Relevance of the dynamics Fisheries in the Southeastern Gulf of Mexico.

Users and resources

Abstract:

The fisheries in Tabasco and Campeche face significant challenges because of their interaction with the hydrocarbon industry. The contextual conditions that imposed the later industry include the decree of safety navigation exclusion zones and extensive vessel transit, which directly and indirectly cause oil spills and impact the fishing industry in the southern Gulf of Mexico at different levels. Implementing concertation strategies between oil and fishing industries requires robust information for informed local and sectorial decision-making. In this study, our objectives were (1) to assess the dynamics of selected fisheries variables (trends in catch volumes, production prices, operating cost based on fuel consumption per kilogram caught, the relationship between variations in fishing volumes and their composition, and trends in product value, among other indicators of fishing efficiency) for artisanal fleets from 306 landing sites in Campeche and Tabasco, Mexico based on public fishing arrival reports from 2015 to 2023, and (2) to compare the overall patterns of selected variables from fishing arrival reports with a thoroughly monitored fishing fleet in Tabasco. This information contributes to fishing performance criteria that may be included in marine spatial planning processes coexistence to increase the feasibility of the coexistence of the oil and fishing industries.

Keywords: Marine spatial planning; Fishing seascape; Small Scale Fisheries.

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Introduction

In 2023, it was pointed out that fish production from capture remains fundamental for human consumption in Latin America, providing around 12 million tons in contrast to nearly 5 million tons from aquaculture production. In Mexico, fishery and aquaculture production in 2023 amounted to more than 1.74 million tons (FAO, 2024). The Mexican states of Tabasco and Campeche, located in the southern Gulf of Mexico, had a fishery production of 18,207 tons and 55,572 tons in 2022, respectively; Tabasco is in the 12th position in national catches and value, and Campeche is the 7th in catches and 4th in value (Comisión Nacional de Acuacultura y Pesca, 2022). The capture of species such as shrimp, octopus, and several varieties of fish represents a significant part of the value of fish production in the region (Comisión Nacional de Acuacultura y Pesca, 2022).

The Campeche Sound and the coasts of Tabasco are recognized as the leading oil extraction areas in Mexico, from which 81% of Mexican oil is extracted (SENER, 2017). However, this region where most of the hydrocarbons in Mexico are extracted coincides with high fishing productivity, particularly in small-scale fisheries, which is vital for the subsistence of coastal communities (Ramos-Muñoz et al. 2020;Espinoza-Tenorio et al., 2022). The coexistence of these sectors has generated a context of competition for resources and territory, where the environmental impacts of oil, such as spills and pollution, have affected the health of marine ecosystems and, consequently, fishing catches (Zalik, 2009; Peña-Puch et al., 2019; Ramos-Muñoz, et al., 2019). Oil exploitation in the region has significantly increased the vulnerability of local socio-ecological systems, affecting not only marine biodiversity but also the resilience of fishing communities (Coronado et al., 2024).

These impacts are compounded by the socioeconomic vulnerability of fishing communities, which rely heavily on marine resources for their livelihoods and often do not receive adequate compensation for losses from oil activities (Espinoza-Tenorio et al., 2019). In addition,

tensions and conflicts between these two sectors have been exacerbated by the displacement of fishers to other areas due to pollution or the occupation of traditional fishing grounds by oil platforms (Pérez-Sánchez & Muir, 2003).

Regarding socioeconomic impacts, hydrocarbon extraction has brought with it unequal development in the regions of Tabasco and Campeche. While the oil industry has generated employment and economic growth in certain areas, it has also created inequalities, where fishing communities, particularly the smallest and most vulnerable, have been marginalized and have experienced a deterioration in their quality of life (Espinoza-Tenorio et al., 2022). In addition, the lack of access to essential services, such as health and education, is exacerbated in these communities due to the overload of local infrastructure accompanying the oil industry (Ramos-Muñoz et al., 2020).

