



SUPPLEMENT

<https://doi.org/10.15517/hn8kwk57>**Fishers' Knowledge Reveals Spatio-Temporal Dynamics of Billfish Sport and Tourist Fisheries on the Pacific Coast of Costa Rica**Daviana Berkowitz-Sklar^{1, 2 *}; <https://orcid.org/0009-0005-7682-4641>Henry Marín Sandoval³; <https://orcid.org/0009-0001-4023-3648>Danielle Bates⁴; <https://orcid.org/0000-0003-0691-0278>Hannah Blondin⁵; <https://orcid.org/0000-0002-9607-6098>Michelle María Early Capistrán⁶; <https://orcid.org/0000-0003-2626-9262>Oswald Schmitz¹; <https://orcid.org/0000-0003-1515-2667>Larry B. Crowder⁶; <https://orcid.org/0000-0003-3131-2579>

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ABSTRACT

Introduction: Addressing ecological and social knowledge gaps is essential for the sustainable management of recreational fisheries. Costa Rica is internationally recognized as a premier sport fishing destination, particularly for billfish such as sailfish (*Istiophorus platypterus*) and blue marlin (*Makaira nigricans*). Despite their socio-economic importance, major knowledge gaps remain in the dynamics of sport and tourist fisheries, hindering effective management. Fishers involved in tourist and sport fishing can provide valuable social-ecological insights into their fisheries and target species.

Objectives: This paper seeks to identify the spatio-temporal patterns of billfish sport and tourist fishing activity along the Pacific coast of Costa Rica and to assess regional differences shaped by social and ecological factors, drawing on the knowledge and perceptions of fishers.

Methods: We conducted semi-structured interviews with sport fishing captains (n=62) from private and charter operations across eight Pacific coast communities: Golfito and Puerto Jiménez in the Southern Pacific (n = 14); Quepos and Herradura in the Central Pacific (n = 34); and Tamarindo, Flamingo, Cuajiniquíl, and El Jobo in the Northern Pacific (n = 14). Interviews included a participatory mapping activity to identify key fishing grounds for sailfish and blue marlin, along with a standardized questionnaire on fisher demographics, fishing seasonality, billfish and non-billfish species caught on the most recent trip (and their reported abundance), offshore distances of their most recent trip, and changes in fishing equipment and technology over time.

Results: Analyses of fisher responses revealed nearshore fishing hotspots within 60 nautical miles of the Pacific coast of Costa Rica and regional differences in fishing seasonality, likely shaped by both oceanographic variability and tourism. Based on reported values, the Central Pacific exhibited the highest mean releases of sailfish and blue marlin and longest mean offshore distances in their most recent trip, compared to fishers operating in the



Northern and Southern Pacific. Fishers in the Northern and Central Pacific reported overall improvements in fishing equipment and technology.

Conclusions: These findings underscore the value of integrating fishers' knowledge into fisheries research, enabling the management of billfish fisheries of Costa Rica to better reflect region-specific fishery dynamics. By capturing fishers' lived experiences and observations, this study supports a participatory approach to billfish fisheries management in Costa Rica.

Key words: billfish; blue marlin (*Makaira nigricans*); fishers' knowledge; fisheries management; recreational fisheries; sailfish (*Istiophorus platypterus*); sportfishing.

RESUMEN

El conocimiento de los pescadores revela la dinámica espaciotemporal de la pesca deportiva y turística de peces picudos en la costa del Pacífico de Costa Rica

Introducción: Abordar las brechas de conocimiento ecológico y social es fundamental para garantizar la gestión sostenible de las pesquerías recreativas. Costa Rica es reconocida a nivel internacional como uno de los mejores destinos de pesca deportiva, particularmente para especies de picudos como el pez vela (*Istiophorus platypterus*) y el marlín azul (*Makaira nigricans*). A pesar de su importancia socioeconómica, persisten importantes brechas de información sobre la dinámica de las pesquerías deportivas y turísticas, lo que limita una gestión eficaz. Los pescadores dedicados a la pesca turística y deportiva pueden aportar conocimientos socioecológicos valiosos sobre sus pesquerías y las especies objetivo.

Objetivos: Este estudio busca identificar los patrones espacio-temporales de la pesca deportiva y turística de picudos a lo largo de la costa del Pacífico de Costa Rica y evaluar las diferencias regionales influenciadas por factores sociales y ecológicos, a partir del conocimiento y las percepciones de los pescadores.

Métodos: Realizamos entrevistas semiestructuradas con capitanes de pesca deportiva, tanto de operaciones privadas como de charter, a lo largo de la costa pacífica de Costa Rica en ocho localidades: Golfito y Puerto Jiménez en el Pacífico Sur ($n = 14$); Quepos y Herradura en el Pacífico Central ($n = 34$); y Tamarindo, Flamingo, Cuajiniquíl y El Jobo en el Pacífico Norte ($n = 14$). Las entrevistas incluyeron una actividad de mapeo participativo para identificar zonas clave de pesca de pez vela y marlín azul, junto con un cuestionario estandarizado sobre la demografía de los pescadores, estacionalidad de la pesca, especies de picudos y no picudos capturadas en el viaje más reciente (y su abundancia reportada), distancias recorridas en el viaje más reciente y cambios en los equipos y tecnología de pesca a lo largo del tiempo.

Resultados: A través del análisis de las respuestas de pescadores se identificaron zonas críticas de pesca cercanas a la costa, dentro de las 60 millas náuticas, así como diferencias regionales en la estacionalidad de la pesca, probablemente influenciadas tanto por variabilidad oceanográfica como por el turismo. Con base en los valores reportados, el Pacífico Central presentó los promedios más altos de liberaciones de pez vela y marlín azul, así como las mayores distancias promedio recorridas mar adentro en el viaje más reciente, en comparación con los pescadores del Pacífico Norte y Sur. Los pescadores del Pacífico Norte y Central señalaron mejoras generales en equipos y tecnología de pesca.

Conclusiones: Estos resultados resaltan la importancia de integrar el conocimiento de los pescadores en la investigación pesquera, permitiendo que la gestión de las pesquerías de picudos en Costa Rica refleje mejor las dinámicas pesqueras específicas de cada región. Al incorporar las experiencias y observaciones de los pescadores, este estudio destaca la importancia de los enfoques participativos para la conservación y el manejo de las pesquerías de picudos en Costa Rica.

Palabras clave: conocimiento de pescadores; gestión pesquera; marlín azul (*Makaira nigricans*); peces picudos; pesca deportiva; pesquerías recreativas; pez vela (*Istiophorus platypterus*).

INTRODUCTION

Costa Rica is internationally recognized as a premier recreational fishing destination, where high catch rates of billfish—particularly blue marlin (*Makaira nigricans*) and sailfish (*Istiophorus platypterus*), but also striped marlin

(*Kajikia audax*), and black marlin (*Istiompax indica*)—are reported (Ehrhardt & Fitchett, 2006), along with other target species including wahoo (*Acanthocybium solandri*), yellowfin tuna (*Thunnus albacares*), roosterfish (*Nematis-tius pectoralis*), dorado or mahi-mahi (*Coryphaena hippurus*) (see Villalobos-Rojas et al.,

2014), as well as snook (*Centropomus spp.*) (see Soto Jiménez et al., 2010). In addition to their importance to Costa Rica's recreational fisheries (sport and tourist fisheries), billfish are top predators and can exert top-down influence on community structure and ecosystem stability (Kitchell et al., 2006; Baum & Worm, 2009). Recognizing their ecological and tourism value, Costa Rica declared sailfish and marlins as species of special interest for recreational fishing in 2005 in the Costa Rica Fisheries and Aquaculture Law (Law 8436; Asamblea Legislativa de Costa Rica, 2005), later adding roosterfish in 2014 (INCOPECA, 2014). However, limited characterization of recreational fishing dynamics in Costa Rica has constrained effective fisheries management.

