Using Human Ecology and Feedback-Guided Analysis to Understand the Relationship Between Ecotourism and Poaching

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Abstract

The inherent complexity of social-ecological systems (SES) can make them difficult to understand and manage, particularly with regards to human-wildlife issues such as poaching. This study uses an approach to human ecology that uses conceptual models and templates within feedback-guided analysis to analyze the complex relationship between ecotourism and poaching in a marine protected area in the Dominican Republic. Our findings show that the application of these templates through a sequenced process is advantageous as it: (i) enables a comprehensive understanding of SES; (ii) helps manage complexity as a system; and (iii) allows researchers to identify the feedback structures driving human-environment interactions that may perpetuate ecosystem decline. These benefits represent a valuable starting point for more comprehensive policy-making and management.

Keywords: ecotourism, marine reserves, overfishing, social-ecological systems, systems thinking, tourism

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Introduction

Within human-environment interactions, poaching—the illegal taking or killing of wildlife—has now become a global crisis (Nellemann et al., 2014). Poaching is bad for wildlife, and undermines sustainable development, disrupts the rule of law, and generates revenue for organized crime and conflict. Poaching is therefore detrimental

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to the livelihoods of surrounding communities (Kahler et al., 2013). One solution to poaching is sustainable tourism, in particular ecotourism, defined as “responsible travel to natural areas that conserves the environment, sustains the wellbeing of the local people, and involves interpretation and education” (International Ecotourism Society, 2015, “Ecotourism Definition” section). However, few studies explore how ecotourism can reduce poaching, particularly in developing countries. Although some authors identify cases where ecotourism helps mitigate poaching (see Eshoo et al., 2018; Morais et al., 2018; Saikim et al., 2016), explicit studies are rare, and focus largely on land-based conservation, rarely aquatic environments.

In addition, a systematic understanding of the social–ecological situation and the human–environment interactions that occur within communities is largely absent in the literature. Human–environment interactions influence both poaching and the capacity of ecotourism to mitigate poaching, and mapping these interactions is crucial to developing our understanding of this topic. One way forward is to analyze these interactions through the lens of human ecology and systems thinking. Human ecology has emerged as a science that studies the interrelationships between humans and the environment (Marten, 2001), and can help clarify the root causes of environmental issues, including poaching, and suggest ways to manage them.

Here, we rely on human ecology and feedback-guided analysis to better understand the relationship between ecotourism and poaching from a dynamic systems perspective. Feedback-guided analysis was developed by Proust et al. (2012) as a three-stage modeling process that reduces complexity within a system while identifying feedback structures driving systemic change. Feedback-guided analysis uses templates similar to conceptual models, but that offer additional advantages when used to study complex systems (Lawrence et al., 2019; Lischka et al., 2018). First, they are transposable across sites, allowing a certain level of comparability of feedback mechanisms where systems share the same structures. Second, they can be used as frameworks to unravel complexity within a system and comprehensively analyze the diverse factors and interactions present within social–ecological systems (SES) (Proust et al., 2012). Third, they can map out cross-sector interactions between institutions, communities, individuals, and wildlife so researchers can identify how these interactions can be better managed.

This study uses feedback-guided analysis to study poaching in a marine protected area (MPA), La Caleta National Marine Park (MP), in the Dominican Republic. La Caleta is a municipal district within the province of the capital Santo Domingo. At the latest census in 2010, the district’s population was 63,137 people, from diverse, but mostly poor, socioeconomic groups (“poor” is not clearly defined in the census report). Some residents own small colmados (convenience stores), while others work in the enterprise zone of the area (Departamento de Coordinación Estadística, 2019). A small portion of the population practices subsistence fishing. Historically, these fishers lived in the land area of the present-day La Caleta MP,
before being relocated in 1972 to government housing after President Balaguer ordered the construction of the area’s terrestrial infrastructure. In 1986, the marine park was established and fishing became illegal within the park. The “Case study area” and “Findings and discussion” sections below provide more information on La Caleta MP.

This study has two aims:

1. Identify how the human–environment interactions of the SES of La Caleta MP drive or hinder the capacity of ecotourism to be used as a tool for conservation by mitigating poaching.
2. Further the understanding of how feedback-guided analysis can be used to analyze the persistent problems affecting our world today—in this case, poaching.