In this context, our objectives were to assess the dynamics of selected fisheries variables (trends in catch volumes, production prices, operating cost based on fuel consumption per kilogram caught, the relationship between variations in fishing volumes and their composition, and trends in product value, among other indicators of fishing efficiency) for artisanal fleets from 306 landing sites in Campeche and Tabasco, Mexico based on public fishing arrival reports from 2015 to 2023, to compare the overall patterns of selected variables from fishing arrival reports with a thoroughly monitored fishing fleet in Tabasco.

Methodology.

The arrival notices of the small-scale vessel and the industrial fleet registered in the states of Tabasco and Campeche from 2017 to 2023 were used to identify the ten principal fisheries and evaluate their trends in catch volumes, average price per kilogram of catch, and frequency of species reporting. The arrival reports were obtained from the National Fishing and Aquaculture Commission (CONAPESCA) and contain fields such as the Fishing National Register (FNR), economic unit name, fishing area, port name, fishing office, state, species name, price per kilogram, and kilogram of catches, among other data.

To determine the ten most significant fisheries, the Relative Importance Index (RII) was used, calculated with the following equation:

$$RII = \frac{\%\text{Catch} + \%\text{Value} + \%\text{Frequency}}{3}$$

where:

- %Catch is the percentage of the total landing weight (kilograms) for a particular species relative to the total landing weight of all species.

- %Value is the percentage of the total value (MXN) for a particular species relative to the total value of all species.

- %Frequency is the percentage of times a particular species is reported relative to the total number of reports for all species.

From these fisheries, the main trends in average prices per kilogram of catch and catch volumes were identified. Records corresponding to oysters and species categorized as "Others" were excluded from the arrival notices.

Economic units such as fishing cooperatives, permit holders, or companies that record their catches in the arrival notices were identified to assess changes in fleet behavior, and comparisons between 2017 and 2023 were made.

Subsequently, data from the Vessel Monitoring System (VMS) of the Mexican industrial fishing fleet with home ports in the states of Tabasco and Campeche were analyzed from 2018 to 2023. This database was obtained from CONAPESCA. It contains the vessel name, economic unit names, FNR, date, geographical position, course, and velocity. The monthly distance traveled per vessel and the hours of operation were obtained by analyzing these data. Additionally, the fishing usage areas by the industrial fleet were determined using a hexagonal binning plot with the Matplotlib library from Python. The parameters used for the hexagonal binning plot included a grid size of 40, a minimum count of 5 for the bins, and value limits set from 0 to 500. This method allowed for a detailed spatial analysis of the fishing activities, highlighting the most frequented areas by the industrial fleet.

For the analysis of the coastal fleet, NEMO position transmitters installed on four small-scale fishing vessels were used, covering the period from 2022 to 2023. Using this data, the

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monthly distances traveled, engine operating hours and an estimate of gasoline consumption were calculated using the following equation:

$$Q \cong H \times 36.9 \frac{l}{h} \times 6000 \ r/min$$

where:

- **Q** is the approximate consumption in liters,
- **H** is the number of hours the engine operates, obtained from the timestamp of the position while in motion,
- **36.9 L/Hour** is the consumption factor at 6000 revolutions per minute.

The cost per liter of gasoline was estimated using the monthly average price history in Mexico from 2022 to 2023.
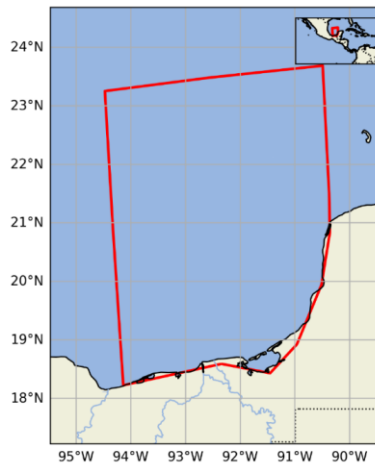
Study area

Figura 1. Study area

The study area encompasses the states of Tabasco and Campeche, both located in the southeastern region of Mexico with coastlines along the Gulf of Mexico. These states share a tropical climate and have economies driven by the oil industry and fishing.

