crear un marco de protección legal para zonas de rompientes. Por ejemplo el caso de la Ley de Rompientes en Perú (Scheske *et al.*, 2019).

Con la finalidad de explorar posibles estrategias para conservación y manejo de zonas de rompientes en México, en esta tesis se desarrolló un caso de estudio en la RMSBTS (Arroyo *et al.*, 2019). En este caso ejemplar, se identificó que la protección de zonas de rompientes integra diversos actores y vincula distintos componentes ecológicos, sociales, culturales, políticos y económicos. Para poder tener una comprensión más profunda de las RMS, y de los temas relacionados con la gobernanza ambiental y sostenibilidad que son relevantes para una amplia gama de actores, incluida la comunidad local, representantes de OSC y académicos, se utilizó el marco Sistemas Socio-Ecológicos (SES) que ha ayudado a entender los procesos integradores que caracterizan a las zonas costeras del mundo. Al utilizar el marco SES se identificaron los componentes del sistema y su articulación con las zonas de rompientes en la RMSBTS. El marco utiliza cuatro categorías analíticas: 1) sistema de recursos, 2) unidades de recursos, 3) gobernanza y 4) actores.

El Sistema de recursos de la RMSBTS está integrado por cinco zonas de rompientes. En la zona norte de la Bahía de Todos Santos hay una comunidad con un puerto pesquero denominado El Sauzal. La costa de la RMSBTS está compuesta por una combinación de playas rocosas, playas de arena y playas de canto rodado rodeadas por acantilados. En la zona central de la bahía hay un puerto de usos mixtos y la ciudad rompe con las condiciones naturales de la línea costera. Al sur de la bahía hay playas de arena, playas que frecuentemente son visitadas por surfistas principiantes y familias locales. Las olas frecuentemente vienen del oeste y noroeste, y las marejadas más fuertes son durante la temporada de otoño e invierno. Además, la Bahía de Todos Santos está caracterizada por una gran biodiversidad (ver Capítulo 3).

En las unidades de recursos se identificaron las características particulares de cada zona de rompientes y su relación con el sistema de recursos naturales. San Miguel, Tres Emes y Stack's están localizadas en la comunidad del Sauzal donde la pesca juega un papel significativo, especialmente la pesca de pulpo y erizo. Esta zona está caracterizada por las pozas de marea, bosques de algas y suelos rocosos. A San Miguel lo destaca su valor histórico como cuna del surf en México; esta zona de rompiente forma parte del Arroyo de San Miguel, un ecosistema ripario que aporta arena y canto rodado para formar la clásica ola de San Miguel. La playa de Tres Emes está localizada en una zona industrial; toda la zona está concesionada a la Administración Integral Portuaria de Ensenada (API). Stacks también está localizada dentro del área de concesión de la API y tiene problemas de acceso y descargas de aguas residuales al mar. Una de las grandes preocupaciones para estas dos playas es la propuesta del proyecto "Puerto el Sauzal II y Baja Marina Náutica". Salsipuedes está localizada en la zona norte de la Bahía de Salsipuedes, y es reconocida internacionalmente por su rompiente de fondo rocoso y playa de canto rodado en una caleta al norte de la bahía. Las Islas de Todos Santos albergan una de las olas grandes con mayor reconocimiento a nivel mundial: Killers. Hoy las Islas de Todos Santos son parte de la Reserva de la Biosfera de las Islas del Pacífico.

Analizar la gobernanza permitió identificar los procesos y elementos que determinan las relaciones de poder y autoridad en la toma de decisiones de temas relacionados con la protección de los ecosistemas costeros en la ciudad de Ensenada. La gobernanza en la RMSBTS son procesos y relaciones definidos por diversos actores e instituciones que trabajan en un enfoque de gobernabilidad adaptativa y de colaboración para la gestión de las zonas de rompientes. Se encontró que el proceso de colaboración basado en el aprendizaje ha sido una forma efectiva para el desarrollo de estrategias de conservación en la reserva, siempre buscando adaptarse al cambio para mejorar o mantener un estado deseable, combinando liderazgo, experiencia, uniendo organizaciones y estableciendo reglas y estrategias comunes. El desarrollo de un plan efectivo para proteger las zonas de rompientes implica colaboración y consenso dentro del comité local y con otros actores clave bajo el sistema geopolítico actual. En una escala legislativa y regulatoria más amplia, las principales leyes e instituciones gubernamentales que configuran el marco político y legislativo para la reserva son La *Ley* General del Equilibrio Ecológico y la *Protección al Ambiente*, SEMARNAT, SEMAR, SEGOB, CONAGUA, ZOFEMAT y CONANP. En una escala regional, la gobernanza está siendo principalmente definida por la Ley de Protección al Ambiente de Baja California y la Secretaria de Protección al Ambiente y los lazos de colaboración con las diferentes OSC. En una escala municipal existen diversas instituciones que juegan un papel determinante, tal es el caso del Departamento de Ecología y Medio Ambiente del municipio y el IMIP. Particularmente en Ensenada ha existido una importante agenda de planificación local para proteger los recursos naturales de la región, basada en procesos interactivos entre la comunidad, el medio ambiente y los actores gubernamentales. Específicamente dentro de la RMSBTS, vincular esfuerzos con otras organizaciones y crear redes y alianzas han permitido desarrollar estrategias efectivas para abordar problemas comunes como 1) calidad del agua y contaminación por residuos sólidos en las playas a través del programa Playas Limpias de Ensenada y la Limpieza Internacional Costera; 2) contaminación plástica marina a través de la campaña "Ensenada Libre de plásticos"; y 3) contaminación por desechos marinos a través de un proyecto común con la Comisión Nacional de Áreas Naturales Protegidas (CONANP).

