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RESEARCH ARTICLE

Drivers and potential solutions for transnational Illegal, Unreported and Unregulated fishing (IUU) in the Gulf of Honduras

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Abstract

1. The threat of Illegal, Unreported and Unregulated (IUU) fishing to global fisheries, particularly in lower-income tropical regions, underscores the urgent need for science-based solutions.
2. This study explores the drivers and potential solutions to IUU fishing by Honduran fishers in the Cayman Crown reef, located within the territorial waters of Guatemala and Belize. We integrate science-based and practical, local knowledge through household surveys and stakeholders' workshops, engaging fishers, government agencies and non-governmental organizations NGOs to assess motivations for IUU fishing and possible interventions.
3. Survey results reveal distinct spatial patterns in IUU fishing, with fishers from Omoa and Puerto Cortés being more likely to engage in IUU activities compared to those from Tela. Moreover, 16% of surveyed households reported involvement in Cayman Crown harvesting at some point, confirming previous findings on cross-border IUU fishing in the region.
4. The primary drivers of IUU fishing include the overexploitation of local fish stocks, declining landings (−44%), and economic hardship exacerbated by the COVID-19 pandemic and extreme weather events. In response, stakeholders identified five key themes for potential solutions: governance, capacity building, livelihood diversification, environmental awareness, and bilateral cooperation. Governance, capacity building, and diversification emerged as the most promising solutions, with fishers expressing a strong desire for greater participation in management, training opportunities, and alternative income sources.
5. Synthesis and applications: In summary, our study underscores the vital need for a collaborative, cross-border and inclusive strategy that accounts for the

heterogeneous drivers and solutions of IUU fishing across municipalities and stakeholder groups. Strengthening co-management mechanisms, enhancing capacity building and implementing context-appropriate livelihood diversification initiatives could improve fisheries governance and reduce illegal fishing incentives. Additionally, regional cooperation between Honduras, Guatemala, and Belize is essential to harmonize regulations and enforcement. This study provides a replicable framework for assessing IUU fishing in data-poor contexts and underscores the importance of participatory approaches in fisheries governance to ensure long-term sustainability and the well-being of coastal communities.

KEYWORDS
Cayman Crown reef, diversification strategies, governance, low-income country, small-scale fishery (SSF)

1 | INTRODUCTION

Illegal, Unreported and Unregulated fishing (IUU) is a major global challenge, threatening both the sustainability of marine resources and the livelihoods of millions who depend on fisheries for subsistence and economic stability (Christensen, 2016; FAO, 2022). It is estimated that IUU fishing accounts for approximately 20% of global fish catches (Agnew et al., 2009). The problem is particularly pervasive in low-income countries that depend on fishing for livelihoods and food security (Damanaki & Lubchenco, 2011), often exacerbated by weak governance systems (Salas et al., 2007). In many low-income countries, small-scale fisheries (SSF) dominate the sector, characterized by multi-species, multi-gear approaches that sustain coastal communities (Salas et al., 2007). However, the prevalence of IUU fishing in SSFs is particularly concerning, as these fisheries often lack formal monitoring and management structures, leading to resource depletion and increased vulnerability of fishers (Cinner et al., 2012).

Effective fisheries management requires governance structures that integrate scientific and local ecological knowledge (LEK; Wilson et al., 2006), as well as participatory approaches such as co-management (Jentoft, 1989) and Territorial Use Rights for Fishing (TURF) systems (Quynh et al., 2017). Co-management, which involves shared decision-making between the government and resource users, has been successful in various regions by fostering compliance and improving conservation outcomes (Gelcich et al., 2010). Similarly, TURFs have been implemented as a means to grant exclusive fishing rights to local communities, promoting resource stewardship and reducing overfishing (Gelcich et al., 2019; Viana, 2019). However, despite these advancements, transboundary fisheries remain a significant challenge, particularly when IUU fishing is driven by economic necessity, weak regulations, and geopolitical conflicts (Lindley & Techera, 2017; Petrossian, 2015).

The Gulf of Honduras spans approximately 10,000 km^2 of Caribbean waters across Belize, Guatemala and Honduras (Figure 1). It is a priority area for marine conservation (Heyman & Kjerfve, 2001) and sustains primarily SSF using a multi-gear and species approach (Heyman & Granados-Dieseldorff, 2012) to target species such as snappers and groupers (Perez-Murcia, 2020). Despite historically high landings of approximately US$ 12.7 million (Heyman & Granados-Dieseldorff, 2012), local fishers in the area have reported a continuous decline in catches over the past two decades. This decline is largely attributed to overfishing and IUU (see examples in Baremore et al., 2021; Heyman & Granados-Dieseldorff, 2012; Kramer et al., 2000; Perez et al., 2009). In some cases, IUU fishing has led to escalating conflict between Belize and Guatemala, ultimately leading to confrontations between fishers and military forces (Perez et al., 2009). These challenges illustrate the urgent need for collaborative, transboundary management approaches to address IUU fishing in the region.

One key area of concern is Cayman Crown reef, a transboundary reef system located at the border of Belize and Guatemala, which has been recognized for its high ecological and economic importance (Giro, 2019). This reef is targeted by small-scale Honduran fishers, who travel beyond national waters to fish in foreign territories, largely due to declining fish stocks in their traditional fishing grounds (Perez-Murcia, 2020). To protect this unique habitat and curb IUU fishing, Belize and Guatemala have implemented fishing bans and protected area designations, but IUU fishing continues to be an issue (Rivera, Nuñez-Vallecillo, et al., 2022).