The paper first provides a brief analysis of the templates used in feedback-guided analysis, then describes the case study area, followed by the study’s methodology. The last section includes the findings and discussion, which provide an analysis of how the templates were used to examine the problem of poaching in La Caleta MP and its relationship to ecotourism.

Templates in feedback-guided analysis

This section outlines the sequence of templates used when studying SES using a human ecology and feedback-guided analysis approach. These templates help make sense of a highly complex system and narrow the focus into a more manageable model that still captures the essential variables (i.e., the fewest of categories of variables to be considered by policy-makers) driving system change. Although Dyball and Newell (2015) propose an overview template as the first one to use when analyzing a system, we argue that a preliminary analysis of the situation itself is required so as to clearly understand the constituent parts that make up the system. Therefore, we propose that the first template be a conceptual model representing the SES under study. This conceptual model uses Boyden’s (2011) transition framework as a guiding foundation.

The second template used in this study is an overview template in the form of a cultural adaptation template (CAT). The CAT provides an influence diagram that helps capture interactions across the different subsystems that make up a larger system (Dyball & Newell, 2015). These interactions are always present in contested social–ecological environments and play a crucial role in their behavior (Dyball & Newell, 2015). Generally, the CAT will be composed of subsystems with their own high-level state variables. For the purpose of this research, the interactions between four major subsystems in La Caleta MP are considered:
i. **State of Cultural Paradigms:** The combined worldviews, mental models, knowledge, assumptions, beliefs, and priorities of a given community. These play a large role in determining the rate of progress towards sustainability and may change when a community acquires new knowledge (Holland, 1992).

ii. **State of Community:** The societal roles that make up a community (Dyball & Newell, 2015), including political, social, and economic variables. Examples include local legislation, economic arrangements, workforce structure, institutions, and education systems. Many of these are known to influence poaching (Rizzolo et al., 2017).

iii. **State of Human Health and Well-Being:** The overall level of comfort, security, and happiness of a community. Here we focus only on food and economic security, safety and social cohesion, and their relationship to poaching, but this subsystem could also include universal health needs more broadly (Boyden, 2016).

iv. **State of Ecosystem:** Both natural and built environments (Dyball & Newell, 2015). For example, buildings, vehicles, roads, and natural elements such as atmosphere, plants, soil, biodiversity, or climate. Here we focus on the natural environment of the marine park and its built infrastructure.

The third template is the problem-space diagram. As its name implies, this template helps bring into focus the specific problem under study (Proust et al., 2012). By doing so, the problem-space diagram focuses attention on the system's feedback structures. To develop the problem-space diagram, “intermediate” variables representing a particular issue within the system are chosen. Importantly, the problem-space diagram must maintain the same feedback structure and causal links of the CAT. As a result, each subsystem within the CAT contributes a category of variables to the problem-space diagram (Dyball & Newell, 2015).

The final template is a specific system of interest (SSoI) diagram. According to Dyball and Newell (2015), the SSoI represents a simple causal-loop diagram encompassing at least one variable from each of the subsystems constituting the problem-space diagram. Similar to the problem-space diagram, the SSoI diagram also maintains the feedback structure of the CAT. However, it may include further system-state variables and causal links. Since the SSoI represents a causal-loop diagram, its causal links can be assigned polarities that indicate the direction in which the driving variable changes the affected variable. Importantly, the state variables that make up the SSoI are not aggregate variables like in the problem-space diagram. They are single, well-defined variables with behavior that can be quantified and observed over time (Dyball & Newell, 2015).

Each template is presented in the “Findings and discussion” section.
Case study area

La Caleta MP is the first marine area declared a national underwater park in the Dominican Republic. It is located on the southern coast, adjacent to the town of La Caleta and Las Américas International Airport to the town’s south, and approximately 20 km to the east of the national capital, Santo Domingo. Historically, the indigenous people, the Taínos, used this area for fishing (Torres, 2003). Over the nineteenth and twentieth centuries, more modern settlements were established within the land areas of the present-day marine park, also dependent on subsistence fishing. In the 1970s, scuba diving was introduced, leading to an uptake in spearfishing. Combined with the artisanal fishing already present, the marine resources of the area began to decline (Torres & Ulloa, 2010). As a result, several organizations advocated for the park to become the first underwater marine park in the country, successfully achieving this in 1986, when La Caleta MP was declared an MPA. Despite this designation, fishing in the protected area continued.