A distinctive feature of Costa Rica's legal framework for recreational fishing is the differentiation between *sport* and *tourist* fishing, which are terms used interchangeably in many countries but defined separately under the Costa Rican Law 8436. Sport fishing according to Costa Rican law refers to non-commercial capture by nationals or foreigners for sport, leisure, or recreation, without profit motives (Art 2, Law 8436; Asamblea Legislativa de Costa Rica, 2005). In contrast, tourist fishing is defined as the capture of aquatic resources to generate revenue from tourism services, typically associated with charter operations (Art. 79, Law 8436; Asamblea Legislativa de Costa Rica, 2005). As of January 2026, 352 boats hold active recreational fishing licenses on the Pacific coast, including 111 tourist fishing licenses associated with commercial charter operations and 241 sport fishing licenses associated with private, non-commercial operations (INCOPECA, 2026). For vessels operating under tourist and sport fishing licenses, there are nine different autonomy ranges, which specify the maximum legally permitted distance from shore for each license type (MOPT, 2024).

At the national and local levels, the recreational fisheries sector promotes sustainable use of marine resources while providing opportunities for coastal development. Studies have underscored its multiple contributions—economic,

social, environmental, and individual—both in Costa Rica (CIMAT & ICT, 2021; Moreno Díaz & Jiménez Elizondo, 2022) and in international contexts (McManus et al., 2011; Pollnac & Poggie, 2008; Voyer et al., 2017). Both sport and tourist fishing are part of a broader service industry, which contributes approximately 5% of Costa Rica's Gross Domestic Product (GDP) and supported more than 272,000 jobs in 2019 (ICT, 2023). It was estimated that the activity generated USD 599 million in 2010, representing 2.13% of national GDP (Soto Jiménez et al., 2010). More recent assessments confirm that recreational fishing continues to generate 520 million annually, highlighting its steady economic relevance, while also contributing to the well-being and quality of life of individuals involved in the sector (Chacón-Cascante & Marín Sandoval, in press).

Despite its socioeconomic importance, the recreational fishing sector faces multiple threats. Overfishing of target species and bycatch, coupled with climate-driven changes such as ocean warming, oxygen depletion, and shifting productivity, threatens the sustainability of fisheries worldwide (Halpern et al., 2008, 2015). In the Eastern Tropical Pacific (ETP), both recreational and commercial fisheries, including artisanal, longline, and purse seine fleets, interact with billfish. Billfish are primary targets of offshore recreational fishing fleets, whereas they are generally caught as bycatch and occasionally targeted by commercial fisheries (Punt *et al.*, 2015; Horodysky *et al.*, 2016; IATTC, 2024). The most recent assessments indicate that sailfish stock status in the ETP remains highly uncertain due to substantial data limitations and unreported catch, while blue marlin assessments indicate signs of recovery from historical depletion. Nevertheless, continued data gaps and limited reporting, particularly from recreational fisheries, constrain confidence in long-term sustainability (IATTC, 2024). In Costa Rica, recent analyses of sportfishing records have documented declines in sailfish catches (Haulsee et al., 2022; Marrari et al., 2023; Chaves-Campos et al., 2025), underscoring concerns



that climate change and climate variability—in addition to direct anthropogenic stressors – may be altering fish distributions, population dynamics, as well as fishing activities. Addressing these concerns requires greater attention to the social-ecological dimensions that shape the fishery and its socioeconomic context (Arlinghaus et al., 2016), especially through understanding the spatio-temporal dynamics of fish populations in relation to sport and tourism fishing activities.

Sport and tourism fishing dynamics vary along Costa Rica's Pacific coast, yet regional differences in their magnitude and seasonality have not been formally studied. A study conducted in 2020, prior to the impacts of the COVID-19 pandemic in Costa Rica, found that most interviewed tourists participated in sport and tourism fishing in the Central Pacific region (81%), followed by the Southern Pacific (19%), and the Northern Pacific region (3%); the total sum of percentages exceeds 100% as some visitors fished in more than one region (CIMAT & ICT, 2021). The dominance of activity in the Central Pacific likely reflects the region's extensive sport fishing and tourism infrastructure, anchored by two major marinas: Marina Pez Vela in Quepos and Los Sueños Marina in Herradura inaugurated in 2010 (Villalobos-Rojas et al., 2021a) and 2001 (Villalobos-Rojas et al., 2021b), respectively. In the Southern Pacific, Marina Bahía Golfito serves as one of the region's major marinas, which opened in 2017 (Madrigal, 2017). The Northern Pacific supports a growing tourism sector, which has recently expanded with the inauguration of Marina Flamingo in 2023 (Tico Times, 2023). Sport fishing seasons for target species are also known to vary along the coast, although formal characterizations of sport fishing seasons remain absent from the scientific literature or institutional reports. A study by the Central America Fisheries and Aquaculture Organization (OSPESCA) reported sport fishers' perceptions that sailfish and marlins are fished year-round in Costa Rica, but it did not provide regional details within the country (OSPESCA, 2007). Thus, although fishing

occurs year-round, the timing of peak activity, which is known by fishers to vary along the Pacific coast, have not been quantified. Understanding regional similarities and differences in infrastructure, fishing effort, seasonality, and catch composition is essential for characterizing spatio-temporal dynamics needed to inform effective management.

To this end, fishers themselves represent a valuable source of information to better understand the spatial and temporal social and ecological factors underpinning recreational fisheries. Fishers' knowledge can help fill critical data gaps on the dynamics of fishing activity and target species (Léopold et al., 2014; Mason et al., 2019; Thurstan et al., 2018; Löki et al., 2023). In Costa Rica, sport and tourism fishers interact with marine environments daily, year-round, and across generations, generating fine-scale insights into their target catch that are difficult to replicate through formal monitoring by scientific agencies, which are often constrained by limited field seasons and resources (Bessesen & González-Suárez, 2021; Haulsee et al., 2022). Beyond helping to fill data gaps on target species, fishers can also provide valuable contextual and experiential knowledge on both the natural and human dimensions of the systems in which they operate, including diverse social, economic, and governance aspects of the fishery and associated human behaviors (Stephenson et al., 2016).

Here, we report on findings from interviews with sport and tourism fishers along Costa Rica's Pacific coast that enable the characterization of spatial and temporal patterns of the recreational fishery targeting billfish, particularly sailfish and blue marlin, while also considering other billfish and non-billfish species. We examine reported fishing grounds, seasonal activity, recent catches, distances to fishing grounds, and changes in fishing technology and infrastructure. By comparing across the Southern, Central, and Northern regions in Costa Rica, this study provides new insights into the regional dynamics of the country's recreational fishery and highlights the value of fishers' knowledge for informing sustainable

management of sport and tourist fisheries targeting billfish and associated species.

MATERIALS AND METHODS

Interviews: Between June-August 2022 and July-September 2023, we conducted semi-structured interviews with 62 sport fishers from communities along the Pacific coast of Costa Rica where sportfishing activity occurs: Golfito and Puerto Jiménez in the Southern Pacific ($n = 14$); Quepos and Herradura in the Central Pacific ($n = 34$); and Tamarindo, Flamingo, Cuajiniquil, and El Jobo in the Northern Pacific ($n = 14$). For this study, the fishers' home ports were assigned to Northern, Central, and Southern Pacific regions according to the national planning and socioeconomic strategy classifications of Costa Rica, referred to as the Chorotega Region (Northern Pacific), the Central Pacific region, and the Brunca Region (Southern Pacific) (Ministerio de Planificación Nacional y Política Económica (MIDEPLAN), n.d.). These

regional designations do not extend to delineated offshore fishing zones (Fig. 1).