Results

The fishing arrival notices analysis

The analysis of arrival notices for the small-scale fishing fleet revealed various trends and identified the principal fisheries holding fish production in Tabasco and Campeche. Table 1 describes the participation and importance of each reported fishery, highlighting octopus with a Relative Importance Index (RII) of 21.16, representing 17.90% of the catches and 33.73% of the fishing value. This data underscores the significant contribution of octopus both in terms of volume and economic value, with a total of 1,004 economic units who have participated in the fisheries from 2017 to 2023.

Additionally, the fishery species such as snook, Amberjack, Gafftopsail catfish, mojarra, red snapper, bluewing Searobin, and gulf weakfish stand out, collectively accounting for 45.15% of the RII. These species are crucial for the economic sustainability of small-scale fishing and diversification in the catch. Snook, for example, ranks second in importance with an RII of 11.81, representing 6.78% of the catches and 16.26% of the economic value, involving 1,385 economic units, surpassing the number of units participating in octopus fishing.

Table 1. RII Ranking of Small-Scale Fishing Species.

RANK	Fishery name	% Capture	% Value	% Frequency	Economic units	RII
1	Pulpo (Octopus)	17.90	33.73	11.84	1004	21.16
2	Robalo (Snook)	6.78	16.26	12.40	1385	11.81
3	Jurel (Amberjack)	15.37	4.82	12.68	1335	10.96
4	Bandera (Gafftopsail catfish)	8.00	3.42	4.61	848	5.34
5	Mojarra	4.21	4.63	5.78	731	4.87
6	Rubio (Bluewing Searobin)	3.56	1.89	8.32	1094	4.59
7	Jaiba (Blue crab)	7.15	3.35	2.61	160	4.37
8	Guachinango (Red snapper)	2.60	6.00	3.27	707	3.96
9	Corvina (Gulf weakfish)	2.60	2.10	6.15	1163	3.62
10	Caracol (Snail)	6.01	2.94	1.55	174	3.50
	TOTAL	74.18	79.14	69.21	8601	74.18

Bluewing Searobin, Red snapper,

Table 2. Ranking IIIR deep-sea fishing species.

RANK	Fishery name	% Capture	% Value	% Frequency	Economic units	RII
1	Camarón (Shrimp)	73.81	84.81	45.14	54	67.92
2	Guachinango (Red snapper)	3.77	4.38	9.09	42	5.75
3	Jurel (Amberjack)	5.44	3.06	7.50	33	5.33
4	Fauna (Bycatch)	1.79	0.11	9.81	45	3.91
5	Mero (Mere)	2.60	2.30	6.03	32	3.64
6	Besugo (Sea bream)	2.46	1.26	5.49	29	3.07
7	Pargo (Porgy)	1.22	0.96	4.44	37	2.20
8	Bandera (Gafftopsail catfish)	2.84	0.53	2.14	18	1.83
9	Rubia y Villajaiba (Yellowtail Snapper)	0.94	0.52	3.53	30	1.66
10	Tiburon (Shark)	1.01	0.75	1.05	12	0.94
	TOTAL					

The analysis of the deep-sea fishing fleet's catches reported in the arrival notices from 2017 to 2023 identified the main species caught and their trends. Table 2 shows that shrimp fishing stands out significantly, with a Relative Importance Index (RII) of 67.92, representing 73.81% of the catches and 84.81% of the total value of deep-sea fishing.

Red snapper represents an RII of 5.75, contributing 3.77% of the catches and 4.38% of the value reported by 42 economic units. Meanwhile, with an RII of 5.33, Amberjack accounts for 5.44% of the catches and 3.06% of the monetary value, with 33 economic units.

Bycatch also shows a notable presence with an RII of 3.91, capturing 1.79% and representing 0.11% of the economic value, distributed among 45 economic units. Generally, this set of species are incidental catches or bycatch.