In response to this complex socio-ecological challenge, our study investigates the motivations and potential solutions to IUU fishing by Honduran fishers in Cayman Crown. Using a mixed-methods approach, we conducted 117 household surveys and two workshops conducted in November 2021 and March 2022, involving local stakeholders from key Honduran municipalities engaged in harvesting in the Cayman Crown reef. We aim to identify the socioeconomic drivers of IUU fishing, assess stakeholder perceptions of fisheries governance and management, and explore potential solutions, including strategies for income diversification, capacity building and transboundary cooperation. By integrating local ecological knowledge (LEK) with scientific and policy-based insights, our research

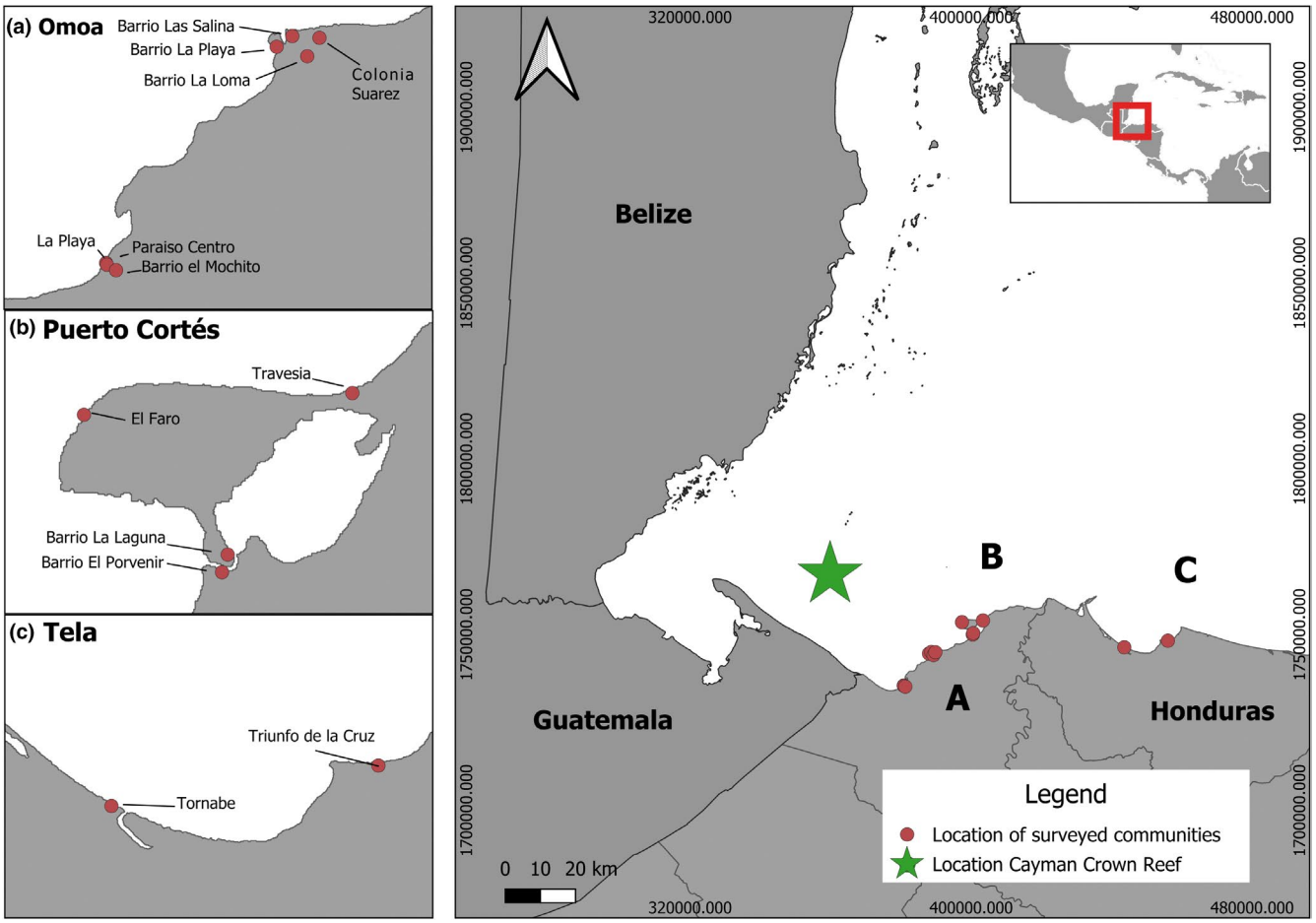

FIGURE 1 Map of the study region: Municipalities of Omoa (a), Puerto Cortés (b) and Tela (c). Red dots indicate the Honduran communities that are known to harvest in Cayman Crown and the green star the general location of the Cayman Crown reef.

contributes to the development of inclusive and adaptive fisheries management strategies that account for the unique challenges of transboundary SSFs in the Gulf of Honduras.

2 | METHODS

2.1 | Study area

The Cayman Crown reef, which straddles the border between Belize and Guatemala, is a unique reef system which boasts over 60% live coral cover (Giro, 2019). It is a high relief spur and groove system within the fracture zone of the Cayman Crown Trench with a vertical relief of up to 32 m (Heyman et al., 2023). Due to its ecological and economic importance, it is protected by both Belize (an expansion of the Sapodilla Cayes marine reserve; Statutory Instrument 107 of 2020) and Guatemala (10-year fishing ban; Ministerial Decree 85–2020). Nonetheless, recent declines in fish biomass have been observed in the area (McField et al., 2022). Furthermore, a great deal of fishing in the area is IUU from small-scale Honduran fishers (Giro, 2019; Perez-Murcia, 2020). Thus, protection efforts could fail if fishing effort from Honduran fishers continues.

2.2 | Household surveys to assess IUU fishing and its causes

We conducted household surveys following the methodology outlined by the Coral Reef Alliance, which has been employed throughout the north coast of Honduras (Rivera, Nuñez-Vallecillo, et al., 2022; Rivera & San Martín, 2019). These surveys were divided into three key sections: (1) Demographic information, (2) Fishing activity and (3) Illegal, Unreported and Unregulated fishing in Cayman Crown. The aim of the survey was to identify the main communities engaged in fishing activities within the Cayman Crown reef and quantify changes in their landings over the past 10 years. A total of 117 surveys were administered across 13 communities in three municipalities of Honduras (Omoa, Puerto Cortés and Tela) from November 16 to December 21, 2022. Prior to their implementation, the surveys underwent piloting with input from three fishers. The full survey is included in Supporting Information (S1).