We specifically interviewed sportfishing captains operating charter or private vessels, as they are key decision-makers regarding when and where to fish. We focused our study on sport fishers with at least 10 years of experience targeting billfish along the Pacific coast of Costa Rica, with the exception of Cuajiniquil and El Jobo. Since sport fishing activity is relatively new in this region, most fishers interviewed in Cuajiniquil and El Jobo had less than 10 years of experience targeting billfish. We used snowball sampling to recruit fishers who met the above criteria (captains with >10 years of experience targeting billfish) (Naderifar et al., 2017). Initial participants were identified by key collaborators in each community, and subsequent participants meeting the selection criteria were recruited through referrals from previously interviewed participants. Interview participation was constrained by fishers' availability and logistical considerations. Most

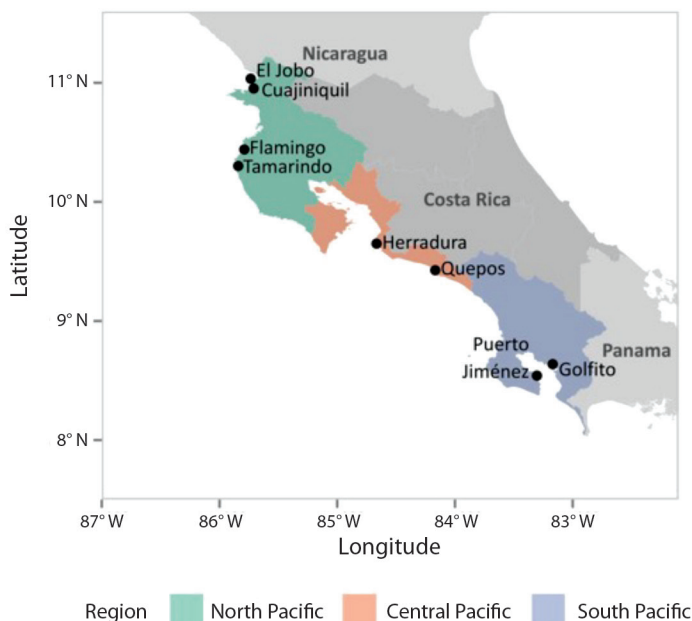


Fig. 1. Map of Costa Rica indicating the Pacific coast communities where fishers were interviewed in 2022–2023. Southern Pacific: Golfito and Puerto Jiménez ($n = 14$). Central Pacific: Quepos and Herradura ($n = 34$). Northern Pacific: Tamarindo, Flamingo, Cuajiniquil, and El Jobo ($n = 14$). Northern, Central, and Southern Pacific regions follow demographic delimitations established by Ministerio de Planificación Nacional y Política Económica (MIDEPLAN), n.d.).



fishers interviewed were Costa Rican (85.5%), while smaller proportions from the United States (11.3%) and Nicaragua (3.2%). All fishers were male.

The 62 interviews were conducted in English and Spanish, lasting from 45 minutes to 2 hours each. We conducted a participatory mapping exercise to characterize each captain's perception of the spatial extent of sailfish and blue marlin fishing grounds. The interviews also included a standardized questionnaire designed to characterize key aspects of sport fishing activity. Fishers responded with reference to their own fishing activity. Here, we report results from items with short, closed-ended responses that generated quantitative data on fisher demographics, fishing seasonality, species caught on the most recent trip (and their reported abundance), distances traveled on the most recent trip, and changes in fishing equipment since the onset of the fisher's activity.

All analyses reflect fishers' knowledge and experiences as reported at the time and place of interviews. Because the data are self-reported and sample sizes within each region were limited, the results should be interpreted as indicative of general patterns rather than precise estimates of catch, effort, or other metrics of fishing activity. To ground our interpretations in fishers' knowledge, we shared initial findings with a subset of participants and collaborators selected for their extensive experience fishing billfish, ensuring representation from each region. Feedback from these consultations was incorporated into the discussion. The interview protocol was approved by both Stanford University's Institutional Review Board (IRB) for human subjects research on June 10, 2022 (protocol #62556) and Yale University's IRB for human subjects research on April 25, 2022 (protocol #2000032625).

Fishing experience and activity characteristics: We collected information on each fisher's fishing background and typical fishing activity to assess how variation across and within regions in fishers' experience and fishing practices might influence their knowledge of

fishing grounds, catch composition, travel distances, seasonality of target species availability, and changes in fishing equipment and technology. Fishers reported the number of years they had targeted billfish, the number of months per year they typically fished (as an indicator of temporal consistency), and the proportion of their trips specifically targeting billfish. We also asked whether fishers captained charter vessels, typically associated with touristic fishing licenses, or private boats, generally associated with sportfishing licenses, as these sectors often differ in travel distance and in their temporal consistency throughout the week and year. Fishers were not asked directly about the types of fishing licenses on the boats they captained. Finally, fishers reported the percentage of trips that were overnight, which generally indicates longer travel distance and greater fishing effort compared to single-day trips.

To contextualize interview-based findings within broader patterns of sportfishing activity, we used publicly available national fishing license records from the Instituto Costarricense de Pesca y Acuicultura (INCOPESCA). Bases of operation registered for active licenses were categorized into Northern, Central, or Southern Pacific zones following the national planning and socioeconomic regional classifications established by MIDEPLAN. A single license could not be assigned to a regional category because its registered base of operation encompassed the entire Pacific coast and was therefore excluded from regional summaries. License records were last updated in January 2026 and therefore do not reflect the exact numbers of fishing licenses during the 2022-2023 interview period. License data are interpreted as reflecting recent regional patterns in recreational fishing activity rather than a precise representation of recreational fishing activity at the time of interviews.

Spatial distribution of fishing grounds: During the participatory mapping activity, respondents were asked to draw digital polygons in an ArcGIS Field Maps (Esri, 2023) survey created for this study using an electronic

tablet, to indicate where they catch sailfish and blue marlin. Fishers were asked “*In what areas do you fish for sailfish?*” and then “*In what areas do you fish for blue marlin?*” For each polygon drawn, respondents were asked to specify the months in which they fished in that area. No guidance was provided on the scale or size of the areas of the polygons, allowing respondents to indicate locations at the level of detail they felt most comfortable with, ranging from specific points to broader regions. The map included a longitude–latitude grid at the degree scale; the names of major marinas, coastal towns, and islands; the Costa Rica Exclusive Economic Zone (EEZ); distance buffers of 5 nm, 25 nm, 50 nm, and 100 nm from the coast; and the ArcGIS Oceans Basemap with bathymetry (Fig. S1).

For analysis, respondent-drawn polygons indicating fishing grounds used in different months were overlaid onto a $0.25^\circ \times 0.25^\circ$ grid. To account for differences in sample size among regions, each intersecting grid cell was assigned a weighted presence equal to 1 divided by the total number of interviewed fishers in that region. These weights were summed per cell and rescaled from 0 to 1, where 1 represents the highest degree of overlap. Because polygons from all months were combined, the resulting heatmaps represent annual fishing activity rather than monthly patterns.

Cross-regional fishing activity: To assess fishing activity outside a fisher’s home port region, participants were asked, “*What general region(s) do you fish in?*”. Responses included broad regions or specific coastal locations, which were subsequently classified into the Northern, Central, or Southern Pacific regions, as well as an “other countries” category when applicable.

Seasonal fishing patterns: We assessed fishers’ perceptions of seasonal patterns, by asking: “*Are there particular months in the year that are better for catching sailfish?*” and “*Are there particular months in the year that are better for catching blue marlin?*” Some fishers

described fishing seasons using general terms such as “winter” or “summer” rather than specific months. To enable month-based analysis, these responses were standardized by assigning November–May to “summer” and May–November to “winter”, as May and November are considered transitional months between the rainy (“winter”) and dry (“summer”) seasons (Ulate, 2001; Alfaro, 2002).

Catch and travel distances from most recent trips: To obtain a standardized snapshot of catch composition, fishers were asked: “*In the most recent fishing trip in which you targeted billfish, did you catch and/or release any fish? If so, what species did you catch and/or release, and how many?*”. Because sport and touristic fishing licenses only allow for catch and release of billfish, while other species (e.g. tuna) may be legally retained within established legal limits (Asamblea Legislativa de Costa Rica, 2005), the term “catch” in this study refers to all fish that were caught, regardless of whether they were released or retained.