In the mid-2000s, the non-government conservation agency Reef Check Dominican Republic (DR) enacted a co-management program of La Caleta MP in collaboration with the Ministry of Environment, La Caleta City Council, the Ministry of Culture, and the local fishers. Within this new phase of co-management, Reef Check DR developed a series of management objectives and a continuous monitoring program of the park’s coral reefs (Reef Check DR, n.d.). Reef Check DR also identified stakeholder groups that use the park and began a process of training and awareness-raising with them. As a result, a local fishing and tourism services cooperative (COOPRESCA2) was created in collaboration with the local fishers. The collaboration between Reef Check DR and COOPRESCA sparked several initiatives to protect the park’s coral reefs, including a sustainable fishing program, a rezoning of the park to its current range as shown in Figure 1—designating areas for snorkeling and diving, no-fishing zones, and areas that support sustainable fishing—and a community-based ecotourism (CBET) initiative in the form of a dive center called El Carey (Reef Check DR, n.d.).

El Carey was established to complement the sustainable fishing program and economically support local families by commercializing tourism goods and services while also contributing to the conservation of the marine resources and environment of La Caleta MP. Reef Check DR and COOPRESCA organized community workshops to develop the dive center’s strategy and business plan. Moreover, Reef Check DR also supplied all the necessary equipment, such as scuba and snorkeling equipment, uniforms, a dive boat, air compressor, dry bags, lifejackets, kayaks, paddleboards and paddles, marine radios, and GPSs for the operations of the dive center (R. Torres, personal communication, October 18, 2019). Importantly, as part of establishing the

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2 Cooperativa de Pesca y Prestadores de Servicios Turísticos de La Caleta (La Caleta Fishermen and Tourism Service Providers)
dive center, Reef Check DR and the fishers from COOPRESCA signed an agreement that the fishers would stop fishing inside the diving area of the marine park (marked with dashed lines in Figure 1), to prevent conflict between COOPRESCA’s two business activities (fishing and tourism), and to conserve fish and coral populations for divers to enjoy (R. Torres, personal communication, October 18, 2019). However, this vision has not yet been achieved due to several factors, including cultural and social traditions, poor enforcement of regulations, community conflicts, poor destination management, and a lack of resources and skilled labor. Combined, these factors not only enable poaching to continue but have also hindered the management of both La Caleta MP as a marine park and of the dive center. These factors and their interactions will be further analyzed in the “Findings and discussion” section.

Figure 1. Zoning map of La Caleta MP
Source: Lab Percepción Remota INTEC 2008 as commissioned by Reef Check DR. Translated from Spanish to English by the first author. Reproduced with permission from Reef Check DR.
Study methodology

In this research, a case study approach was deemed appropriate, as it allows researchers to explore individuals, populations, locations, or organizations through their complex relationships, interventions, communities, or programs (Yin, 2003). Case studies usually focus on small samples and are not intended to make statistical inferences related to the wider population but, rather, intend to examine real-life phenomena in detail. In this study, the real-life phenomena are poaching and ecotourism conservation in La Caleta MP.

Both primary and secondary data were used. Secondary data were obtained from books and gray literature that provided detailed information about the creation and historical management of La Caleta MP. Primary data included qualitative in-depth, semi-structured interviews, conducted over two weeks in October 2019. The interviews aimed to capture a comprehensive picture of each participants’ background, attitudes, and behaviors in their own words (Schutt, 2017). The questions were drafted and categorized based on the four major subsystems that make up the CAT.

Study participants \((N = 28)\) included fishers from La Caleta \((n = 9)\) (including the spearfishers, identified as those who continue to poach inside the marine reserve), local government representatives \((n = 3)\), members of the community (non-fishers) of La Caleta \((n = 4)\), local non-government organizations representatives \((n = 3)\), managers and employees of private sector institutions \((n = 4)\), and recreational users of La Caleta MP \((n = 5)\).

The data were analyzed using thematic analysis, whereby each interview was coded inductively in NVivo (Adler & Clark, 2011). This analysis revealed 14 high-level aggregate variables driving system change (see Table 1). These high-level aggregate variables provided the foundation to develop the conceptual model for the SES, as well as for the feedback-guided analysis templates referred to in the previous section. Secondary data were also used for the development of the conceptual model that provides a broad analysis of the social–ecological system of La Caleta MP.