To assess differences in perceived landings collected from the surveys between 2012 and 2022, we employed R computing software (R Core Team, 2018) to conduct a series of statistical tests on the combined dataset and for each municipality (Omoa, Puerto Cortés, and Tela). Prior to analysis, the normality of the differences

between paired observations was assessed using the Shapiro–Wilk test. As the normality assumption was violated, we used Wilcoxon signed-rank tests as a non-parametric alternative. These tests allowed us to evaluate whether significant differences existed between fish catches in 2012 and 2022 while accounting for the paired nature of the data. Additionally, ties in the data were handled by computing approximate p-values for the Wilcoxon signed-rank tests. To control for the risk of Type I error arising from multiple comparisons, a Bonferroni correction was applied to the pairwise tests for each municipality.

2.3 | Workshop on drivers for IUU fishing

On November 22, 2021, we organized a workshop that brought together fishers ($n = 18$), government agencies ($n = 2$) and representatives from non-governmental organizations ($n = 11$ participants from 8 different organizations) from three municipalities (Tela, Omoa, and Puerto Cortés). The workshop was designed to gather detailed insights into the factors contributing to the decline in catch in the region. Participants were randomly divided into six focus groups, and discussions revolved around changes in landings and the impact of the COVID-19 pandemic (refer to Supporting Information for focus group questions, S2 and S3). Following the focus group sessions, each group presented a summary of their findings to all participants, sparking a broader group discussion.

2.4 | Workshop on potential solutions to IUU fishing

On March 4, 2022, we organized a second workshop involving key actors to discuss potential solutions to IUU in Cayman Crown from Honduras fishers. The participants included fishers ($n = 5$) government agencies ($n = 5$) and NGOs ($n = 14$) from three municipalities (Tela, Omoa and Puerto Cortés). In this paper, 'stakeholder organizations' refers to local non-governmental organizations (NGOs), co-managers of protected areas and government agencies involved in fisheries management and marine conservation. Fishers were selected based on specific criteria: (1) active involvement in fishing as their primary livelihood, (2) membership in a fishers' association and (3) recognition as community leaders. During this workshop, participants received information about the Cayman Crown reef and the socioeconomics of Honduran communities operating within the region. They were divided into four focus groups: (1) Fishers from Omoa and Puerto Cortés, (2) Fishers from Tela, (3) Stakeholder organizations (government and NGOs) from Omoa and Puerto Cortés and (4) Stakeholder organizations (government and NGOs) from Tela. Within these focus groups, participants engaged in discussions concerning strategies to enhance the sustainability of Honduran communities involved in Cayman Crown harvesting (refer to Supporting Information for focus group questions, S2 and S3).

2.5 | Workshop data analysis

Both workshops were conducted through online platforms due to COVID-19 restrictions in Honduras, and comprehensive recordings were made. Subsequently, all workshop sessions were transcribed, and for the second workshop, five key themes on potential solutions were extracted from the discussions. The frequency of mentions for each key theme was assessed across different stakeholder groups, including fishers and stakeholder organizations from Omoa, Puerto Cortés and Tela. To ensure impartiality, two different reviewers independently reviewed the videos and transcriptions. Average mention counts were calculated for each theme by group and reviewer, and a semi-quantitative data analysis was performed using R computing software (R Core Team, 2018). Additionally, direct quotes representing the perspectives of participants were extracted and categorized under each theme. These quotes were included to enrich the analysis and highlight the nuanced differences between stakeholder groups.

Research involving human participants in this study was conducted in strict adherence to ethical standards and regulations. Ethical approval for this research was obtained from the Mesoamerican Reed Fund following the safeguards in their Environmental and Social Management System (ESMS; https://marfund.org/en/esms/#Safeguards), which aims to maximize benefits to the environment and communities while minimizing and mitigating any potential negative impacts.

Informed consent to participate in the study was obtained from all human participants, who were all above the age of 16. Written consent was not obtained because some interviewees were unable to read and write. To ensure inclusivity and full participation, verbal consent was used instead. Participants were explicitly informed that their personal information, including names, would be kept confidential, securely stored and used only as necessary during data collection. Additionally, consent for publication was obtained to ensure that individuals' identities remain protected. Moreover, this study adhered to the data sharing policy of the Coral Reef Alliance, which maintains the secure handling of personal identifiers and ensures that such information is not publicly disclosed or shared.

3 | RESULTS

3.1 | General information from the household surveys

A total of 117 household surveys were carried out in 13 communities, which were traditionally known to harvest illegally in Cayman Crown. Demographic results varied greatly among communities. The percentage of women head of household ranged between 0 and 100%, and was generally higher in Tela Bay and in Omoa. Additionally, the percentage of households which relied on fishing as their livelihood or main source of subsistence also ranged between 0% and 100%, where Barrio La Loma and Paraíso Playa relied

TABLE 1 Summary of household survey data collected across three municipalities (Omoa, Puerto Cortés and Tela) in the Gulf of Honduras.

Municipality	Community	Number of surveys	Percent by age range			Percent women head of household	Percent of fishing households
			20–35	36–55	>55		
Omoa	Barrio El Mochito	5	40	40	20	40	60
	Barrio la Loma	1	100	0	0	0	100
	Barrio La Playa	5	20	40	40	0	80
	Barrio Las Salinas	4	0	50	50	25	50
	Colonia Suarez	1	0	100	0	100	0
	Paraiso Centro	4	25	75	0	75	25
	Paraiso Playa	4	0	75	25	0	100
Puerto Cortés	Barrio La Laguna	19	31.6	47.4	21.1	26.3	52.6
	El Faro	17	17.6	29.4	52.9	17.6	58.8
	El Porvenir Mercado	9	22.2	33.3	44.4	11.1	55.6
	Travesia	1	0	100	0	0	0
Tela	Tornabe	20	30	60	10	70	40
	Triunfo de la Cruz	27	48.1	29.6	22.2	29.6	55.6

Note: The table includes the number of household surveys conducted in each community, the percentage of respondents within specified age ranges, the percentage of women who are heads of households, and the percentage of households with a relationship to fishing activities. Age ranges reflect the demographic composition of surveyed households, while the relationship to fishing refers to households engaged in or dependent on fishing for livelihood or subsistence.

completely on fishing in contrast to Colonia Suarez and Travesía, which had no reliance on fishing. Based on this information, the municipality with the highest reliance on fishing was Omoa (Table 1).