Sport fishers were also asked to provide additional details about their most recent trip to contextualize information on fishing activity and effort, including the date, offshore travel distance, and start and end times; total fishing hours were calculated from the reported start and end times. Reported catch values are presented as raw counts. For respondents in the Southern Pacific, all reported distances were assumed to begin at the outer edge of Golfo Dulce (Matapalo), based on consultations with fishers before, during, and after interviews, which confirmed that distances are typically measured from this point. If fishers provided their catch for a fishing trip lasting more than a day, we took the average catch for the entire fishing trip (no. of fish/no. of days) for each species. Although fishers were asked specifically about offshore distance, some responses may reflect a combination of offshore travel and along-coast movement from their home port. To address this, interview transcripts were reviewed for contextual clarification. When a reported distance was clearly



associated with along-coast fishing, a value of zero was assigned. Some responses could not be conclusively separated into offshore versus along-coast components and may therefore reflect a combination of both. Only fishers who reported that they were the captain on their most recent trip were included in the analyses.

We focused specifically on the most recent trip because catch composition can vary substantially among trips and requires detailed recall of specific species, quantities, and effort. Prior research on autobiographical memory shows that respondents recall the most recent event in a series more accurately, particularly when memories involve many similar incidents (Bradburn et al., 1987).

Improvements in fishing equipment and technologies: Fishers in the Central and Northern Pacific were asked about changes in fishing equipment and technologies. This question was developed after initial interviews with fishers based in the Southern Pacific, who repeatedly, without being prompted, described changes they had experienced over time, particularly in fishing gear, communication equipment (e.g. radio), sonar and navigation technologies, radar systems, the number of rigs typically deployed, boat size, and the type of bait used. Because onboard technologies and equipment capabilities can shape where and when fishers operate, assessing perceived changes in these elements is

relevant for understanding the spatio-temporal dynamics of sport and touristic fishing activities in the region. Following sequential exploratory mixed-methods approaches (Patton, 2015; Creswell & Plano Clark, 2018), these themes informed the response categories included in a standardized Likert-scale question (Likert, 1932) which was subsequently administered only in the Central and Northern Pacific.

Statistical analyses: Continuous outcomes were assessed for normality (Shapiro–Wilk) and homogeneity of variances (Levene). Because these assumptions were violated ($\alpha = 0.05$), regional differences were assessed using the Kruskal–Wallis test, followed by Dunn’s post-hoc pairwise comparisons with Bonferroni adjustment. Categorical outcomes were compared across regions using Fisher’s exact test. When overall tests were significant for binary variables, pairwise Fisher tests with Bonferroni-adjusted p-values were conducted.

RESULTS

Fishing experience and activity characteristics: On average, fishers had 23.2 years of experience targeting billfish (SD = 10.0, range 1.5–49.0) and fished 10.7 months per year (SD = 2.5, range 2.7–12.0) (Table 1). The number of years targeting billfish (Northern Pacific: n = 13), the percentage of trips targeting billfish

Table 1

Respondent demographics and fishing activity by region. Total number of boats and license types from INCOPESCA (updated January 2026). One license (of 352 total) was listed with a base of operation as “Pacific Ocean” and could not be assigned to a specific region; therefore, it is not included in this table. For the Southern Pacific, the percentage of trips targeting billfish was reported by a subset of respondents (n = 8). For the Northern Pacific, the years of experience fishing for billfish was reported by a subset of respondents (n = 13). All other variables reflect the full sample size for each region shown in the table.

Region	Total boats (by license type)	Number interviews (by fishing activity)	Mean years of fishing for billfish	Mean number of months fishing per year	Mean % of trips targeting billfish	% of fishers who do overnight trips
Northern Pacific	56 (40 touristic, 16 sportfishing)	14 (12 charter, 0 private, 2 both)	18.1 (sd = 13.5, range = 1.5–48.0)	11.5 (sd = 1.3, range = 7.5–12.0)	55.9 (sd = 29.7, range = 10.0–98.0)	overnight = 7.1, no overnight = 92.9
Central Pacific	240 (48 touristic, 192 sportfishing)	34 (21 charter, 2 private, 11 both)	25.3 (sd = 7.8, range = 14.0–49.0)	11.2 (sd = 1.8, range = 5.0–12.0)	92.0 (sd = 11.6, range = 40.0–100.0)	overnight = 58.8, no overnight = 41.2
Southern Pacific	55 (22 touristic, 33 sportfishing)	14 (12 charter, 1 private, 1 both)	22.9 (sd = 9.8, range = 13.5–43.0)	8.7 (sd = 3.6, range = 2.7–12.0)	73.4 (sd = 17.2, range = 50.0–95.0)	overnight = 42.9, no overnight = 57.1

(Southern Pacific: $n = 8$), and the number of months fishing annually varied significantly by region (Kruskal–Wallis, $p = 0.035$, < 0.001 , and 0.023 , respectively; Table S1). Post-hoc Dunn tests (Table S2) revealed that fishers in the Central Pacific had significantly more years of experience targeting billfish compared to those operating in the Northern Pacific ($p = 0.032$), but no other differences were significant across regions. Central Pacific fishers had a significantly higher percentage of trips targeting billfish than Northern or Southern Pacific fishers (Central $>$ Northern, $p < 0.001$; Central $>$ Southern, $p = 0.012$), whereas there was no significant difference between Southern and Northern Pacific fishers. Fishers in the Northern Pacific reported fishing for more months than fishers in the Southern Pacific ($p = 0.037$), but there were no other significant differences across regions for the number of fishing months.

Overnight trips varied significantly by region (Fisher's exact, $p = 0.003$; Table S3). Specifically, 58.8% of Central Pacific fishers and 42.9% of Southern Pacific fishers reported overnight trips, compared with 7.1% in the Northern Pacific. Pairwise Fisher's exact tests with Bonferroni correction showed that the number of fishers in the Central Pacific that conduct overnight trips was significantly higher than those in the Northern Pacific ($p = 0.001$), whereas differences between Northern and Southern Pacific fishers and between Central and Southern Pacific fishers were not significant ($p > 0.05$) (Table S4). Regional differences in the numbers of captains of private vs. charter operations were not statistically significant (Fisher's exact test, $p = 0.226$; Table S3).

In the northernmost communities of Cua-jiniquil and El Jobo, where the average percentage of trips dedicated to billfish was 36% ($sd = 30$), all fishers reported roosterfish as a target species. Half of the respondents also reported targeting sailfish and tuna, while 16.7% reported targeting mahi-mahi, snapper, marlins, wahoo, barracuda, and jacks.

Spatial distribution of fishing grounds:

A total of 58 fishers based in the Southern,

Central, and Northern Pacific regions engaged in participatory mapping for sailfish and blue marlin fishing areas. For sailfish, respondents drew polygons spanning 5.86° of latitude (5.19° – 11.05° N) and 3.90° of longitude (86.80° – 82.90° W). For blue marlin, respondents drew polygons that spanned a larger area further offshore, spanning 5.95° of latitude (5.08° – 11.03° N) and 4.95° of longitude (87.85° – 82.90° W).

Fisher-drawn polygons were aggregated to show the overall annual footprint of fishing activity in heatmaps composed of $0.25^\circ \times 0.25^\circ$ grid cells. The maximum number of overlapping polygons in a single grid cell was 31 for sailfish and 32 for blue marlin. Each grid cell was assigned a weighted overlap index ranging from 0 to 1, where higher values represent greater overlap among respondents. Most hotspots (defined as grid cells with a weighted overlap index > 0.5) for fishing activity for both species occurred within the first 60 nautical miles from the coast along the Pacific coast. Within these first 50 nautical miles, there is a high degree of overlap in preferred fishing areas for the two species (Fig. 2).