This conceptual model is presented in the “Findings and discussion” section, based on Boyden’s (2011) transition framework, as a way of classifying state variables that make up the SES. This classification, in turn, helps guide further segregation of the SES, so its subsystems can be identified and feedback-guided analysis can be conducted (Dyball & Newell, 2015). In this case, the conceptual model helps segregate the complex system of La Caleta MP into separate parts, to visualize the specific elements that constitute the relevant SES. This provides the basis for the

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3 Private sector institutions included tourism operators and major infrastructure development projects in close proximity to La Caleta MP.
CAT, the problem-space diagrams, and the SSoI diagrams. Following the conceptual model of the SES of La Caleta MP, an overview template in the form of a CAT will be presented. The CAT has been proposed as a common framework where variables that measure the state of a subsystem are grouped together and their high-level links and connections are analyzed, to understand how these interactions affect the overall system under study (Dyball & Newell, 2015). As previously mentioned, in the case of this study, these subsystems include State of Cultural Paradigms, State of Community, State of Human Health and Well-Being, and State of Ecosystem.

Finally, a problem-space diagram and a SSoI diagram will be presented. The primary data from the interviews were used to develop these diagrams. Specifically, the data collected through the interviews allowed the researchers to not only understand and visually represent the SES of La Caleta MP through the conceptual models and the templates in feedback-guided analysis, but to also understand participants’ perception of the management of the protected area and El Carey Dive Center, including its capacity to contribute to conservation outcomes by mitigating poaching.

Findings and discussion

Social–ecological system conceptual model

The first step is to understand the case study through the use of a conceptual model that illustrates the SES of La Caleta MP. This conceptual model is presented in Figure 2, and summarizes the components identified through primary and secondary data that make up the SES of La Caleta MP and their general interactions. Each box in Figure 2 represents a component of La Caleta MP and its community, including, for example, human activities, societal arrangements, and the natural and built environments in the system. The lines and arrows represent the components’ connections and interactions.

The conceptual model presented in Figure 2 allows us to understand the high-level interactions occurring in La Caleta MP. These interactions can be analyzed in greater depth through the CAT, the problem-space diagrams, and SSoI diagrams. As previously mentioned, the data analysis revealed 14 high-level aggregate variables making up each of the four subsystems of La Caleta MP. These aggregate variables are briefly described in Table 1. They each form part of the four subsystems of (State of) Cultural Paradigms, Community, Human Health and Well-Being, and Ecosystem.
Figure 2. A conceptual model of the SES of La Caleta MP
Source: Created by the authors. Based on Boyden (2011) and Marten (2001).
Note: RCDR = Reef Check Dominican Republic; COOPRESCA = local fishing and tourism cooperative – see Footnote 2 for full definition; NGO = nongovernment organization; CBET = community-based ecotourism; GEF = Global Environmental Facility; IAF = Inter-American Foundation; GCFI = Gulf and Caribbean Fisheries Institute; AERODOM = an airport company.
Table 1. Summary of aggregate variables within each subsystem with brief findings