The capture frequency also reveals valuable information. Shrimp were captured in 45.14% of the reports, followed by bycatch with 9.81% and red snapper with 9.09%.
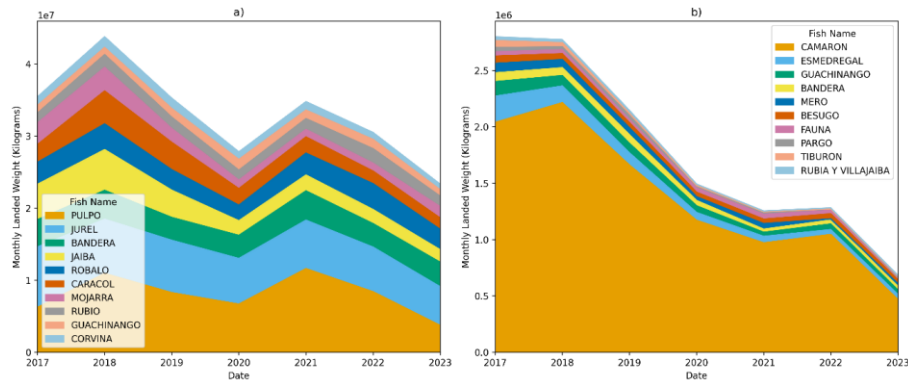
Figure 1. Catch volume of the leading fisheries for 2017-2023, a) small-scale fisheries and b) deep-sea fisheries.

When visualizing the catches reported in the arrival notices corresponding to the states of Tabasco and Campeche, we can observe in Figure 1(a), which represents small-scale fisheries, that octopus is the dominant species in catch volume throughout the entire period. Starting in 2018, the catch volume of octopus experiences a significant decrease, with a brief increase in production in 2021, followed by a gradual decline until 2023, which reports the lowest catch volumes. Other species, such as Amberjack, Gafftopsail catfish, and snook, also show similar trends in catch volume, with Amberjack notably increasing steadily until 2021, when it peaked before decreasing to a minimum in 2023 with around 5,000 tons.

In Figure 1(b), corresponding to the catches reported by the deep-sea fishing fleet, shrimp stand out notably, representing the most significant catch volume during the studied period. The catch volume increased until reaching its peak in 2018, with 2,100 tons, followed by a steady decline until 2023, when it reached a minimum of 600 tons.
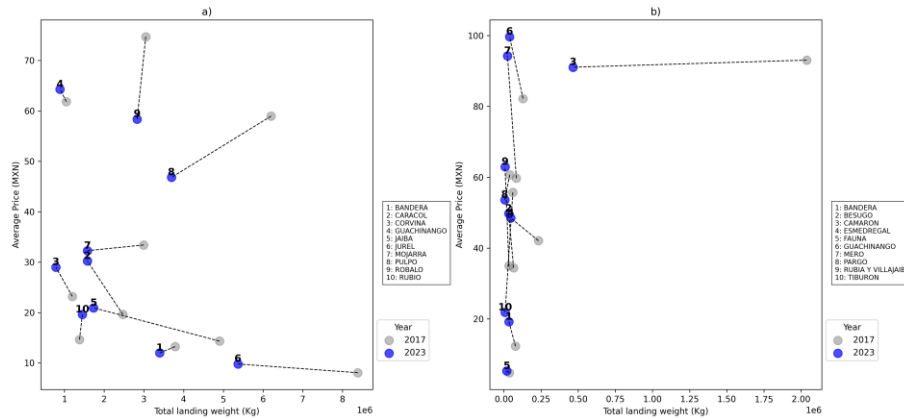
Figure 2. Comparison of Landed Weights and Average Prices of the Main Species Captured by Their RII in 2017 and 2023 in the Regions of Tabasco and Campeche.