3.2 | IUU fishing and its perceived causes

Our survey results reveal distinct patterns of Illegal, Unreported and Unregulated (IUU) fishing in the Gulf of Honduras, particularly within the municipalities of Omoa, Puerto Cortés and Tela. Fishers from the Omoa and Puerto Cortés municipalities exhibited a higher propensity to engage in IUU activities within the Cayman Crown region when compared to their counterparts from Tela; 77%, 75% and 0% of fishers indicated that part of their harvest came from Cayman Crown, respectively. Additionally, 69% of Omoa fishers and 54% of Puerto Cortés fishers indicated that the closure would impact them personally whereas none of the Tela fishers believed it would impact them. Notably, specific communities such as La Playa, Las Salinas, La Laguna and El Mochito had a small subset of fishers exclusively involved in Cayman Crown harvesting (Figure 1). However, this exclusive group accounted for only 5% of all surveyed households. Moreover, a 16% of all households reported an involvement in Cayman Crown harvesting at some point in the past. Additionally, 90% of the fishers that reported carrying out IUU fishing in Cayman Crown indicated that their main target is snappers, particularly Yellowtail snapper (*Lutjnaus synagris*) and 95% indicated that their main gear was hook and line.

The survey data also indicated a perceived decline in fish landings from 2012 to 2022 across all municipalities. Based on the average percent change perceived in catches in each municipality, Tela experienced a significant decrease of 43.2%, while Omoa saw a moderate reduction of 12.3% and Puerto Cortés endured a substantial decline of 65.3% (Figure 2). These decreases were statistically significant for the combined data (Wilcoxon signed-rank test, $p < 0.0001$) and exclusively for Puerto Cortés (Wilcoxon signed-rank test, $p = 0.001$). Nonetheless, the decreases in Tela and Omoa were not significant after applying a Bonferroni correction for multiple comparisons (Wilcoxon signed-rank test, $p = 0.31$ and $p = 0.29$, respectively).

3.3 | Drivers of IUU fishing

Fishers' perceptions on the decrease in landings were confirmed in the first workshop (Table 2). All participants agreed that fishing resources had significantly declined, with a perceived decrease in landings of up to 70%, and that the size of fish caught has decreased as well. These declines were attributed to overfishing and destructive fishing practices that inevitably led to environmental degradation (Table 2). The decline in commercial species, especially groupers (Serranidae) and snappers (Lutjanidae), which according to surveys were the target species for IUU fishing in Cayman Crown by many fishers, led them to fish further away from their usual fishing grounds. The fishers reported travelling up to 4 h and 24 nautical miles out at sea due to the declines (Table 2).

In addition to the decline in fish stocks, the COVID-19 pandemic greatly impacted the commercialization of their catches, with many of their main buyers, such as supermarkets and restaurants,

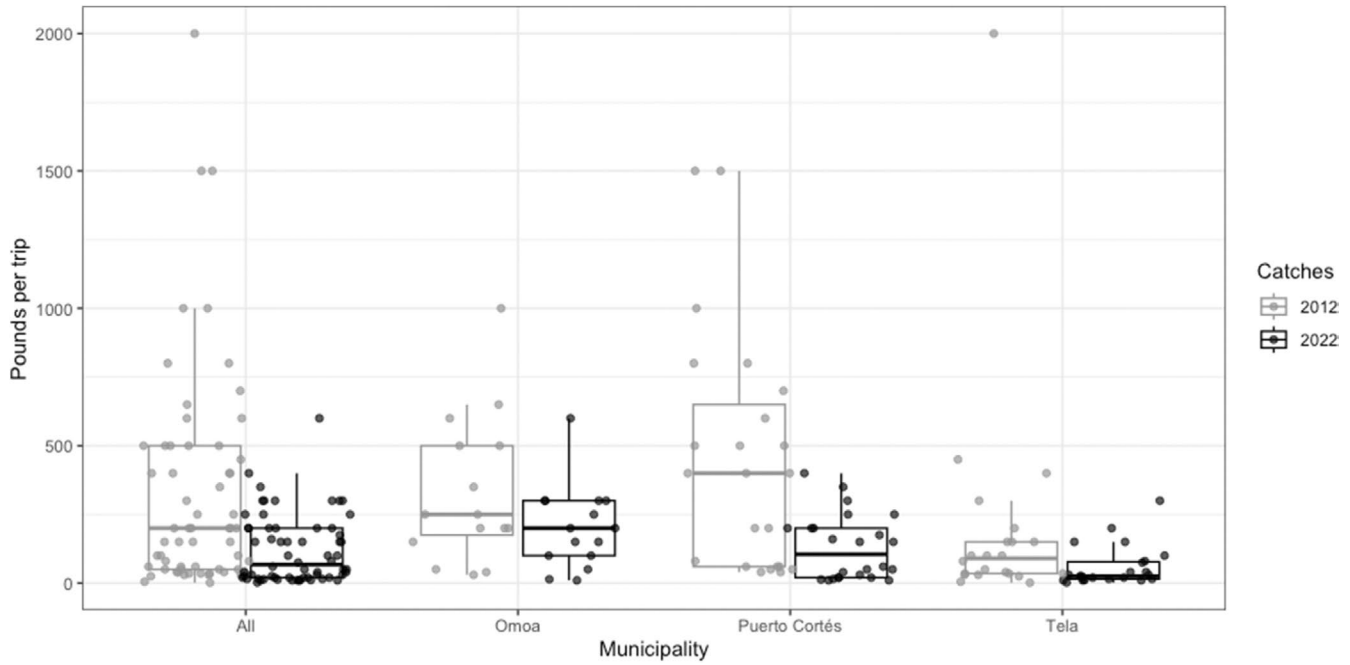

FIGURE 2 Box plots showing the distribution of pounds of fish caught per trip across Honduran municipalities and for all data combined (labelled 'All'). The central line within each box represents the median value, while the edges of the box indicate the first (25th percentile) and third (75th percentile) quartiles, showing the interquartile range (IQR). Whiskers extend to the smallest and largest values within 1.5 times the IQR from the lower and upper quartiles, respectively, highlighting the spread of the data. Individual points represent raw data values and provide insight into the variability within each group. Colours distinguish catches from 2012 (grey) and 2022 (black).

closing. Fishers' reported up to 3000 lbs. per trip being lost due to this situation (Table 2). This has led to fishers losing their markets and being forced to rely on subsistence fishing. Furthermore, the tropical storms Eta and Iota, which hit in November 2020, caused damage to the fishers' gears, equipment and vessels. In response, fishers have had to adopt novel, local distribution pathways, such as door-to-door and phone sales, to sell their landings. Finally, due to all these cumulative factors, fishers reported a lack of profitability in fishing which has led them to diversify their livelihoods and migrate to other areas (Table 2).