<table>
<thead>
<tr>
<th>Subsystem and description</th>
<th>Aggregate variables</th>
<th>Brief findings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State of Cultural Paradigms:</strong> includes worldviews, mental models, knowledge, assumptions, beliefs, norms, and priorities</td>
<td>Environmental concerns</td>
<td>Interviewees reported mixed levels of the importance placed on caring for nature.</td>
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<td></td>
<td>Social norms</td>
<td>There is a reluctance to denounce poachers because of fear of vengeance from poachers.</td>
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<td></td>
<td>Attitudes</td>
<td>Spearfishers appear open to contributing their skills and knowledge to the improvement of the project but social conflict between different stakeholder groups has prevented them from doing so, leading to ongoing poaching as “a form of rebellion” (Participant 25).</td>
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<td></td>
<td>Traditional livelihoods</td>
<td>Fishing represents spearfishers’ “lifestyle and culture,” according to Participant 25, with high levels of traditional knowledge of La Caleta MP.</td>
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<tr>
<td><strong>State of Community:</strong> includes societal roles and a set of political, social, and economic variables, e.g., local legislation, economic arrangements, structure of the workforce, institutions, and the political, social, and education systems</td>
<td>Governance and regulations</td>
<td>Interviewees refer to “paper parks” (Participant 23) with a lack of consistent and adequate regulation. “There is no authority here that can supervise and enforce the regulations relating to the park” (Participant 10).</td>
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<td></td>
<td>Stakeholder relations management</td>
<td>The findings highlighted issues arising from conflicting stakeholder relationships between Reef Check DR, the fishers, the spearfishers, and government institutions.</td>
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<td></td>
<td>Tourism destination management</td>
<td>Findings show that (1) tourism numbers have been declining due to the park’s deteriorating infrastructure; (2) the CBET project is not generating income; (3) park users are unwilling to pay the set scuba diving fee; (4) there is no promotional strategy for La Caleta MP; (5) the declining health of the ecosystem deters paying scuba divers.</td>
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<td></td>
<td>Dive center functioning</td>
<td>Interviewees suggest that despite significant investment by Reef Check DR to help the community establish and manage the dive center, the community has not been able to manage it in a way that leads to its success.</td>
</tr>
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<td></td>
<td>Institutional support</td>
<td>Findings showed that while Reef Check DR has provided ongoing support, government institutions are not adequately supporting the project.</td>
</tr>
<tr>
<td><strong>State of Human Health and Well-Being:</strong> includes economic security, life satisfaction, sense of belonging, and safety</td>
<td>Economic needs</td>
<td>The data indicates significant poverty in La Caleta and that the spearfishers poach to support themselves and their families.</td>
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<td></td>
<td>Safety</td>
<td>Findings indicate a lack of safety and security in the park.</td>
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<td></td>
<td>Social cohesion</td>
<td>Interviewees suggest that some people do not denounce poachers because they have a personal relationship with them and are reluctant to let their denouncing affect the social cohesion present between community members.</td>
</tr>
<tr>
<td><strong>State of Ecosystem:</strong> includes built infrastructure and natural ecosystem</td>
<td>Natural environment</td>
<td>Interviewees indicate that La Caleta MP had an abundance of species but overfishing has caused ecosystem decline.</td>
</tr>
<tr>
<td></td>
<td>Built environment</td>
<td>Interviewees indicate the park is currently poorly maintained and has experienced severe deterioration.</td>
</tr>
</tbody>
</table>

Note. (La Caleta) MP = marine park; (Reef Check) DR = Dominican Republic; CBET = community-based ecotourism.  
Source: Authors’ summary.
The cultural adaptation template (CAT)

The CAT works as an influence diagram that captures interactions across the different subsystems of La Caleta MP. A general CAT is presented in Figure 3. Although this is a good starting point, we are also interested in understanding how the high-level aggregate variables interact across the four subsystems. As a result, we have expanded on the generic CAT in Figure 3 to include the high-level aggregate variables present in La Caleta MP and summarized in Table 1. These variables are nested within each of the four subsystems, as illustrated in Figure 4.

In Figure 4, the four subsystems are represented by the bigger circles, with the high-level aggregate variables that constitute them nested within them (refer to Table 1). The curved arrows, labeled as links 1–7, represent the high-level causal links driving state-change processes that impact the overall system (Dyball & Newell, 2015). The interactions of the four subsystems and their aggregate variables through these high-level causal links result in processes that feed back into the system to continue influencing the variables and subsequently the entire system.

These processes are represented in the CAT as Health Effects, Social Effects, Environmental Effects, and Co-Effects (Begossi et al., 2015; Dyball & Newell, 2015). They are all feedback loops with their own states undergoing changes, but are driven by the seven causal links. In doing so, these interactions change the states of the different subsystems and, over time, the entire system of La Caleta MP. The following section provides a detailed explanation of how the seven high-level causal links influence each subsystem and drive the feedback loops that impact them and the aggregate variables within them. These interactions, in turn, influence ecotourism’s capacity to mitigate poaching.
Link 1 (L1) captures how the dominant worldviews and cultural paradigms of La Caleta result in planning and management that drive changes in the State of Community (Begossi et al., 2015). In La Caleta MP, these cultural paradigms relate to traditional livelihoods, environmental concerns, and the attitudes and social norms of the community. In particular, traditional livelihoods are directly related to subsistence fishing. For example, Participant 11 said that fishing is “my sustenance.” The level of concern for the environment also influences people's behaviors, as do attitudes and social norms. In the case of poaching, for example, several attitudes and social norms drive both the prevalence of poaching and individuals’ decisions.
to stop participating in the practice. For example, Participant 10 says “I understand everything with conservation” and that he has stopped poaching, sustaining himself by taking divers out to the reefs, but not channeling the income generated through COOPRESCA, as initially agreed upon with Reef Check DR.