En cuanto a la caracterización de actores se identificó que, aunque los usuarios de las playas de la RMSBTS son predominantemente la comunidad de surf local e internacional, hay diversos grupos formales involucrados en las actividades de la RMS y hay otros programas y proyectos que tienen un impacto directo en la conservación de las zonas de rompientes. La petición inicial para designar la Bahía Todos Santos como RMS fue presentada por un grupo de organizaciones, entre ellas SurfEns y Pronatura Noroeste, con el apoyo de Costasalvaje. Pero con iniciativas tales como 1) el esfuerzo de la comunidad local para proteger la playa de Tres Emes de un sistema de toma y descarga de agua de mar industrial, 2) la participación de representantes de la reserva en el programa de Playas Limpias de Ensenada, y 3) el proyecto de limpieza y monitoreo de las islas de Todos Santos ha integrado a nuevos actores. Los actores clave en la RMSBTS incluyen la comunidad local de surfistas, la comunidad residente, surfistas visitantes, académicos, OSC y autoridades locales, así como el comité local de la reserva y otras organizaciones internacionales. Posteriormente, con el marco DIPSIR se determinaron las actividades específicas que afectan las zonas de rompientes, su impacto en el medio ambiente, y las respuestas reales o posibles a esas actividades. El DPSIR fue una herramienta práctica para comunicar el pensamiento sistemático transdisciplinario y la experiencia local sobre amenazas en las zonas de rompientes. Con este marco y los indicadores asociados fue posible medir la sostenibilidad de la RMSBTS, y se plantea que puede ser utilizado y adaptado para evaluar y monitorear otras zonas de rompientes alrededor del mundo.

Se identificaron dos fuerzas motrices principales que afectan a las zonas de rompientes de la RMSBTS y su entorno: 1) desarrollo urbanos en la zona costera y 2) desarrollo industrial internacional (manufactura y pesca). Ambas fuerzas están vinculadas a actividades que ejercen presión directa sobre la reserva: i) cambio de uso de suelo, ii) privatización y concesiones, iii) introducción de infraestructura costera iv) descargas ilegales de aguas residuales y liberación de contaminantes y residuos sólidos a los ecosistemas costeros. Hoy hay dos propuestas de proyectos importantes para el área de El Sauzal: la extensión del puerto El Sauzal, un proyecto que afectará la zona de rompientes, el acceso a la playa y los ecosistemas costeros y marinos cercanos a la costa, y la construcción de un ferrocarril que pasará por áreas residenciales y el valle de Guadalupe.

Dentro de las presiones que tienen impacto directo en los componentes físicos de las zonas de rompientes están el cambio de uso de suelo, el otorgamiento de concesiones y la privatización de la zona costera. En la zona de San Miguel el uso de suelo no es un factor de amenaza, ya que el uso de suelo es principalmente habitacional, turístico, recreacional y mixto comercial-habitacional, y el arroyo de San Miguel está destinado a conservación. Por otro lado, Tres Emes y Stacks están localizados dentro de una zona con uso industrial y están dentro de la zona de concesión de la API, por lo que el uso de suelo en estas dos playas si representa una amenaza a las zonas de rompientes. Asegurar el uso recreativo de las playas de Tres Emes y Stacks es una tarea complicada, ya que estas dos zonas están destinadas para infraestructura industrial y urbana. En cuanto a la introducción de infraestructura costera, en San Miguel se encuentran los restos de una rampa y un embarcadero que aparece en imágenes de 1966. A lo largo de los años el embarcadero desapareció debido al oleaje y la fuerte corriente, y la rampa para embarcaciones pequeñas está cubierta con una mezcla de arena y rocas. En Tres Emes, actualmente hay un sistema de tuberías para toma y descarga de agua de mar cerca de la zona de rompiente. En Stacks, de acuerdo con los surfistas locales, la extensión del muelle del puerto en el 2010 parece haber tenido un efecto en la calidad de la ola.

Para la evaluación del estado de las zonas de rompientes se definieron cuatro temas: i) pérdida de hábitats naturales, ii) acceso restringido a la playa, iii) alteración de la geomorfología costera, y iv) contaminación de agua y playas, y residuos marinos. Para medir el impacto de las actividades humanas en los componentes físicos, biológicos y sociales de la RMSBTS, utilizamos los siguientes indicadores: i) la pérdida de biodiversidad, ii) el deterioro de la salud del ecosistema, iii) la falta de espacios en las áreas costeras para actividades recreativas, iv) la erosión costera, y v) la alteración de las olas.