3.4 | Potential solutions to IUU fishing

In the second workshop, potential solutions identified in both the focus groups and general discussions focused on five key themes: (1) Governance, (2) Diversification, (3) Capacity building, (4) Environmental awareness and (5) Bilateral cooperation. Table 3 provides descriptions, topics encompassed by each theme and direct quotes from the workshop relating to each theme. In general, the governance theme related to increasing community participation in management through outreach, collaboration and empowerment as well as reducing threats and improving protection of natural resources (Table 3). Diversification regarded diversifying options both within (gears and target species) and beyond the fishery (new livelihoods; Table 3). Capacity building was mentioned in relationship with all other themes and centered on enhancing fishing communities' knowledge and skills of the fishery, natural resources and other livelihoods (Table 3). The environmental awareness theme focused on generating knowledge on the status of the resource, the existing management policies and their expected outcomes (Table 3). Finally, the bilateral cooperation theme emphasized the importance of collaboration and communication among all affected countries. Specifically, it highlighted the need to involve Honduras in the development and enforcement of regulations, acknowledging that, although the Cayman Crown reef lies outside its territorial waters, this IUU fishery remains a source of income for Honduran fishing communities.

When analysing percentage of mentions for each theme per group, we notice that there is a high heterogeneity among groups (Figure 3). Nonetheless, the theme with the most mentions by most of the groups (with the exception of Tela fishers) was governance, they all agreed they wanted a seat at the table and have their voices heard. In fact, the fishers from Omoa and Puerto Cortés mentioned that they are not organized and lack representation when government decisions are made and the stakeholder organizations mentioned "They must be involved in decision-making and the creation of regulations. If they see the benefits, it will be easier to raise awareness and make them part of the process." when talking about the fishers. The second most mentioned theme was capacity building. The fishers mentioned a lack of training opportunities which was also observed by the stakeholder organizations a local NGO member mentioned "We need to train people in topics related to the activities they already perform because many times projects or

TABLE 2 Summary of key themes and findings from the first workshop discussions with fishers from Omoa, Puerto Cortés and Tela.

Theme	Summary of findings	Direct quotes	Observations
Fishing practices	Fishing is passed down through generations, often from fathers or uncles	"My father taught me to fish with handlines. It's what we've always done."	Older fishers are more dependent on traditional methods, while younger generations are losing interest
Decline in fish stocks	Fish stocks have declined by 60%–70%, especially for groupers and other commercial species	"Groupers used to be abundant. Now the younger generation doesn't even know them."	Decline attributed to overfishing, destructive gear (nets, diving), and coral damage
Travel distance for fishing	Fishers now travel 3–4 h to reach productive fishing grounds, increasing costs and time at sea	"We used to fish near the coast. Now we go 24 nautical miles out."	Increased distance is leading to higher expenses and physical strain for fishers
Economic challenges	Fishing is no longer profitable, with catches barely covering costs	"Fishing doesn't provide hope for future generations."	Many fishers are seeking to diversify their livelihoods or migrating for better opportunities
COVID-19 impacts	Sales and distribution were disrupted, leading to significant economic losses	"We lost about 3000 lbs. of product during Easter because everything was closed."	Many turned to door-to-door sales or donated unsold fish to avoid complete loss
Environmental degradation	Coral reefs and coastal ecosystems are severely degraded, impacting fish availability	"The reef is in terrible condition, and there are barely any fish left near the coast."	Degradation attributed to illegal gear use, pollution, and lack of enforcement
Future concerns	Many expressed concerns that fish stocks may collapse within 5 years if overfishing continues	"If things don't change, there won't be any fish left for the next generation."	Calls for stricter enforcement and education on sustainable practices were common

Note: The table includes synthesized qualitative results categorized into themes. Each theme is supported by a summary of findings, direct quotes from participants and relevant observations to provide context. Quotes illustrate the perspectives and experiences of fishers, while observations highlight broader implications for fisheries management and sustainability in the Gulf of Honduras.

alternatives are presented to them, but it is not what they want or have the capacity to do." (Table 3).

The stakeholder organizations noted that overexploitation of local fishing stocks is the main driver of IUU fishing and that a lack of information on fish landings from SSF in the region hinders efforts to address this issue. They believe that monitoring will be key in addressing overexploitation. Additionally, they identified the need to increase environmental awareness on the current status of the fishery and the impacts of protection of Cayman Crown. The stakeholder organizations emphasized the importance of incorporating fishers in the decision-making process. However, they mentioned that bilateral cooperation between the Honduran government agencies and the Guatemalan and Belizean governments in the Gulf of Honduras is currently scarce. In fact, members of the Honduran government mentioned "We need to improve communication between the authorities of the countries involved, as there is currently no coordination between the authorities of Belize, Guatemala, and Honduras, nor with the fisheries institutions. Monitoring efforts and enforcement are critical, but the lack of communication hinders their effectiveness.". The stakeholder organizations suggested that involving Honduran authorities in meetings, law enforcement, and the creation of laws could greatly reduce IUU fishing by stopping it before it happens. It is important to highlight that bilateral cooperation was primarily mentioned by the stakeholder organization, whereas fishers mentioned it much less frequently (Figure 3).