Cross-regional fishing activity: All fishers reported fishing in their home region, but the extent of fishing in additional areas varied by region (Fig. 3). Southern Pacific fishers were most likely to extend their activities into other regions, those from the Central Pacific showed a mix of local and multi-regional fishing, and Northern Pacific fishers largely restricted their fishing to their home waters. Among Southern Pacific fishers, 35.7% reported fishing only within the Southern Pacific, while 42.9% fished in both the Southern and Central Pacific. Smaller proportions reported broader activity: 14.3%, fished across all three regions (Southern, Central, and Northern Pacific), and 7.1% fished in the Southern Pacific as well as in other countries. For Central Pacific fishers, just over half (52.9%) reported fishing only in the Central Pacific. Others indicated broader ranges: 23.5% fished across all three regions (Central, Northern, and Southern), 8.8% in both the

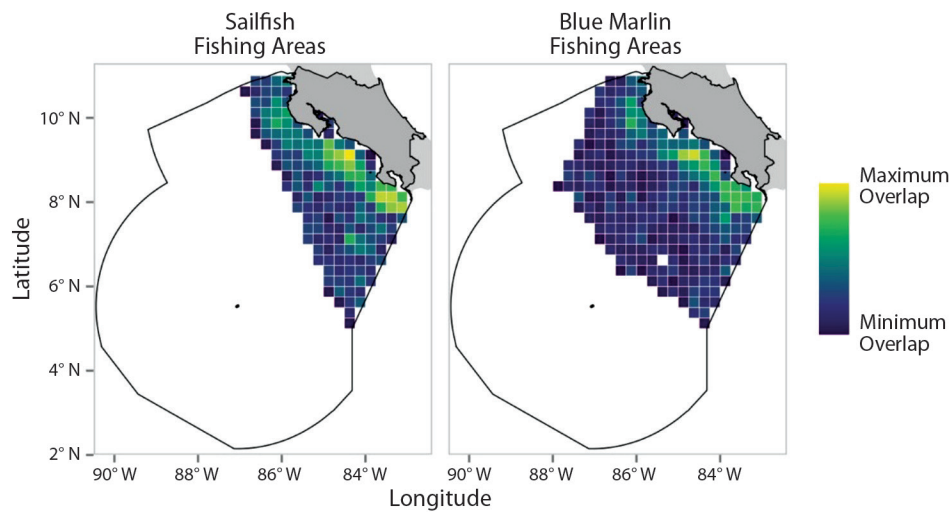


Fig. 2. Heat maps of aggregated participatory mapping fishing areas for sailfish and blue marlin across all months of the year. Polygons drawn by 58 fishers were generalized to a $0.25^{\circ} \times 0.25^{\circ}$ grid, with values weighted by the total number of fishers interviewed in each region and summed within each pixel. Values are normalized from 0 to 1, where 1 indicates the highest degree of overlap. Due to the generalized resolution, these maps do not represent precise fishing locations and may include overlap with land, islands, or protected areas.

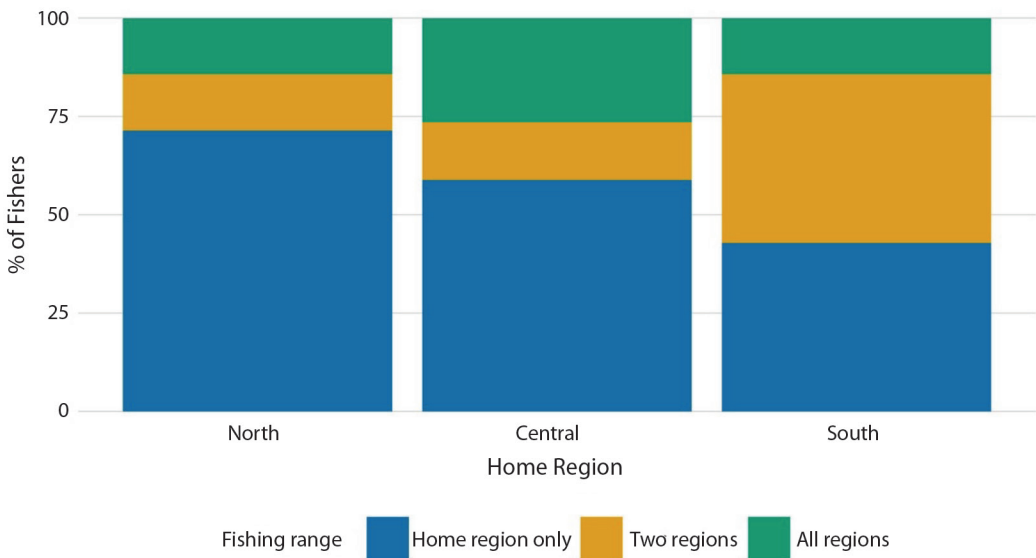


Fig. 3. Fishing range by home region. Responses to “In what general region(s) do you fish?” by fishers based in the Northern (n = 14), Central (n = 34), and Southern (n = 14) Pacific regions. Categories represent the number of regions along Costa Rica’s Pacific coast in which fishers operate (Northern, Central, Southern).

Central and Southern, and 5.9% in the Central Pacific as well as other countries. Smaller proportions (2.9% each) of fishers based in the

Central Pacific reported fishing in the Central and Northern Pacific; Central and Northern and Southern Pacific, as well as other countries;

and Central and Southern Pacific, and other countries. Among Northern Pacific fishers, the majority (71.4%) reported fishing exclusively in the Northern Pacific. The remainder reported fishing across all three regions (14.3%), in both Central and Northern regions (7.1%), or in both Northern and Southern regions (7.1%).

Seasonal fishing patterns: According to fishers (> 50% agreement within each region), the best months for sailfish were reported as July–October in the Northern Pacific, January–April in the Central Pacific, and January–March in the Southern Pacific (Fig. 4). For blue marlin, Northern Pacific fishers identified August–October as the best months, Central Pacific fishers highlighted June–August and December, and Southern Pacific fishers emphasized

July–December (Fig. 4). Overall, sailfish peaks clustered in the dry season in the Southern and Central Pacific and during the rainy season in the Northern Pacific, while blue marlin peaks occurred primarily rainy-season months extended later into the year in the Central and Southern Pacific. In the Northern Pacific, the best months for blue marlin according to fishers were clustered within the rainy season; however, fewer fishers provided responses for blue marlin because not all participants target this species.

Fishers noted that the months identified above for sailfish and blue marlin fishing represented the best times to target each species, citing factors such as fish availability and catchability, local oceanographic dynamics (e.g., seasonal northern winds in the Northern Pacific

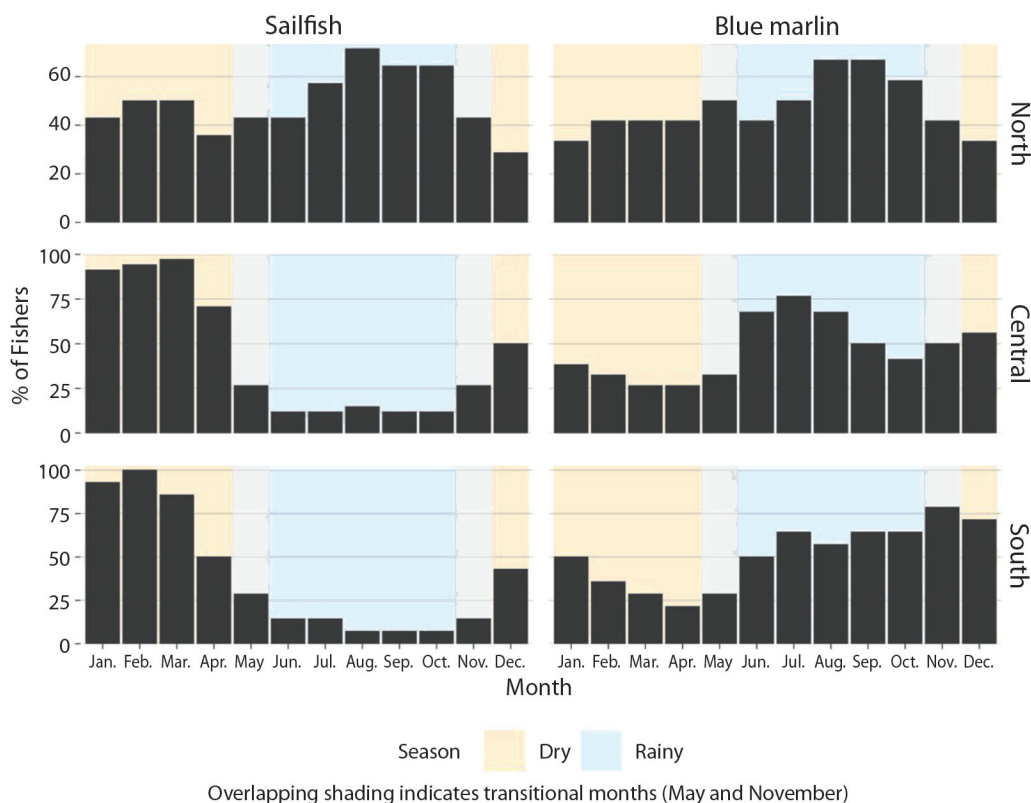


Fig. 4. Best fishing months for sailfish and blue marlin. Bars represent the number of fishers in the Northern (sailfish: $n = 14$; blue marlin: $n = 12$), Central ($n = 34$), and Southern ($n = 14$) Pacific of Costa Rica who identified each month as among the best for targeting these species, based on responses to the question: “What are the best fishing months for sailfish and blue marlin?”.