L2 captures the process whereby cultural paradigms evolve as a result of changes and evolutions in the state of the community, which, in the case of La Caleta MP, encompasses several high-level aggregate variables: governance and regulations, stakeholder relations management, institutional support, tourism destination management, and dive center functioning. Together, these categories influence societal roles within La Caleta MP, as well as the political, social, economic, and educational systems. Any changes in specific variables within each of these systems will result in a change in the local State of Cultural Paradigms. Together, L1 and L2 lead to a Social Effects feedback loop that continuously drives adaptive or maladaptive change in both local cultural paradigms and the community itself (Dyball & Newell, 2015).

An example of this is given by Participant 25, who says that because of the education the community received, she was able to “learn about the norms and features of the park more.” She also states some people have stopped fishing because of that education. Participant 4 agrees, saying “now that we understand that it’s a protected area … we have tried to stop fishing.” Another example relates to the low stakeholder collaboration. For example, Participant 23 says “the lack of integration of the community” has led to the dive center’s failure. As a result, Participant 10 states that not even “the people managing the dive center are earning a wage,” affecting the high-level variable of Economic Needs within the State of Human Health and Well-Being subsystem (L3).

L3 captures the activities within the State of Community that affect the State of Human Health and Well-Being. Similar to L2, the five aggregate categories within the State of Community affect human health and well-being. In La Caleta MP, for example, poor enforcement of regulations, bad governance, collusive or conflicting relationships between stakeholders, lack of support from institutions in the form of capital and capacity-building, and mismanagement of the dive center and the tourism destination influence the three categories that make up the State of Human Health and Well-Being. This in turn affects poaching in the marine park. For example, Participant 4 says that people continue to fish because “there is no enforcement” and for “economic reasons.” This low level of enforcement in the State of Community directly influences the economic needs found in the State of Human Health and Well-Being; the less enforcement, the more poaching occurs, which in turn influences fishers’ income.
Meanwhile, L4 captures changes in the State of Human Health and Well-Being that affect cultural paradigms. For example, as economic security increases for some fishers and poaching decreases, observations and assessments are made about the State of Human Health and Well-Being that influence cultural paradigms, with its aggregate variables changing. For instance, traditional livelihoods for some fishers changed to ecotourism. According to Participant 4, “we have benefited directly from the dive center.” However, this is not true across the entire community, as the fishers who derive an income from ecotourism do not evenly share the benefits with the community. This leads to other stakeholder groups, for example, the spearfishers, continuing to fish within the MPA to support their livelihoods. Nevertheless, because of the dive center, attitudes towards ecotourism and poaching for some fishers were also affected, resulting in a change in social norms. These same attitudes led to an acceptance of conservation and some fishers decided to stop fishing inside the MPA. For example, Participant 4 says that “when this project commenced, our methodology was completely changed from being predators to being conservationists.” Combined, L1, L3, and L4 create a feedback loop of Health Effects that may lead to evolution in the State of Cultural Paradigms, as long as L4 remains strong.

In terms of the feedback loop of Environmental Effects, this is caused by L1, L5, and L6. As long as L6 remains strong, this feedback loop can lead to changes within cultural paradigms based on environmental outcomes. In the case of L5, the link represents how individual and collective activities within the community can directly impact the functioning and structure of the State of Ecosystem in La Caleta MP. More clearly, because of changes within the aggregate variables of the State of Community, ecosystem health may improve or decline. For example, stronger enforcement of regulations will lead to increased species abundance. Indeed, Participant 16 says that “the little time I have been involved with this work, I have seen an increase in [species] population.” Further, changes in the aggregate variables with the State of Community also led to an improvement in the park’s infrastructure, and dive center facilities. For example, according to Participant 23, because of the funding that Reef Check DR secured, they were able to “rebuild the office, build bathrooms, and install light bulbs” at the park.