En relación al estado de las zonas de rompientes y el impacto de las actividades humanas en los aspectos físicos de las zonas de rompientes se identificó que hay cambios notables en las tres playas. Los cambios en la línea de costa de San Miguel se vinculan principalmente con la intervención humana en la desembocadura de la cuenca, pero es necesario desarrollar estudios de técnicos para determinar cómo se ha visto afectada la calidad de la ola después del cambio de dirección en el cauce del arroyo. En la playa Tres Emes los cambios que presenta la línea costera a lo largo de los años se atribuyen a la erosión natural del acantilado debido a los fuertes vientos, las grandes marejadas, las mareas altas y las fuertes corrientes. Sin embargo, las tuberías para la toma y descarga de agua de una planta de procesamiento de langosta instalada de manera permanente en el año 2017, ha afectado la estabilidad de los acantilados de la playa. En Stacks, la construcción de muros de contención a lo largo de la playa ha tenido un efecto en el transporte de arena en la costa y en los procesos de erosión de los acantilados. Las observaciones ocasionales del acantilado junto con el análisis de las imágenes de Google Earth han resaltado la presencia de diversos deslizamientos de tierra, escurrimientos, descargas de aguas residuales y grietas en los acantilados, así como procesos de erosión natural del acantilado y la costa, aunque el litoral no tiene modificaciones perceptibles importantes. Los acantilados ubicados en la zona sur de la playa de San Miguel también se han visto afectados por escurrimientos de agua de las casas y el complejo turístico construido en la cima de los acantilados; estos han provocado derrumbes en la zona de la bahía al sur de la rompiente.

En lo relacionado al componente biológico, la mayor parte del ecosistema costero en San Miguel conserva su condición natural, pero hay diferentes problemas sobre todo en el cauce del arroyo: flora invasiva, extracción de arena y vertido de residuos sólidos urbanos. En Tres Emes, la construcción de varios edificios industriales ha disminuido considerablemente los hábitats naturales; casi todo el hábitat natural ha sido sustituido por complejos industriales. Las imágenes de Google Earth muestran que entre el 2004 y el 2017 en la costa de Stacks hay un aumento considerable de construcciones (casas y edificios industriales). En Tres Emes, la presencia del ser humano y el uso ocasional de productos como el cloro como una técnica de pesca ha provocado una disminución de la fauna marina en la zona del intermareal rocoso. Otra de las preocupaciones por afectaciones a la flora y fauna marina es la relacionada con el control de la calidad del agua que se descarga en el océano y el funcionamiento inadecuado ocasional de las plantas de tratamiento. En los resultados de las muestras de agua en San Miguel, Tres Emes y Stacks no hubo presencia significativa de enterococos y coliformes. Aun así, durante las entrevistas con usuarios locales encontramos que la mayoría de los surfistas han sufrido una infección o enfermedad de la piel después de haber surfeado en las playas de Tres Emes y Stacks; también suelen percibir olores extraños del agua. En el registro de contaminación por solidos se identificó que uno de los problemas más comunes en las playas de San Miguel y Tres Emes son las colillas de cigarro y corcholatas. En Stacks el problema más fuerte es la contaminación por plásticos.

En cuanto a problemas relacionados con el componente social se identificó que la falta de accesos a la playa es un tema común en toda la costa de Ensenada. El crecimiento urbano a lo largo del corredor Tijuana-Ensenada ha promovido la urbanización de espacios con frente al mar, lo que ha resultado en el cierre de accesos públicos a la playa. La playa de San Miguel se encuentra dentro de una zona residencial privada con acceso controlado; el camino para ingresar a Tres Emes pertenece a la Administración Portuaria y el acceso a Stacks es principalmente a través de una propiedad privada que está actualmente en venta. En cuanto a la afluencia de surfistas a las playas, la cantidad de personas ha variado durante los últimos años debido a diferentes factores tales como: la epidemia de influenza, la percepción de seguridad en México por parte de los surfistas visitantes, el aumento de surfistas locales, los cambios en la economía local y estadounidense, la accesibilidad de los surfistas locales a equipo deportivo, entre otras cosas. San Miguel ha sido sede de diversas competencias locales e internacionales y es la sede del Baja Surf Club Invitational, uno de los primeros torneos de surf en México. Además, es una de las paradas para un circuito binacional de surf que se realiza entre California y Baja California. Al igual que San Miguel, Tres Emes es un espacio de entrenamiento para los equipos juveniles nacionales y estatales de surf. La ola Tres Emes ha mantenido la calidad a lo largo de los años debido a que el arrecife no ha sido modificado. El plan inicial para instalar un tubería industrial de toma y descaraga de aguas atravezando el arrecife principal que produce la ola de Tres EMES representó una amenaza para la zona de rompiente, pero como respuesta a las acciones de la RMSBTS y la presión de la comunidad local, la tubería se reubicó hacia el sur. Sin embargo, esta nueva ubicación todavía representa una amenaza para la seguridad de los surfistas, especialmente los principiantes.

Como respuesta a las actividades antropogénicas que afectan las zonas de rompientes, en los últimos cuatro años, la RMSBTS ha liderado esfuerzos junto con OSC regionales, actores clave, instituciones académicas y el gobierno local para resolver problemas en las playas de Ensenada. Los indicadores que se aplicaron a las tres zonas de rompientes de la RMSBTS permitieron identificar actividades específicas que afectan las zonas de rompientes, su impacto en el medio ambiente, y las respuestas reales o posibles a esas actividades, base sobre la cual se desarrolló un plan estratégico y los lineamientos generales para la conservación y manejo de zonas de rompientes en la RMSBTS. Los cinco temas principales sobre los cuales se desarrolló el plan estratégico son:

Amenazas	Metas	Estrategias
Desarrollo costero no sostenible que amenaza los ecosistemas costeros y las zonas de rompientes.	Contar con herramientas para la protección legal de las zonas de rompientes.	Desarrollar Áreas protegidas de Surf.
Calidad de agua.	Mejorar la calidad de agua en las playas de Ensenada.	Programa de monitoreo de calidad de agua.
Contaminación por sólidos.	Reducir la contaminación por sólidos en las playas de Ensenada.	Programa de plásticos
Acceso a las playas	Asegurar el acceso a las playas.	Integrar las playas a los programas y planes de desarrollo.
Deterioro de la salud de los ecosistemas y pérdida de biodiversidad.	Asegurar el uso sostenible y la conservación de los recursos naturales y ecosistemas coteros.	Promover la creación de ANP en ecosistemas costeros.