restricting fishing activity), and socio-economic drivers, including the timing of peak tourism during rainy and dry seasons. However, when asked specifically about the months corresponding to their participatory-mapped fishing areas, many—if not most—fishers reported fishing year-round for sailfish (64.3%, $n = 9$ in the Southern; 96.7%, $n = 29$ in the Central; and 71.4%, $n = 10$ in the Northern Pacific) and blue marlin (85.7%, $n = 12$ in the Southern; 93.5%, $n = 29$ in the Central; and 46.2% in the Northern Pacific).

Catch and travel distances from most recent trips: At the time of the interview,

fishers reported the most recent trips ranging from March to August 2022 and from May to August in 2023. This analysis includes 13 fishers based in the Northern Pacific, 34 in the Central Pacific, and 13 in the Southern Pacific who reported most recent fishing trips in which they were captains (Fig. 5). Among Southern Pacific fishers, 11 reported the distance traveled and 12 reported the total time fishing. The average travel distances reported by fishers for their most recent trips were 13.4 ± 9.9 nm in the Northern Pacific, 49.4 ± 35.1 nm in the Central Pacific, and 30.4 ± 15.1 nm in the Southern Pacific (Table S5). The average total number of hours for the fishing trip was 6.9 ± 2.7 hours in

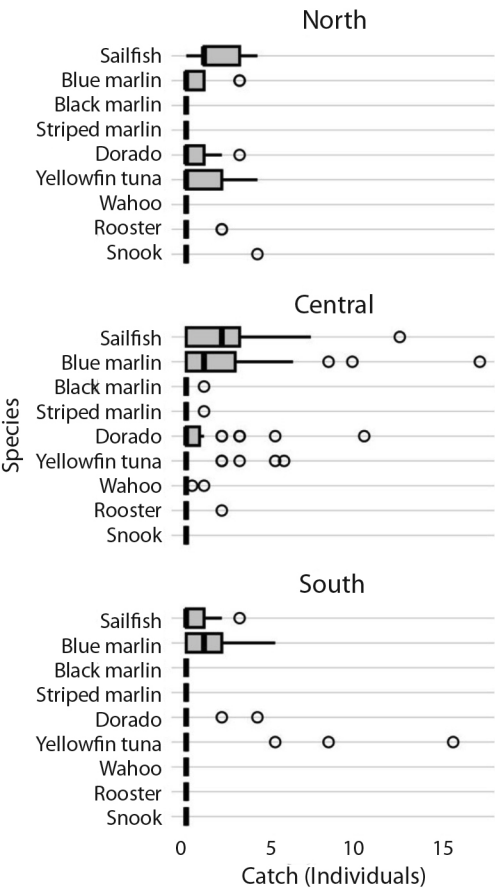


Fig. 5. Released catch from fishers’ most recent trips (March to August 2022 and from May to August in 2023), by species and region. Aggregate answers to the question: “What species did you catch on your most recent trip?” by fishers in the Northern ($n = 13$), Central ($n = 34$), and Southern ($n = 13$) Pacific of Costa Rica. Boxplots show the distribution of the number of individuals reported released or caught per trip, with points indicating outliers.

the Northern Pacific, 7.4 ± 2.2 hours in the Central Pacific, and 6.6 ± 2.4 hours in the Southern Pacific (Table S5). Only travel distance to fishing grounds varied significantly across regions for the most recent trip reports (Kruskal-Wallis, $p < 0.001$; Table S6). Post-hoc Dunn tests (Table S7) show that fishers in the Central ($p < 0.001$) and Southern Pacific ($p = 0.037$) traveled significantly longer distances than those in the Northern Pacific. Trip distances did not differ significantly ($p > 0.05$) between fishers in the Central vs. Southern Pacific.

In the most recent trips, sailfish and blue marlin were generally the most prevalent reported releases, particularly in the Central Pacific (Table S8). Central Pacific fishers released on average 2.1 ± 2.5 sailfish and 2.3 ± 3.6 blue marlin per trip, representing the highest numbers of billfish among regions. Northern Pacific fishers also reported sailfish releases (1.7 ± 1.3), while Southern Pacific fishers released fewer sailfish (0.5 ± 1.0) but comparable numbers of blue marlin (1.5 ± 1.8). Striped and black marlin were each reported only once, both in the Central Pacific, and were not reported in the Northern and Southern Pacific.

Releases and catches of inshore species, roosterfish and snook, were rare overall, with most reports coming from fishers in the Northern Pacific (0.3 ± 0.8 roosterfish and 0.3 ± 1.1 snook; Table S8). Wahoo only had two reports in the Central Pacific and none in the Northern and Southern Pacific. Mahi-mahi and yellowfin tuna were reported in all regions, though patterns differed. Mahi-mahi was captured and/or released most frequently in the Central Pacific (0.9 ± 2.0), with fewer reports in the Southern (0.5 ± 1.2) and Northern (0.5 ± 1.0) Pacific. Yellowfin tuna stood out in the Southern Pacific, with an average of 2.2 ± 4.6 tuna caught and/or released per trip; however, this pattern was strongly influenced by a few trips with very large catches (up to 15 tuna), while most Southern Pacific trips reported few or none. In the Central (0.5 ± 1.4) and Northern Pacific (1.0 ± 1.5), yellowfin tuna releases were more moderate and more consistent among trips.

Kruskal-Wallis tests (Table S9) indicated significant differences among regions in the number of sailfish reported on fishers' most recent trip ($p = 0.029$). For other species, no significant regional differences were detected (all $p > 0.05$). Post-hoc Dunn tests (Table S10) revealed that sailfish catches in the Central Pacific were significantly higher than those in the Southern Pacific ($p = 0.031$) while no significant difference was observed between Central and Northern Pacific fishers and Southern and Northern Pacific fishers ($p > 0.05$).

Improvements in fishing equipment and technologies: 40 fishers in the Central and Northern Pacific regions were asked about changes in fishing technology and infrastructure (Fig. 6). Of these, nine did not respond to the item on sonar technology (five in the Central Pacific and four in the Northern Pacific), and nine did not respond to the item on radar technology (two in the Central Pacific and seven in the Northern Pacific), as they did not use these devices. Items were measured on a 5-point Likert scale (1 = Greatly Worsened, 5 = Greatly Improved).

Overall, fishers reported improvements in most categories of fishing technology and infrastructure (Fig. 6). In the Northern Pacific, the greatest gains were reported for fishing gear (100%), communication with other boats (86%), sonar technology (80% of fishers), and navigation technology (79%). More moderate improvements were noted for radar technology (71%) and the number of rigs (57%), while perceptions of boat size improvements were evenly split (50% reporting no change and 50% reporting improvement). Improvements in bait type were reported by only 29% of Northern Pacific fishers.