In the case of L6, this link represents how changes in the State of Ecosystem lead to modifications of local cultural paradigms. For example, Participant 16 says she observed “an increase in species abundance” within the park, which in turn increased visitation rates initially. As more people took up the new alternative offering of ecotourism, some fishers shifted from subsistence fishing to ecotourism as their main source of income. Such shifts also caused changes in attitudes and social norms relating to conservation. Some fishers, for example, began to give more value to species when they are alive, rather than when they are caught and sold as food. Unfortunately, over time, enforcement of regulations decreased and community conflicts increased, leading to a decline in both ecosystem health and visitation rates.
Finally, L7 represents how natural processes and environmental conditions affect variables that measure human health and well-being. The health of the fisheries, for example, may directly influence the local community’s economic security. Such influence can be positive or negative, depending on whether stakeholders benefit from ecotourism. In Figure 4, L7 is represented by a dual arrow, namely because in the case of La Caleta MP, changes in the State of Human Health and Well-Being also impact the State of Ecosystem. For example, as tourism increases, it positively impacts on fishers’ economic security as they generate more income from ecotourism activities than they do from fishing. In some individual circumstances, this led to a reduction in poaching and therefore an improvement in ecosystem health. Indeed, a 2019 study assessing coral reef status and trends in the Dominican Republic found that of 12 sites studied, La Caleta MP had the highest coral cover and the highest abundance of parrotfishes (Steneck & Torres, 2019). Granted, unlike fish, corals are not a targeted species in the marine park. Although it seems park management in La Caleta MP positively influences ecosystem health, not all fishers are able to support themselves through ecotourism, forcing some of them to continue fishing illegally in the protected area, influencing the State of Ecosystem.

Together, L1–L5–L7–L4 drive the feedback loop of Co-Effects, which refers to co-benefits as well as co-costs (Dyball & Newell, 2015). It is a cross-sector feedback loop that can lead to cultural adaptation based on how changes in the State of Ecosystem directly affect the health and well-being of the La Caleta community. This effect will, in turn, feed back into the State of Cultural Paradigms. Any changes within the dominant worldview will also lead to improvements or decline in the State of Ecosystem (Begossi et al., 2015). As Participant 4 says, the community’s “methodology was completely changed from being predators to being conservationists” when the project started. However, this is not the case with every stakeholder group, in particular the spearfishers who continue to fish inside the protected area. Nevertheless, according to Participant 27, a spearfisher, “if we were offered a job [in the CBET project], we would stop fishing.”

The problem-space diagram

Having established the CAT to analyze the general interactions present in La Caleta MP, we can use the problem-space diagram to narrow our focus to the three main challenges preventing ecotourism from mitigating poaching in La Caleta MP: (1) the continuation of poaching by the spearfishers, (2) poor dive center functioning, and (3) poor tourism destination management. Each of these challenges are presented as three separate problem-space diagrams in Figure 5, accompanied by the SSoI diagram related to them. While it is possible to use more than one problem-space diagram with a given CAT and more than one SSoI related to each problem space (Dyball & Newell, 2015), this study only uses one SSoI per problem-space diagram.
Figure 5 shows a problem-space diagram for each of the above problem spaces. Here we focus our discussion on Problem Space 2, the functioning of the dive center. We have chosen this focus because our findings suggest that the dive center is the most contentious part of the CBET project. In our wider study we have conducted parallel analyses of all three, but here the analysis of the dive center will illustrate the utility of our proposed method. For example, COOPRESCA’s management of the dive center has resulted in conflicting relationships between different stakeholder groups in the community—namely, the fishers from COOPRESCA, and the spearfishers who are excluded from the cooperative and who thus continue to fish in the protected area. Additionally, the quality of the dive center services is perceived to be poor; an intermediate aggregate variable which has replaced State of Community subsystem in the CAT, as shown in the problem-space diagram in Figure 5(c).
Together, the contentious relationships between the different stakeholder groups and the perceived poor quality of the dive center services limit ecotourism’s capacity to mitigate poaching in La Caleta MP, as income is concentrated in only a few people through the ecotourism offering and, in most cases, the ecotourism business is not channeled through the dive center.

Moreover, a key concern in the diving community is the level of safety and well-being of scuba divers who use the dive center. Safety and well-being is perceived to be extremely low due to the issues raised above. As a result, we have replaced the template variable State of Human Health and Well-Being with the more focused variable Safety and Well-Being. In addition, the perceived low quality of the dive center services influences the Attractiveness of Marine Park. Consequently, we have chosen this variable to correspond to the template variable State of Ecosystem. Finally, our findings reveal that for some community members, capacity-building has had a positive impact on their knowledge and skill development; both necessary to properly manage the dive center. Therefore, we have replaced the state variable State of Cultural Paradigms with the variable Level of Community Education and Training. Now that we have established a problem-space diagram, we can begin to unpack these issues further through the SSoI diagram, shown in Figure 5(f).