Tomando como base el caso de RMSBTS, en este trabajo se realizó una selección de categorías de ANP de la *LGEEPA* que contemplen la dimensión social, biológica y física y que sean compatibles para la protección de zonas de rompientes. La protección de estas no sólo es asegura la conservación de los atributos físicos para que una ola rompa, sino asegurar también la conservación de los componentes biológicos y los valores sociales, históricos y culturales de la zona. Si bien las estrategias para RMSBTS se basan en las principales amenazas que se presentan en la tabla anterior, de manera general para ampliar la experiencia de esta reserva al territorio nacional se contemplan para México tres oportunidades principales:

1) Integrar la actividad del surf y las zonas de rompientes a planes de manejo de ANPs existentes, tal es el caso de la zona de la rompiente de Killers en las Islas de Todos Santos en México, las cuales pertenecen a la Reserva de la Biosfera de las Islas del Pacífico.
2) Proteger las zonas de rompientes bajo categorías de áreas protegidas existentes en la *LGEEPA, UNESCO O UICN.*
3) Certificación de playas

En relación a las ANP, la *LGEEPA* establece que "las zonas del territorio nacional y aquellas sobre las que la Nación ejerce soberanía y jurisdicción, en las que los ambientes originales no han sido significativamente alterados por la actividad del ser humano, o que sus ecosistemas y funciones integrales requieren ser preservadas y restauradas, quedarán sujetas al régimen previsto en esta Ley y los demás ordenamientos aplicables". Uno de los objetivos de las ANP es proteger los entornos naturales de zonas, monumentos y vestigios arqueológicos, históricos y artísticos, así como zonas turísticas, y otras áreas de importancia para la recreación, la cultura e identidad nacionales y de los pueblos indígenas (Cap. I, Sección 1, art 45). La *LGEEPA* actualmente reconoce nueve categorías de ANP: Reservas de la biósfera; parques nacionales; monumentos naturales; áreas de protección de recursos naturales; áreas de protección de flora y fauna; santuarios, parques y reservas estatales, así como las demás categorías que establezcan las legislaciones locales; zonas de conservación ecológica municipales, así como las demás categorías que establezcan las legislaciones locales, y áreas destinadas voluntariamente a la conservación (Cap. I, Sección 1, art 45). Para el manejo de las ANP la *LGEEPA* establece un esquema de zonificaciones, en donde cada zona y subzona tiene objetivos y actividades particulares (art. 47 y 47 bis). Algunas de las categorías de protección afines para la protección de rompientes en México son:

Categoría de protección.	Descripción.	Ventajas	Desventajas
Parque nacional	Representaciones biogeográficas, a nivel nacional, de uno o más ecosistemas que se signifiquen por su belleza escénica, su valor científico, educativo, de recreo, su valor histórico, por la existencia de flora y fauna, por su aptitud para el desarrollo del turismo, o bien por otras razones análogas de interés general.	Uso diversificado. Enfoque integral para la conservación de la biodiversidad, la CONANP brinda apoyos económicos a las comunidades dentro de las ANP, permite actividades de investigación, recreación, turismo de bajo impacto y educación ambiental.	La definición del área para la ANP es un proceso complejo. Falta de personal, presupuesto y capacitación de algunas ANP; marco jurídico no alineado entre sectores, especialmente en las ANP marino-costeras.
Parque Estatal	Los parques estatales se constituirán, de uno o más ecosistemas que se signifiquen por su belleza escénica, su valor científico, educativo, histórico, de recreo, por la existencia de flora y fauna, por su aptitud para el desarrollo del turismo sostenible o bien por otras razones análogas de interés general.	Uso diversificado. Además de actividades relacionadas con la protección del ecosistema y los recursos naturales, permite actividades de investigación, recreación, turismo de bajo impacto y educación ambiental.	En general protege áreas pequeñas. Programas de manejo inexistentes o no actualizados en algunos casos, no obstante, que la legislación estatal no siempre está actualizada. No existen presupuesto fijo por parte de las entidades federativas para el manejo de los parques estatales.
Geoparque	Son áreas geográficas únicas y unificadas, en las que se gestionan sitios y paisajes de importancia geológica internacional, con un concepto holístico de protección, educación y desarrollo sostenible.	Promueven la conexión del patrimonio geológico con el patrimonio natural y cultural del área. Buscan aumentar la conciencia y la comprensión del aprovechamiento sostenible de los recursos de la Tierra, la mitigación de los efectos del cambio climático y la reducción del impacto de los desastres naturales. Tienen un enfoque de abajo hacia arriba.	No es una designación legislativa. Sin embargo, los sitios deben estar protegidos por la legislación indígena, local, regional o nacional según corresponda. No es una designación definitiva.