In the Central Pacific, reported improvements were even more pronounced, with nearly all respondents indicating positive changes in navigation technology (96%), fishing gear (92%), radar technology (88%), boat size (81%), and communication with other boats (81%). More moderate improvements were reported for sonar technology (71%) and bait type

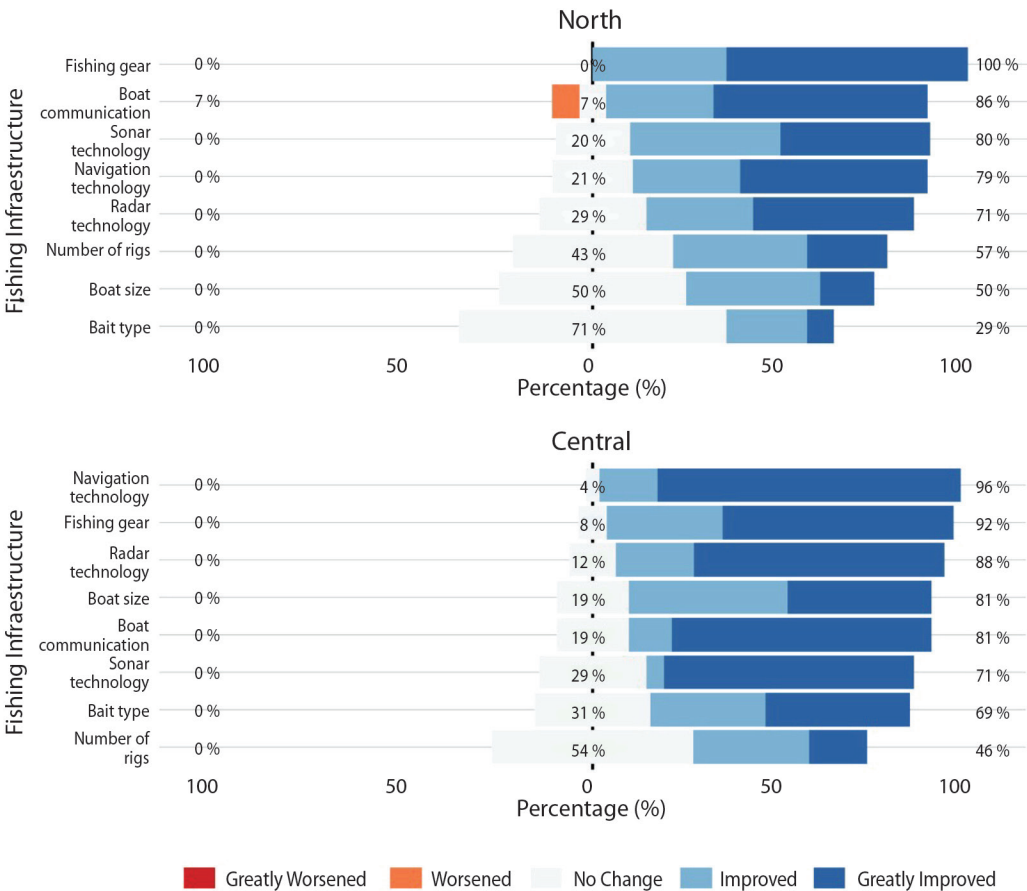


Fig. 6. Reported changes in fishing technology and equipment, by category and region. Bars show the percentage of fishers in the Northern (up to n = 14) and Central Pacific (up to n = 26) of Costa Rica who rated changes on a 5-point Likert scale (1 = greatly worsened, 5 = greatly improved). Non-responses for sonar and radar reflect that some fishers do not use these technologies.

(69%), while perceptions of improvements in number of rigs were mixed (46% reporting improvement, 54% reporting no change).

DISCUSSION

This study provides new insights into the spatial and temporal dynamics of Costa Rica’s sport and tourism fisheries, highlighting potential regional differences and similarities that shape fishing activities along the Pacific coast of Costa Rica. Although it is important to note caveats such as a relatively small sample

size and the scarcity of official and scientific data for contextualization, the patterns identified in fishing grounds, target species, and other aspects of fishing practices offer important considerations for fisheries management and conservation.

Fisher-reported fishing areas and seasonal activity provide valuable insights that help fill spatio-temporal gaps in knowledge of billfish distributions and fishing access, particularly in regions where systematic monitoring is limited. Accordingly, spatial patterns derived from participatory mapping are interpreted as

generalized regional representations of fishing activity rather than precise fishing locations. Although sailfish and blue marlin are highly migratory species, participatory mapping revealed that most fishing hotspots for these species occur within the first 60 nautical miles of Costa Rica's Pacific coast, underscoring the importance of coastal and shelf-associated waters for sport and tourism fisheries. This finding is consistent with previous studies showing that billfish often associate with continental shelf breaks and seamounts, which are key fishing grounds for recreational fleets (Campbell et al., 2003; Morato et al., 2010; Richert et al., 2017). Furthermore, the broader offshore extent of blue marlin fishing grounds identified in the participatory mapping may reflect species-level differences in habitat use. Although these data cannot confirm habitat preferences, previous studies have shown that sailfish tend to associate more strongly with coastal waters than blue marlin (Ortiz et al., 2003; Bubley et al., 2020).

Beyond billfish habitat-related factors that may influence the spatial distribution of fishing grounds, access to these areas is also strongly shaped by economic and logistical constraints. Many sport fishers operate smaller vessels or charter boats that are subject to cost limitations, boat size restrictions, and regulations established by charter companies and the government authorities (MOPT, 2024). The prominence of these near-shore hotspots, as described by fishers, highlights both the ecological and socioeconomic value of coastal habitats for billfish and the fisheries that target them. This information provides spatial information relevant to ongoing management efforts, such as the exclusion of the tuna purse-seine fleet from the first 80 nautical miles off the coast (Asamblea Legislativa de Costa Rica, 2022).

Fishing grounds were not confined to a single region within the Pacific Coast of Costa Rica, as many fishers reported operating across multiple regions. Southern Pacific fishers were the most likely to extend their activities beyond their home region, Central Pacific fishers showed a mix of local and multi-regional

fishing, and Northern Pacific fishers largely restricted their fishing to their home waters. Although this inquiry did not explicitly capture seasonal patterns, fisher movements are likely influenced by seasonality, oceanographic conditions, and tourism. Unprompted comments during interviews provided additional context for these spatial dynamics. For example, several Northern Pacific fishers noted that they travel south to the Central Pacific during the dry season, when strong winds and associated oceanic conditions limit offshore fishing in northern waters. Fishers from both the Northern and Southern Pacific also mentioned fishing in the Central Pacific during major tournaments, such as those documented by Marrari et al. (2023) and Ehrhardt et al. (2025). In addition, the Central and Northern Pacific regions support a higher-volume tourism model compared to the lower-intensity, ecotourism-based economy of the Southern Pacific (Hunt et al., 2015). This difference may contribute to more consistent year-round touristic fishing activity in these northerly regions, potentially attracting fishers from the Southern Pacific during Costa Rica's low tourism season in the rainy months. These reported cross-regional movements highlight the need for sport and touristic fishing activity to be managed holistically, recognizing that fishers frequently operate dynamically along the coast and do not necessarily remain within the region of their home port.

Fisher-reported seasonal peaks for sailfish and blue marlin likely reflect a combination of the movement ecology of these species as well as the accessibility of these species to fishers driven by ecological and oceanographic processes such as habitat compression, socioeconomic factors such as tourism season, and logistical constraints related to sea conditions. In the Central and Southern Pacific, sailfish peaks occurred during the dry season, while blue marlin fishing peaks extended later into the year across mostly rainy months—a pattern consistent with regional recreational fisheries datasets. A different study using recreational fishing reports from the Southern Pacific of Costa Rica showed that sailfish sightings per



unit effort (SPUE) peaked during dry season (January–April), whereas blue marlin SPUE peaked in May, August, and November, corresponding to rainy season and the transitional month of November (Haulsee et al., 2022). These patterns align with our finding that Southern Pacific fishers identify the dry season as a better period for fishing sailfish compared to blue marlin. Similarly, another study using recreational fishing reports from Costa Rica also showed peaks for sailfish between January and April in the Southern and Central Pacific, which were positively associated with warm, oxygen-rich surface waters but negatively correlated with sea surface temperature at a three-month lag, consistent with increased prey production following cooler, upwelling-favorable periods (Marrari et al., 2023). These studies, based on recreational fishing reports in Costa Rica and the broader ETP, show that seasonal and interannual changes in SST, thermocline depth, and nutrient supply likely influence both prey availability and the extent of oxygenated surface habitat for billfish in Costa Rica. Additionally, because the dry season coincides with Costa Rica's tourism high season, increased charter activity during these months may also influence reported fishing effort and encounter rates, potentially reinforcing seasonal patterns reported by fishers.