**Dive center functioning specific system of interest (SSoI)**

As shown in Figure 5(f), we have now assigned positive polarity to the causal links that make up the dive center functioning SSoI diagram. A causal link with a positive polarity means that as one variable increases or decreases, the second variable changes in the same direction. A negative polarity would indicate that as one variable increases or decreases, the second variable changes in the opposite direction (Proust et al., 2012). The dive center functioning SSoI shows that all the feedback loops are reinforcing, meaning that both negative and positive change continue to be amplified across the system.

The dive center functioning SSoI extracts a specific variable from the problem space, which relates to the quality of the dive center services. Our findings indicate that one of the issues affecting the provision of adequate services is the quality of the dive center’s equipment. Several interviewed scuba divers said they do not feel safe using the equipment, as it is either broken, poorly maintained, or not maintained at all. As Figure 5 shows, a decrease in the quality of the diving equipment will decrease the quality of the diving experience (L5), which in turn will decrease visitor numbers (L7). L3 also shows that visitor numbers are affected by the quality of the diving equipment; as the latter decreases, the former decreases as well.

Additionally, a decrease in the quality of the diving equipment will also decrease the focus on following operational procedures in the dive center, which feeds back to continue propelling the decline of the diving equipment—as the diving equipment
becomes damaged, the fishers who manage the dive center attempt to continue offering the services with improvisations outside the agreed operational procedures—for example, by relying on divers to bring equipment. This reinforcing feedback loop is represented by L1 and L2 in Figure 5(f). If, on the contrary, the focus on following operational procedures in the dive center were to increase, the quality of the diving equipment would increase with it. However, our findings indicate that the fishers responsible for the dive center's functioning are not following procedures agreed upon when the dive center was initially established. Finally, L4 and L6 are shown with positive polarity, expressing that the fishers managing the dive center will learn from experience. That is, as visitor numbers increase—because of higher quality diving experiences and equipment—the community members’ focus on following operational procedures in the dive center will also increase in order to maintain high visitor turnover.

As can be seen, using these templates can help make sense of highly complex systems and the interactions driving change within them. Indeed, the same analysis can be replicated with Figures 5(b), 5(d), 5(e), and 5(g), which represent problem-space and SSoI diagrams for poaching and destination tourism management. Such analysis can help uncover further system behavior, as well as potential leverage points where a small change in one variable can produce big changes across the entire system (Meadows, 1999). In the case of the dive center functioning SSoI, for example, we have identified that improving the quality of the dive center equipment and the focus on following procedures can increase the quality of diving experience and visitor numbers; a potential intervention point for policy-makers and managers.

**Conclusion**

Adequately addressing challenges relating to environmental protection requires a robust understanding of the human–environment interactions present in SES that drive a system’s structure and behavior. Systemic understanding can be quite difficult, though, as systems are inherently complex, ambiguous, and uncertain (Proust et al., 2012). Using a series of well-defined templates can help make sense of that complexity by providing clear guidance on how to analyze such systems.

As can be seen in this case study of poaching in marine reserves, conceptual models and templates such as the CAT can enable a comprehensive understanding of the drivers that perpetuate human–wildlife interactions and which result in ecosystem decline. First, this study used a conceptual model to visualize the entire SES of La Caleta MP, in order to infer general interactions across the different components that make up the system. Second, we used a CAT as a relatively simple way to begin the process of feedback-guided analysis required for systems thinking.
The CAT has already been employed by several authors as a tool to analyze a wide range of issues present in human–environment interactions (Begossi et al., 2015; Davila, 2018; Dyball & Newell, 2015; Proust et al., 2012), allowing researchers to identify the key feedback processes that occur between the higher-level classes of variables present in complex SES (Begossi et al., 2015). Third, we expanded the CAT into problem-space diagrams and SSoi diagrams, which helped narrow the focus to a particular challenge facing our research group (Dyball & Newell, 2015), in this case, poaching. In addition, the SSoi diagram helped us identify specific feedback structures driving systemic change in La Caleta MP, without compromising on the cross-sector interactions occurring between the four subsystems (Dyball & Newell, 2015).

By applying this framework to La Caleta MP, we (1) identified high-level aggregate variables constituting each of the four subsystems, and (2) analyzed how their interactions influence the entire system of La Caleta MP and, as a result, ecotourism’s capacity to mitigate poaching. This approach can be used by managers, policymakers, and stakeholders to influence the system and identify stronger links between ecotourism and poaching mitigation. This preliminary analysis of the interactions represents a significant starting point for further systems thinking analysis. Future research could use causal-loop diagrams to further explain system behavior and identify ways of influencing positive change.

References


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