According to fisher groups, governance, capacity building and diversification are the main potential solutions to the problem of fisheries overexploitation (Figure 3). As previously mentioned, the fishers stressed that small-scale fisheries are often neglected, and they do not have a voice in the decision-making. They want to see an increase in community participation in fisheries management and greater collaboration between the government and fishing communities. The fishers' mentioned "If we were involved in the decision-making process, it would be easier to follow the regulations because we would understand the reasons behind them." Furthermore, fishers believe that they have not received enough environmental education to truly understand the root of the issue. This was particularly mentioned for younger fishers, the fishers mentioned "We need to raise awareness, especially among younger generations, so they understand that if they continue fishing without regulations, there will be no fish left in the future." (Table 3). Thus, training on environmental responsibility, fund acquisitions, and team building was mentioned as necessary. In addition, fishers expressed interest in developing new livelihood diversification projects, such as tourism, fish processing, crafts, restaurants, and agriculture. However, the fishers mentioned that fishing is a part of their identity and that they are not willing to give up fishing altogether despite it not being profitable.

In the joint discussion, participants reiterated the importance of governance, capacity building, and livelihood diversification as potential solutions. They emphasized the need for all stakeholders to be included in the decision-making process and for the dissemination of information on the status of the reef and fisheries to a wider audience. To start participants agreed that, building technical

TABLE 3 Summary of key themes identified during the second stakeholder workshop related to potential solutions to IUU fishing from Honduran fishers in Cayman Crown.

Theme	Description	References	Topics	Direct quotes
Governance	"The interactions among structures, processes and traditions that determine how power and responsibilities are exercised, how decisions are taken, and how citizens or other stakeholders have their say."	Taken directly from Graham et al. (2003)	Improving outreach Collaboration Empowering the SSF sector Environmental committees Patrols and enforcement Monitoring Rules and norms Reducing threats to SSF	"The decisions are made outside the community, and people who are not involved in fishing become partners without understanding the issues and the work involved in fishing."
Diversification	Promoting diversified livelihood options, both within and beyond the fishery, to reduce dependency on fishing as the primary source of income, while encouraging fishing strategies that utilize a variety of areas, species, and gears to minimize risks and enhance resilience	Charles (1994) Hilborn et al. (2001); Minnegal and Dwyer (2008) and van Oostenbrugge et al. (2002)	Diversifying livelihoods (e.g. tourism, fish processing) Diversifying gears (e.g. nets) Diversifying species (e.g. bivalves). (2002)	"We see an opportunity in tourism, especially activities like snorkelling, diving, and sport fishing, but we lack the training and resources to begin these projects."
Capacity building	Development of conditions that allow fishery stakeholders to generate new or enhance existing knowledge or skills that will promote the sustainability of a fishery	Seijo and Salas (2014) and United Nations Development (2007)	Support with economic factors (e.g. markets and value chains) Support with social factors (e.g. socializing norms) Support with environmental responsibility (e.g. incorporating fishery management tools)	"There are no training opportunities for fishers and divers, which means they often don't understand the damage they can cause."
Environmental awareness	Ability to understand the state of the environment and show concern in the relationship between humans and the environment; this knowledge can be provided through formal and nonformal education processes	Nurhayati et al. (2020) and Yeung (1998)	Direct impacts of the new MPA Indirect impacts of the new MPA Positive impacts of the new MPA (e.g. spill over) Negative impacts of the new MPA	"The state of the fishing resource has declined, and efforts are needed to raise awareness, especially among younger generations."
Bilateral cooperation	Cooperation among countries for the management of marine resources, by establishing joint management, legal and scientific frameworks for the exploitation of marine resources	Gullett (2020); Hey (1989) and McDorman (2008)	Regional consensus to generate new norms and rules Regional consensus to enforce new norms and rules	"We need a trinational alliance to unify regulations and establish closed seasons agreed upon by the three countries."

Note: Each theme includes a description, relevant literature references, associated topics and direct quotes from participants during the workshop. Direct quotes reflect the perspectives and experiences of workshop participants, providing qualitative insights into the issues and proposed solutions.

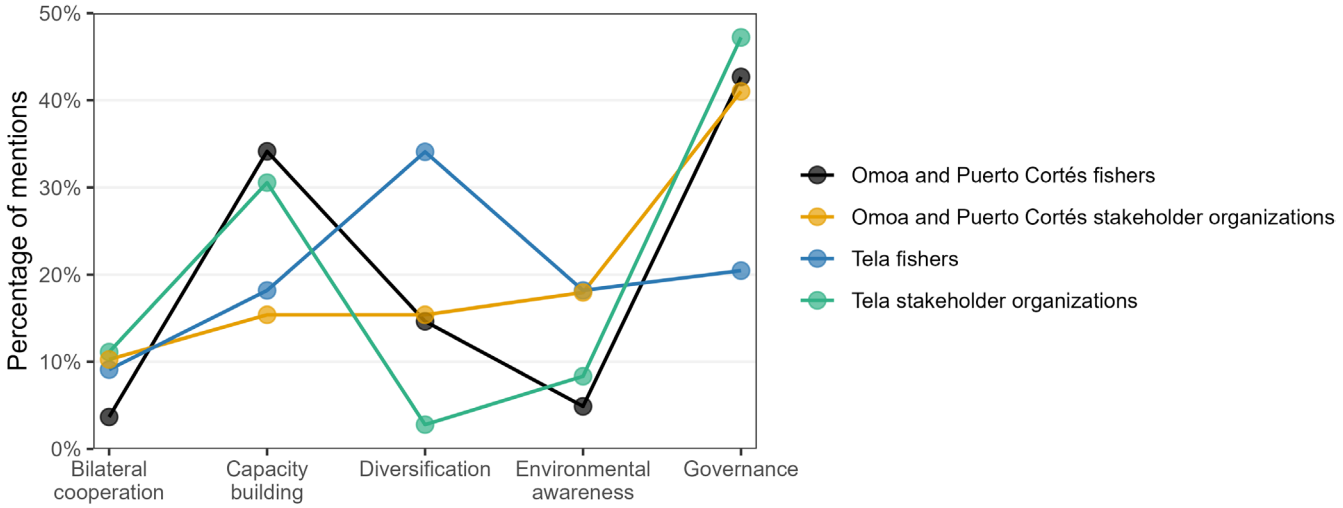

FIGURE 3 Percent of mentions for each of the 5 key themes (Governance, Diversification, Capacity building, Environmental awareness and Bilateral cooperation) by different stakeholder groups during the second workshop. These groups include fishers from Omoa and Puerto Cortés (black line), stakeholder organizations from Omoa and Puerto Cortés (yellow line), fishers from Tela (blue line) and stakeholder organizations from Tela (green line). Each data point represents the percentage of total mentions for a given theme within the respective stakeholder group, highlighting the variation in priority and emphasis among different groups.

and financial capacities in fishers' associations is a critical first step a fisher mentioned "We need alliances with different organizations to secure funding for alternative livelihoods. Otherwise, people will just keep fishing because they have no other options.". This was considered particularly important since the participants acknowledged that fisheries in the region tend to fluctuate.