In contrast, fishers in the Northern Pacific identified the rainy season as the best period for fishing both sailfish and blue marlin. This pattern appears to reflect operational constraints: during the dry season (November–April), the region experiences intense northeasterly winds associated with the Papagayo jet (Pennington et al., 2006), which produces hazardous sea conditions that fishers report as limiting boat access. Yet off the coasts of Central America and Southwest Mexico, seasonal wind jet events like this one are known to drive strong coastal upwelling, shoal the thermocline, and vertically compress the suitable habitat for pelagic predators. In Guatemala, these conditions have been shown to increase sailfish accessibility by concentrating both prey and predators in shallow, oxygenated layers (Ehrhardt &

Fitchett, 2006; Ehrhardt et al., 2025). Therefore, even though upwelling might enhance sailfish availability in other parts of Central America, including northern Costa Rica, fishers' access to offshore grounds is limited by the strong Papagayo winds. In contrast, the influence of the Papagayo jet weakens in Costa Rica's Central and Southern Pacific, where upwelling plumes and mesoscale eddies generated by both the Papagayo and Panama gap winds help to maintain elevated productivity in these regions (Chelton et al., 2000; Marrari et al., 2023), enabling fleets in these regions to exploit increased sailfish availability associated with these oceanographic conditions. These mechanisms remain hypotheses, and more data on sailfish and blue marlin habitat use are needed to disentangle the social and ecological factors likely underlying fishing grounds and seasonal patterns reported by fishers in this study. Furthermore, differences between species in the best fishing months reported by fishers may also reflect perceived changes in the availability of one species, prompting fishers to redirect effort to the other species during certain months (Haulsee et al., 2022; Thurstan et al., 2018). Despite these patterns, many fishers emphasized that both sailfish and blue marlin are targeted year-round, underscoring the consistent importance of these species to the sector.

Regional differences in mean releases of sailfish and blue marlin reported in the most recent trips, representing a limited snapshot of highly variable fishing activity in the rainy season, likely reflect a combination of ecological and social factors, which cannot be disentangled based on this study alone. Higher reported catches in the Central Pacific may be due to greater local billfish availability during the rainy season; however, additional movement ecology studies in this region are needed to clarify possible differences in billfish availability along the Pacific coast of Costa Rica. Central Pacific fishers also reported traveling the farthest distances offshore, followed by Southern Pacific fishers, while Northern Pacific fishers reporting the shortest offshore trips. Longer offshore distances may reflect regional differences in local

environmental conditions that require traveling farther to reach better fishing grounds, as well as differences in the fishers' capacity to venture farther offshore. Greater offshore access may increase the likelihood of encountering billfish, which typically occupy pelagic, offshore habitats (Clyde-Brockway et al., 2025; Haulsee et al., 2022). More broadly, recreational fishing effort is structured by access constraints, including vessel range and proximity to access points, with capacity mediating where and how intensively fishing occurs (Stuart-Smith et al., 2008). In the Central Pacific, greater infrastructural capacity, reflected in larger marinas and higher reported improvement in fishing equipment and boat size observed in this study, may partly explain the higher offshore activity and reported releases of sailfish and blue marlin. Enhanced infrastructure allows fishers to travel farther and target pelagic species more consistently compared to fishers in the Northern and Southern Pacific.

More limited offshore activity in the Northern Pacific is likely influenced by a greater focus on coastal species and by seasonal winds that restrict fishing during the dry months. Other factors potentially influencing reported distances and catches include variable access to fish aggregating devices (FADs) along the Pacific coast and regulations limiting how far fishers can travel offshore—whether imposed by charter operators and boat owners or established by the government (MOPT, 2024). The distribution and use of FADs in Costa Rica, however, remain undocumented in the scientific literature and official reports. Given the limited number of trips and the inherent variability of pelagic fisheries, these results should be interpreted as indicative of possible regional tendencies rather than precise estimates of catch rates.

Reports of general improvements in fishing technology and infrastructure across the Northern and Central Pacific from this study suggest ongoing economic incentives to expand sport and touristic fishing capacity, although persistent regional discrepancies likely reinforce the differences observed in fishing practices.

While fishers in both regions reported equipment and technological upgrades, improvements were more commonly reported in the Central Pacific, where 81% of fishers noted increases in boat size compared to 50% of fishers in the Northern Pacific. The greater perceived improvements in boat size together with a higher proportion of fishers conducting overnight trips and a larger share of sportfishing licenses (associated with private boats) in the Central Pacific, may indicate a greater financial capacity to invest in vessels and gear in this region. These factors may help explain why Central Pacific fishers traveled farther offshore and reported higher billfish releases on their most recent trips. Greater capacity in the Central Pacific may also facilitate the more extensive cross-regional movement reported by fishers from this region compared to those in the Northern Pacific. Additionally, investments in fishing equipment, vessel quality, and marina infrastructure may reinforce regional tourism patterns, especially since boat and crew quality have been shown to be among the main factors influencing tourist satisfaction in Costa Rica's sportfishing sector (Soto Jiménez et al., 2010; Martínez-Vázquez et al., 2021). This, in turn, can drive further investment in fishing operations. Together, these patterns highlight the role of socioeconomic and infrastructural differences in shaping regional variability in fishing effort and outcomes, with important implications for fisheries management. However, these observations should be interpreted cautiously as the data reflect perceptions of change in fishing equipment rather than measured vessel and gear characteristics.

This study highlights the value of fishers' knowledge in filling data gaps of the sport and tourist fishery, providing a holistic perspective that integrates fishers' ecological observations, socio-economic realities, and fishers' daily interactions with the fishery. Because these intertwined social processes shape how ecological experiences are perceived and recalled, interpreting fishers' knowledge requires collaborative research approaches that center participation and co-creation. Such approaches



for integrating fishers' knowledge into science and management are increasingly important as fisheries management moves toward integrated, ecosystem-based frameworks that must incorporate ecological, economic, social, and institutional dimensions (Stephenson et al., 2016). By documenting spatial dynamics, seasonal activity, potential regional differences in catch patterns, and improvements in fishing equipment and technology of sport and tourist fisheries, this study provides foundational information into fishing dynamics. These findings can inform future research that leverages fishers' ecological knowledge to support the management of ecologically and socioeconomically important target species such as billfish. This also highlights the importance of systematic and reciprocal engagement with fishers to better understand the dynamics affecting target species and fishing activities. In Costa Rica, recreational fishing reports have previously been used to examine seasonal and interannual patterns in billfish fisheries (Haulsee et al., 2022; Marrari et al., 2023), illustrating how fisher-generated data can support scientific interpretation of broader temporal trends.

Together, these findings suggest that effective management of Costa Rica's sport and tourism fisheries would benefit from spatially and temporally explicit approaches that account for regional differences in seasonality, fisher mobility, and fishing capacity. Moving forward, management efforts in Costa Rica would benefit from formal mechanisms to document and integrate fishers' knowledge across spatial and temporal scales. This could include systematic collection and maintenance of fishing trip reports, participatory mapping of fishing activities, and incorporation of qualitative perspectives on changing conditions and fisheries management. Such approaches could better align management and conservation measures with fishers' lived experiences, ultimately contributing to the sustainability of both target species and the livelihoods that depend on them.

Author contribution statement: *Daviana Berkowitz-Sklar* conceived the study, designed the survey and methods, conducted interviews, carried out the analysis, and led the writing. *Henry Marín Sandoval* contributed to the conceptualization, conducted additional research, and assisted with manuscript preparation. *Danielle Bates* and *Hannah Blondin* contributed to the conceptualization of the study, assisted with survey design, and provided feedback on the manuscript. *Michelle María Early Capistrán* provided substantive review and editing. *Oswald Schmitz* contributed to the conceptualization, methodology, survey design, investigation, and writing. *Larry Crowder* contributed to the conceptualization, methodology, survey design, investigation, and writing, and secured funding. All authors reviewed and approved the final manuscript.

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See supplementary material
a11v74s2-suppl. 1

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