Acuerdo de destino (ZOFEMAT y Ambientes Costeros)	Es el equivalente a una concesión pero se otorga a dependencias de la administración pública (federación, estados y/o municipios) para el uso y aprovechamiento de la Zona Federal Marítimo Terrestre (ZOFEMAT), los ambientes costeros y los predios federales/terrenos nacionales en determinado espacio, no pagan derechos ni causan impuestos y no tiene fecha de vencimiento.	La CONANP puede solicitar el destino de la Zona Federal Marítimo Terrestre (ZOFEMAT), los ambientes costeros (playas, dunas, manglares y marismas) y de predios federales/terrenos nacionales para la salvaguarda y custodia de un espacio terrotorial. Los AdD facilitan en gran medida que la CONANP pueda llevar acciones encaminadas para proteger la interfaz mar-tierra y de zonas inundables; además asegura la tenencia de la tierra a su favor. Pueden ser utilizados dentro de las ANP para fortalecer su manejo. El SAT condona los costos de concesiones para la conservación. No es un instrumento de política ambiental, pero tiene fortalezas similares a las de la un ANP de competencia Federal, ya que en términos del Derecho Administrativo, es un acuerdo secretarial en el que se otorga el destino para la salvaguarda y custodia de un espacio territorial.	Sólo aplican para entidades de la administración pública federal, y existe la posibilidad de crear esquemas de co-manejo con OSC. Es difícil para una OSC pedir áreas grandes y asegurar su cuidado. Dificultad para financiamiento de largo plazo para el cuidado de la concesión en destino.
Sitios Ramsar	La Convención tiene varios mecanismos para ayudar a los países (partes contratantes) a designar como sitios Ramsar sus humedales más importantes y a adoptar las medidas necesarias para manejarlos de manera eficaz, manteniendo sus características ecológicas. Los sitios Ramsar se designan porque cumplen con los Criterios para la identificación de Humedales de Importancia Internacional. El primer criterio se refiere a los sitios que contienen tipos de humedales representativos, raros o únicos, y los otros ocho abarcan los sitios de importancia internacional para la conservación de la diversidad biológica. Estos criterios hacen énfasis en la importancia que la Convención concede al mantenimiento de la biodiversidad.	Protección legal eficaz junto con el decreto de un Acuerdo de Destino. Cuenta con una gestión sencilla, criterios y estándares internacionalmente reconocidos; y además, como tratado internacional, en teoría, tiene el peso legal de una Ley General en México	Tiene una débil protección legal en México, a pesar de que es un tratado internacional. A cargo de la CONANP como punto focal de la Convención de Ramsar, pero no tiene un presupuesto asignado para el cuidado de los Sitios Ramsar fuera de las ANP.

Certificación de playas.	Las certificaciones son etiquetas de calidad ambiental, en la cual se deben cumplir y mantener una serie de estrictos criterios de calidad del agua, contaminación por sólidos, seguridad, servicios e infraestructura.	Obligan a mejorar el control de calidad de agua, recolección de basura, difusión de información a usuarios, seguridad y vigilancia. Beneficios: Promover la calidad ambiental, sanitaria, de seguridad y de servicios de la playa. Identificar y prevenir los riegos e impactos ambientales. Mejorar la imagen y competitividad del destino. Proteger el medio ambiente y la conservación de la biodiversidad. Colocar al destino a la vanguardia internacional en relación con esquemas similares.	No es una designación legislativa. Requiere de una gran inversión económica y en tiempo. Se requiere de un comité municipal que muchas veces dificulta la operatividad del programa de certificación.
Ordenamiento Ecológico del Territorio	Es un instrumento de la política ambiental que considera la vocación de cada zona o región, en función de sus recursos naturales, la distribución de la población y las actividades económicas predominantes y previene los desequilibrios existentes en los ecosistemas por efecto de los asentamientos humanos, de las actividades económicas o de otras actividades humanas o fenómenos naturales.	Se configura a través de un proceso participativo, guiado por el comité de ordenamiento ecológico, al promover la resolución de conflictos y la construcción de acuerdos, además se identifican las áreas críticas para la conservación en el estudio técnico. Adaptabilidad a través de un proceso de evaluación y adaptación. Cuenta con un marco jurídico bien desarrollado.	No se pueden vincular los espacios marinos y terrestres. Los equipos técnicos no siempre tienen la experiencia y capacidad necesarias para conducir el proceso de elaborar un ordenamiento ecológico. Además, aún no existe una evaluación de la efectividad e implementación de los ordenamientos ecológicos.
Ordenamiento turístico del territorio Zonas de Desarrollo Turístico Sustentable	Tiene por objeto determinar la regionalización turística del territorio nacional a partir del diagnóstico de las características, disponibilidad y demanda de los recursos turísticos; conocer y proponer criterios de zonificación, con el propósito de preservar los recursos naturales y aprovechar de manera ordenada y sustentable los recursos turísticos; y establecer los lineamientos y estrategias turísticas para la preservación y el aprovechamiento ordenado y sustentable de los recursos turísticos.	Potencial para fortalecer el desarrollo turístico sustentable con la conservación del medio ambiente.	Marco legal deficiente, la ley general de turismo no tiene un reglamento actualizado. Las zonas de desarrollo turístico no pueden incluir ANP. Falta de aplicación o aplicación/implementación. Falta de capacidades de la SECTUR, su enfoque principal sigue siendo el turismo masivo (p.ej. Acapulco, Riviera Maya y Los Cabos)

Fuentes: https://www.ramsar.org/es/sitios-paises/los-sitios-ramsar; Koch, V., & BioMar-GIZ, P. (2015); LEY GENERAL DEL EQUILIBRIO ECOLÓGICO Y LA PROTECCIÓN AL AMBIENTE, PROTECCIÓN AL AMBIENTE DEL ESTADO DE BAJA. CALIFORNIA; NORMA MEXICANA, NMX-AA-120-SCFI-2016 QUE ESTABLECE LOS REQUISITOS Y ESPECIFICACIONES DE SUSTENTABILIDAD DE CALIDAD DE PLAYAS (CANCELA A LA NMX-AA-120-SCFI-2006).