4 | DISCUSSION

This study revealed notable patterns of IUU fishing in the Mesoamerican reef region, with fishers from Omoa and Puerto Cortés municipalities being more likely to engage in IUU activities in the Cayman Crown reef compared to those from Tela. Moreover, a 16% of all households reported any involvement in Cayman Crown harvesting at some point in the past, consistent with earlier findings documenting IUU fishing by Honduran fishers in the same region (Perez-Murcia, 2020; Rivera, Nuñez-Vallecillo, et al., 2022). Additionally, fishers reported a sharp decline in fish landings over the past decade, driven by overfishing, environmental degradation and economic challenges exacerbated by the COVID-19 pandemic and tropical storms. Through stakeholder workshops, five key themes emerged as potential solutions: governance, capacity building, diversification, environmental awareness and bilateral cooperation. These findings address a critical gap in understanding the drivers and potential solutions of IUU fishing in the Gulf of Honduras and provide insights into the heterogeneous challenges and solutions that differ among municipalities and stakeholder groups, offering a framework for inclusive and collaborative management approaches in similar tropical low-income nations.

Governance emerged as the most frequently mentioned theme among all stakeholder groups during the workshops, highlighting the importance of incorporating fishers and other stakeholder groups in fisheries management. While community participation in fisheries management has been scarce in Honduras (Luttinger, 1997), there are positive steps toward greater inclusion. For example, the recognition of co-management in the new Honduran Fisheries and Aquaculture Law (Decree 106–2015) demonstrates progress in involving local communities in the decision-making process. Successful examples of community participation in fisheries management have been documented in the region, particularly in the context of SSF. Initiatives such as the Tela Bay fisheries co-management system (Rivera et al., 2021), the Los Micos lagoon Territorial Use Rights for Fishing (Rivera, San Martin-Chicas, et al., 2022) and the Belizean Fishery co-management (Granados-Dieseldorff et al., 2013) and managed access systems (Wade et al., 2019) have shown that including fishers in the decision-making process can lead to better governance and conservation outcomes in protected areas (Fidler et al., 2022).

Building on the importance of governance, livelihood diversification emerged as another key theme for addressing overexploitation and enhancing the resilience of fishing communities. Our results show that Tela fishers, who have greater involvement in informal co-management agreements (Rivera et al., 2021), are more open to reducing overexploitation and engaging in livelihood diversification options compared to fishers from Puerto Cortés or Omoa (Figure 3). Encouraging fisher groups to perceive the need for diversification and fostering their willingness to shift toward more sustainable livelihoods is crucial. While livelihood diversification projects have been suggested as a way to increase income and reduce environmental impacts (Roe et al., 2015; Wright et al., 2016), their success has often been questioned (Noss, 1997; Wright et al., 2016). Importantly, fishers in this and previous studies have emphasized that fishing is a part of their identity and that

they are not willing to give up fishing altogether despite it not being profitable (Rivera et al., 2021; San Martin-Chicas et al., 2021). As such, livelihood diversification options should be compatible with fishing and aligned with their current lifestyles. Ecotourism, handiwork and other community-based initiatives, such as guided tours and handicrafts, have been identified as promising livelihood diversification strategies for coastal communities (McPherson, 2008). These activities not only reduce pressure on fish stocks but also provide alternative sources of income that align with the fishers' cultural and social values. However, the success of such initiatives requires careful planning and the involvement of all sectors in the decision-making process. Equitable distribution of benefits is essential to prevent issues of inequity and marginalization that have hindered past efforts (Moreno, 2005). By ensuring that livelihood diversification projects are inclusive, participatory, and tailored to the unique needs of fishing communities, they can serve as a vital tool for reducing overexploitation and enhancing the sustainability of fisheries in the Gulf of Honduras.

Capacity building emerged as a central theme in the discussions, with both fishers and stakeholder organizations emphasizing the need to enhance technical and financial capacities within fishing communities. Encouragingly, fishers recognized the need for capacity building, which is a promising development since such initiatives cannot be effectively driven from the outside (United Nations Development, 2007). Similar training initiatives have been suggested for other transboundary fisheries to address challenges such as resource depletion and management complexities (Mackett, 1985; Mukasa et al., 2006). Successful examples from the region strategies such as fishery management plans (Rivera, 2018) and fish recovery zones (Green et al., 2017) were cited as useful examples. These initiatives highlight the importance of equipping fishers and local organizations with the necessary skills, knowledge and tools to actively participate in sustainable fisheries management and ensure compliance with established regulations. While education alone may not address all challenges associated with sustainable fisheries management, capacity-building initiatives that integrate education with practical skill development, such as fund acquisition and team building, are essential. These initiatives should be paired with inclusive governance structures that foster shared responsibility among fishers, local organizations and government agencies, reducing the risk of misplaced blame and ensuring compliance with regulations.

Environmental awareness complements these efforts by fostering an understanding of the connections between resource use and ecological health. While environmental awareness is believed to be mostly present in areas with high socioeconomic development, where stakeholders can focus on such issues once their basic needs are met (Duroy, 2005), participants from the Gulf of Honduras emphasized its importance as a potential solution even in low-income communities. They highlighted the need for targeted communication strategies which could involve partnerships with the tourism and media sectors (Holt & Barkemeyer, 2012) or leverage social media campaigns (Wu et al., 2018), to raise awareness about sustainable practices and the long-term benefits of diversification. By integrating environmental awareness into capacity-building initiatives and livelihood diversification efforts, communities can ensure that economic objectives are met without compromising ecological sustainability.

While local governance, capacity building and diversification are crucial steps, addressing the transboundary nature of IUU fishing in the Gulf of Honduras requires regional collaboration. Currently, each country enforces its own measures to regulate fishing activities, such as seasonal bans, size limits and gear restrictions, but these regulations are often developed and implemented independently, leading to inconsistencies that can be exploited by fishers operating across borders (Martinez, 2007). Regional management is also necessary, as previous studies in the region have concluded (Heyman & Granados-Dieseldorff, 2012). A successful example of such coordination is the unified lobster bans under the SICA regulations (Sistema de la Integración Centroamericana (SICA), 2009), which demonstrate how collaborative management can lead to more effective conservation outcomes. Similarly, unified legislation for Cayman Crown fisheries could be key in reducing IUU fishing. While each country has individual conservation efforts, a lack of joint enforcement and harmonised policies creates gaps in regulation that undermine these measures. Empowering existing bridging organisations, such as the Tri-National Alliance for the Conservation of the Gulf of Honduras (TRIGOH), could help unify legislation and facilitate cross-border enforcement, fostering a more integrated and cooperative approach to fisheries management in the region.

It is important to acknowledge that all data presented in this study are based on self-reported information and stakeholders' perceptions, which may introduce biases inherent to perception-based research (Sui & Humphreys, 2017). However, given the data-poor nature of small-scale fisheries in the Caribbean, particularly within the Mesoamerican Reef region (Dunn et al., 2010; Salas et al., 2007), this study provides a valuable first step in disentangling the intensity, drivers, and potential solutions for IUU fishing in Cayman Crown. Previous research has shown that perception-based data can be a useful tool for understanding long-term changes in fisheries when empirical catch records are scarce (Gelcich & O'Keeffe, 2016). While this approach offers important insights, continuous monitoring of SSFs remains essential for developing effective management tools, detecting fishing impacts on biodiversity (Branch et al., 2010), identifying overexploitation, and enhancing enforcement (Salas et al., 2011). Moreover, participatory monitoring efforts and citizen science initiatives have been shown to empower local communities and enhance compliance with conservation measures (Fulton et al., 2019). Therefore, while the findings of this study provide a critical foundation for addressing IUU fishing in the region, they should be complemented with ongoing fisheries monitoring efforts to refine management interventions and ensure long-term sustainability.

5 | CONCLUSION

IUU fishing is a serious threat to both the livelihoods of coastal communities and the sustainability of fishing resources. This problem is

especially prevalent in Honduras, where overexploitation of local fish stocks has led fishers to an increased risk of IUU fishing, such as the fishing done in the Cayman Crown reef by Honduran fishers. Our study provides a novel contribution to the understanding of IUU fishing by examining its cross-border nature in a tropical, low-income region. The results highlight how fisheries management must account not only for the country where the fishery is located but also for neighbouring countries that contribute to both exploitation and enforcement challenges. This underscores the need for coordinated regional management strategies.

Through household surveys and stakeholder workshops, we identified five key themes as potential solutions to IUU fishing, including governance, diversification, capacity building, environmental awareness and bilateral cooperation. Among these, capacity building, governance, and livelihood diversification were identified as the most pressing priorities. A key finding of our study is the heterogeneity of IUU fishing drivers and solutions across different municipalities and stakeholder groups. Fishers in Tela, who have greater involvement in informal co-management agreements, appeared more open to diversification efforts than those in Puerto Cortés or Omoa, suggesting that increasing participation in fisheries governance can facilitate a shift toward sustainable livelihoods. Similarly, stakeholder organizations emphasized the need for stronger collaboration between countries in managing shared resources, as fragmented enforcement and independent national regulations have created regulatory gaps that allow IUU fishing to persist.

This study fills a critical gap in research by providing a replicable methodology for assessing IUU fishing, its drivers, and potential solutions in data-poor contexts. By integrating a scientifically rigorous yet inclusive approach, this research ensures that all stakeholder groups—particularly marginalized ones—are actively engaged in the process. This participatory approach strengthens the relevance of the findings while also building local capacity and trust, both of which are crucial for effective implementation of conservation and management measures.

Despite these contributions, several knowledge gaps remain. The reliance on self-reported data, while useful for capturing stakeholder perceptions, necessitates further validation through long-term monitoring of small-scale fisheries in the region. Improved fisheries data collection is essential to refine estimates of IUU fishing intensity and better assess the effectiveness of proposed interventions. Additionally, while this study highlights the need for cross-border collaboration, further research is needed to explore how governance frameworks can be harmonized across Belize, Guatemala and Honduras to create more cohesive and enforceable management strategies.

Future studies should build upon these findings by investigating the socioeconomic and ecological impacts of implementing co-management, livelihood diversification, and enforcement strategies. Understanding how these interventions influence fishers' behaviours and the sustainability of marine resources over time will be essential for designing adaptive and long-term management solutions. Ultimately, the success of these efforts will depend on the continued engagement and collaboration of all stakeholders—inclusive of fishers, NGOs, government agencies and regional organizations—working together to ensure the sustainability of fisheries and the well-being of coastal communities.

AUTHOR CONTRIBUTIONS

Antonella Rivera and Stuart Fulton conceived the ideas and designed the methodology; Antonella Rivera, Mayra Núñez-Vallecillo, Julio San Martín-Chicas and Paolo Guardiola collected the data; Antonella Rivera and Ricardo González-Gil analysed the data; Antonella Rivera led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest related to this research, its findings or its publication.

DATA AVAILABILITY STATEMENT

Due to ethical considerations and confidentiality agreements with participants, the data supporting this study cannot be publicly archived. However, data are available upon reasonable request by contacting info@coral.org, subject to approval and in accordance with the ethical protocols governing this research.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Supporting Information S1. Household survey questions.

Supporting Information S2. Focus group questions first workshop.

Supporting Information S3. Focus group questions second workshop.

Supporting Information S4. Graph detailing the total number of mentions for each of the five themes (Governance, Diversification, Capacity Building, Environmental Awareness and Bilateral Cooperation) within the four focus groups.

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