Con la finalidad de apoyar a la RMSBTS y otorgar mecanismos para proteger y monitorear las zonas de rompientes en diferentes partes del país, miembros del comité de la RMSBTS crearon Reservas de Surf México, A.C. Este trabajo de tesis será la base para el análisis del marco legal y un inventario de zonas de rompientes que será utilizado como una herramienta práctica para introducir la evaluación ambiental y el monitoreo en las zonas de surf y sus entornos circundantes. En la organización Reservas de Surf México utilizará el esquema del plan para el desarrollo de una Red de Áreas Protegidas de Surf en México y la ficha técnica que se presentaron en uno de los capítulos, y desarrollará la primera base de datos de zonas de rompientes para México. Esta base de datos incluirá estudios técnicos para la protección de zonas de rompientes en México, basados en los términos de referencia para establecer ANP de la *LGEEPA.* Estos estudios proporcionarán datos invaluables para la evaluación, preservación y desarrollo sostenible de las zonas de rompientes y los ecosistemas costeros.

La integración de un marco conceptual y metodológico para definir las amenazas a la que estas están expuestas las zonas de rompientes, es el primer paso para descifrar el camino legal para su protección y preservar los servicios ecosistémicos de las zonas relacionadas con las rompientes de surf. El desarrollo de este marco a partir de las experiencias en la RMSBTS, permitió establecer los criterios para entender y analizar los principales componentes ecológicos y sociales, así como las presiones a las que están expuestas las RMS establecidas y en vías de ser designadas. A su vez, los procedimientos establecidos en esta tesis son herramientas fundamentales para identificar zonas de rompientes para ser incluidas en la Red de Áreas Protegidas de Surf a nivel nacional y/o internacional. La característica participativa de esta metodología permitió reforzar la apropiación de la RMSBTS por parte de la comunidad local, lo que retroalimenta y valora la designación, y desarrolla el interés local por la protección de las zonas de rompientes. Asimismo, el enfoque transdisciplinario de este trabajo, enfatiza la contribución activa de la comunidad surfer, organizaciones de la sociedad civil, autoridades gubernamentales y otros participantes fuera del ámbito académico, a la generación de nuevo conocimiento, estrategias y soluciones derivadas de una lógica local-global y teórica-práctica. La investigación requiere cada vez más de una dirección participativa que incluya las experiencias de las personas afectadas por la investigación; por ejemplo la información generada a partir de las experiencias de los usuarios recurrentes de las zonas de rompiente (surfers) con respecto a los cambios físicos y biológicos a lo largo del tiempo, así como las aportaciones de las organizaciones de la sociedad civil que permitan integrar una perspectiva más amplia de la problemática en las zonas de rompientes. Como mencionan Wickson *et al*., (2006), sólo así, se identificará un problema del mundo real en lugar de un problema conceptual.

Finalmente, es importante mencionar que, por lo funcional tanto del marco conceptual como el metodológico propuesto en esta tesis, es posible recomendar la experiencia para todas las reservas del mundo, adaptándolas a sus especificidades locales, pero la esencia de la metodología es extrapolable y se esperaría que en un futuro cercano todas las reservas de surf del mundo cuenten con planes de manejo y su documentación sea compartida para generar el manal universal para la co-generación del conocimiento y diseño de los planes, y el posterior co-manejo de las mismas.

5. CONCLUSIONES.

Los ecosistemas costeros son ambientes complejos donde interactúan procesos ecológicos y socioeconómicos. En su condición natural, las playas ofrecen oportunidades recreativas (pescar, nadar, caminar, surfear), proporcionan hábitats para una gran diversidad de flora y fauna, y proveen protección a los habitantes de zonas costeras debido a que los cambios en la morfología costera tienen amplias consecuencias para la sustentabilidad de las comunidades y ecosistemas costeros (Mentaschi *et al*., 2018). Sin embargo, hay muchos factores que impiden o limitan el uso de las playas: contaminación por residuos sólidos, contaminación del agua por descargas de aguas residuales o industriales directas al mar, introducción de infraestructura costera o privatización de la línea costera, entre otros. Estos factores tienen un impacto directo tanto en el ecosistema (destruyendo o modificando el hábitat natural), como en los servicios ecosistémicos que estos facilitan. Los servicios ecosistémicos constituyen los beneficios que la naturaleza aporta a la sociedad y hacen posible la vida humana (Constanza *et al*., 1997). Uno de los servicios ecosistémicos que proveen las playas son los culturales, por ejemplo, la fuente de inspiración para las manifestaciones estéticas y las obras de ingeniería, la identidad cultural y el bienestar espiritual (FAO, 2019 en http://www.fao.org/ecosystem-services-biodiversity/es/).

En este sentido, proteger las playas y hábitat que las rodea, incluyendo las zonas de rompientes, significa contribuir a proteger una fuente importante de bienestar para los pobladores de las zonas costeras, como también para los visitantes ocasionales. Asimismo, las playas y zonas de rompientes proveen de espacios naturales de acceso libre para la práctica de diversos deportes. Pero uno de los problemas o retos al momento de definir o desarrollar estrategias para proteger las zonas de rompientes y hábitat que los rodea es comprender lo que esto implica. En este trabajo se planeta que el marco SES y los indicadores que se desarrollaron para evaluar las tres zonas de rompientes de RMSBTS pueden ser adaptados y aplicados a otras Reservas Mundiales de Surf, lo cual facilitará poder identificar las principales actividades que afectan las zonas de rompientes, su impacto en el medio ambiente y el desarrollo de estrategias específicas para abordar cada problema. Pero si bien los marcos SES y DPSIR fueron esenciales para comprender de manera integral el complejo sistema y la dinámica socio-ecológica en la RMSBTS, el marco de co-manejo adaptativo fue el enfoque que permitió planificar acciones para mejorar la gestión de las zonas de rompientes y abordar los problemas de gestión de recursos. Este enfoque transdisciplinario ha permitido integrar una metodología que podría ser aplicada no sólo en otras designaciones de RMS, sino también en la identificación, estudio y manejo de zonas de rompientes para su incorporación en la Red de Áreas Protegidas de Surf, como una herramienta para la conservación y protección de áreas costeras. Particularmente en Ensenada, ha existido una importante agenda de planificación local para proteger los recursos naturales de la región. Esta agenda se ha basado en procesos interactivos entre la comunidad, el medio ambiente y los actores gubernamentales. Vincular organizaciones y crear redes de actores ha permitido desarrollar efectivas estrategias para abordar problemas comunes en la zona costera de Ensenada. Por ejemplo, los temas de calidad de agua y contaminación por desechos sólidos en las playas se están abordando a través del Comité de Playas Limpias de Ensenada y la campaña “Ensenada Libre de Plásticos”.

Los objetivos general y específico planteados en esta tesis se pudieron cumplir exitosamente especialmente porque el trabajo se desarrolló dentro del enfoque de la investigación-acción. Esta técnica de investigación de las ciencias sociales fue la base para construir un marco conceptual integrador, y co-generar con los usuarios y los interesados del recurso, un proyecto describir como un sistema social-ambiental la zona de rompientes de Ensenada para con ellos, mejorar las prácticas de protección de las mismas. Asimismo, el involucramiento en el tema desde lo laboral como de formación académica, permitió profundizar en el análisis de una ANP innovadora: la Reserva Mundial de Surf. El doble rol de la autora de esta tesis, como investigadora e integrante de la organización Save The Waves Coalition y cofundadora de la organización Reservas de Surf México, A.C., permitió en esta tesis la combinación del conocimiento teórico y el conocimiento empírico. Haber participado de manera activa en todas las actividades de la reserva desde el año 2015 hasta la actualidad facilitó la generación de nuevos conocimientos para la construcción del marco conceptual y metodológico para la protección de zonas de rompientes, y la construcción de este marco analítico reforzó las acciones de la reserva. En particular, para el tema de protección de zonas de rompientes, el formar parte de Save The Waves Coalition y ser representante del comité local de la Reserva Mundial de Surf fue determinante para poder contar con información y datos indispensables para el desarrollo de este proyecto de investigación.

6. REFERENCIAS.

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7. ANEXOS.

Anexo 1. Parámetros utilizados para medir calidad de agua en las playas de la Reserva Mundial de Surf Bahía de Todos Santos.

PARAMETRO	METODOLOGIA
ARSENICO	NMX-AA-051-SCFI-2001
CADMIO	NMX-AA-051-SCFI-2001
CIANURO	NMX-AA-058-SCFI-2001
COBRE	NMX-AA-051-SCFI-2001
COLIFORMES FECALES	NMX-AA-042-SCFI-2015
CONDUCTIVIDAD ELECTRICA	NMX-AA-093-SCFI-2000
CROMO	NMX-AA-051-SCFI-2001
DBO_5	NMX-AA-028-SCFI-2001
DQO	NMX-AA-030/2-SCFI-2011
FOSFORO TOTAL	NMX-AA-029-SCFI-2001
GRASAS Y ACEITES	NMX-AA-005-SCFI-2013
HUEVOS DE HELMINTO	NMX-AA-113-SCFI-2012
MATERIA FLOTANTE	NMX-AA-006-SCFI-2010
MERCURIO	NMX-AA-051-SCFI-2001
MUESTREO	NMX-AA-003-1980
NIQUEL	NMX-AA-051-SCFI-2001
NITROGENO DE NITRATO	NMX-AA-079-SCFI-2001
NITROGENO DE NITRITO	NMX-AA-099-SCFI-2006
NITROGENO TOTAL KJELDAHL	NMX-AA-026-SCFI-2010
pH	NMX-AA-008-SCFI-2011
PLOMO	NMX-AA-051-SCFI-2001
SOLIDOS SEDIMENTABLES	NMX-AA-004-SCFI-2013
SOLIDOS SUSPENDIDOS TOTALES	NMX-AA-034-SCFI-2015
TEMPERATURA	NMX-AA-007-SCFI-2013
ZINC	NMX-AA-051-SCFI-2001

Anexo 2. Resultados del estudio de calidad de agua en las playas de la Reserva Mundial de Surf Bahía de Todos Santos.

	Playas			
Tipo de análisis:	San Miguel	Tres emes	Beans	Stacks
Sólidos suspendidos totales	Menor de 9.4 mg/L (NC)	Menor de 9.4 mg/L (NC)	19 ml/L	Menor de 9.4 mg/L
DBO5	19.0mg/L	17.75 mg/L (NC)	25.37 mg/L	24.06 mg/L
DQO	32.64 mg/L	35.08 mg/L	32.64 mg/L	32.64 mg/L
Grasas y aceites	Menor de 3.14 mg/L (NC)	Menor de 3.14 mg/L (NC)	Menor de 3.14mg/L (NC)	Menor de 3.14 mg/L
Nitratos	Menor de 0.10 mg/L (NC)	Menor de 0.10 mg/L (NC)	Menor de 0.10 mg/L (NC)	Menor de 0.10 mg/L
Nitritos	Menor de 0.02 mg/L (NC)	Menor de 0.02 mg/L (NC)	Menor de 0.02 mg/L	Menor de 0.02 mg/L (NC)
Nitrógeno total KJELDAHL	0.93 mg/L	1.16 mg/L	Menor de 0.56 mg/L (NC)	Menor de 0.56 mg/L (NC)
Fósforo total	Menor de 0.250 mg/L (NC)	Menor de 0.250 mg/L (NC)	Menor de 0.250 mg/L (NC)	Menor de 0.250 mg/L (NC)
Nitrógeno amoniacal	Menor de o.56 mg/L (NC)	Menor de 0.56 mg/L (NC)	Menor de 0.56 mg/L(NC)	Menor de 0.56 mg/L (NC)
	Menor de 2 NMP/100ml (no	Menor de 2 NMP/100ml (no	Menor de 2 NMP ml/100(no	4 NMP/100ml

Anexo 3. Formatos y procedimiento para el registro de residuos sólidos en las playas de la Reserva Mundial de Surf Bahía de Todos Santos.

VOLUNTEER
OCEAN TRASH DATA FORM

Ocean Conservancy

Ocean and waterway trash ranks as one of the most serious pollution problems choking our planet. Far more than an eyesore, a rising tide of marine debris threatens human health, wildlife, communities and economies around the world. The ocean faces many challenges, but trash should not be one of them. Ocean trash is entirely preventable, and data you collect are part of the solution. The International Coastal Cleanup is the world's largest volunteer effort on behalf of ocean and waterway health.

HERE IS HOW IT WORKS:

SITE INFORMATION:

Cleanup Site Name: ____________

State or Province: ____________ Zone or County: ____________

Country: ____________ Nearest Crossroad or Landmark: ____________

NUMBER OF VOLUNTEERS WORKING ON THIS CARD:

adults ☐ children (under 12) ☐

MOST UNUSUAL ITEM COLLECTED: ____________

TYPE OF CLEANUP:

Land: ☐ Underwater: ☐ Watercraft: ☐

Please return this form to your area coordinator.
If you are unable to do so, please mail or email it to:

Ocean Conservancy
Attn: International Coastal Cleanup
1300 19th Street, NW, 8th Floor
Washington, DC 20036
cleanup@oceanconservancy.org

Trash Free Seas: www.oceanconservancy.org/cleanup
Be a Green Boater: www.oceanconservancy.org/do-your-part/green-boating
Sponsors: www.oceanconservancy.org/cleanupsponsors

International COASTAL Cleanup

Anexo 4. **Formatos y procedimiento para el registro de residuos sólidos en las playas de la Reserva Mundial de Surf Bahía de Todos Santos.**

COORDINATOR
OCEAN TRASH DATA FORM

Ocean Conservancy

DEAR CLEANUP COORDINATOR:
Thank you for your hard work, dedication and valuable time spent for this important cause! We appreciate your commitment and passion for trash free seas.

Before you complete this form, compile all data from the Volunteer Ocean Trash Data Form. For each item of trash, add the total number of pieces and enter this number in the "Total" box on the back of this data form. Numbers are the only valid form of data, so please DO NOT use words or check marks in the boxes next to ocean trash items.

NAME: **EMAIL:**

CLEANUP SITE DESCRIPTION

Type of Environment (choose one):

- ◯ Saltwater (Ocean/Bay/Estuary)
- ◯ Freshwater (River/Stream/Lake)
- ◯ Inland (No Water Body Present)

Mode of Data Collection (choose one):

- ◯ Land (beach, shoreline or inland)
- ◯ Underwater
- ◯ Watercraft (powerboat, sailboat, kayak or canoe)

CLEANUP SITE LOCATION

Cleanup Site Name (beach, park, etc.):

State or Province: Zone or County:

Country: Nearest Crossroad/Landmark

CLEANUP SUMMARY

Month: Day: Year: Total Number of Volunteers at this site: Adults: Children:

Total Weight of Trash Collected: lbs. or kgs. Total Number of Trash Bags Filled:

Estimated Distance Cleaned: ¼ ½ ¾ 1 2 3 4 5 (circle one) Other:

Distance Measured In: Miles or Kilometers (circle one)

MOST UNUSUAL ITEM(S) COLLECTED:

1. 2. 3.

Please return this form along with all Data Forms to your State/Country Coordinator.

State/Country Coordinators: Please submit Summary Data into the online Data Collection and Reporting Tool at **www.coastalcleanupdata.org.**

International COASTAL Cleanup

If you are unable to contact your State or Country Coordinator, please mail or email this form to:

Ocean Conservancy
Attn: International Coastal Cleanup
1300 19th Street, NW, 8th Floor
Washington, DC 20036

cleanup@oceanconservancy.org
www.oceanconservancy.org/cleanup