When comparing the average prices per kilogram of catch and the total landed weight for small-scale fishing, we observe which fisheries show the most significant changes between 2017 and 2023. In Figure 2(a), decreases in their catches characterize blue crab, Amberjack, octopus, and mojarra fisheries. Crab landed weight decreased by 64.65%, but its price per kilogram increased by 45.99%. Amberjack showed a 15.25% reduction in weight and a 3.99% increase in price per kilogram. Octopus experienced a significant decrease in weight (62.64%) and average price (19.23%). Mojarra maintained its price relatively stable, with a 27.28% decrease in landed weight.

Regarding shrimp fishing, there was the most significant decrease in price per kilogram (14.23%), followed by snook, which also experienced a notable reduction in landed weight (13.02%). On the other hand, red snappers did not show significant changes in either catch or price, with only a slight reduction of 15.25% in weight and a 3.99% increase per kilogram price. These ten fisheries have generally seen a decline in reported catches, with a few exceptions, such as snook, red snapper, and gulf weakfish, which remained relatively stable. For price variations, prices generally remained stable or increased.

In contrast to small-scale fishing, the deep-sea fleet shows significant increases in prices per kilogram. In Figure 2(b), shrimp fishing is exciting as it is the most important fishery for the deep-sea fleet by its RII. For this fishery, 2,038 tons were reported in 2017, and by 2023, the catch had dropped to 466 tons, representing a 77.13% decrease. There was an approximately 83% decrease in red snapper fishing, from 39 tons in 2017 to only 6 tons in 2023. On average, these ten fisheries saw a 72% reduction in their catches.

In contrast to the catches, the average prices per kilogram of catch showed significant increases in most fisheries, with an average increase of 42%. The snapper and shrimp fisheries were the only ones that showed decreased prices, with reductions of 11.6% and 2%, respectively.
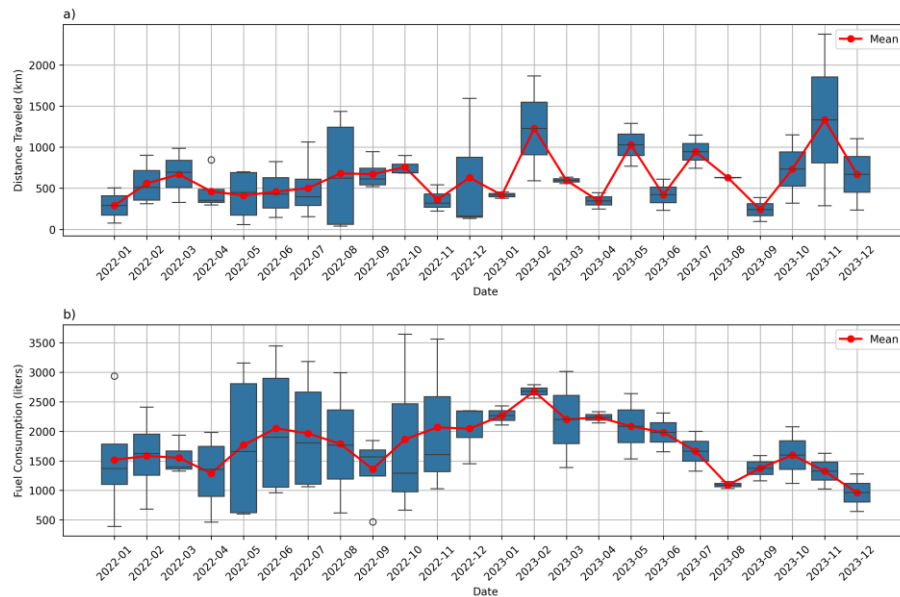
The movements of the fleets

Figura 3. Distancia recorrida mensual (a) y estimación del consumo de combustible de la flota (b), para la flota menor con transmisores NEMO.

In the study conducted throughout 2021 on the operation of four small vessels equipped with NEMO transmitters, significant patterns were observed in the distance traveled and fuel consumption, as illustrated in Figure 3. During the year, the average distance traveled was 626.39 km, with notable fluctuations; the maximum distance reached 1331 km, and the minimum was 240 km, with peaks in May and October and a considerable decline in March.

The second panel (b) shows the estimated monthly fuel consumption, measured in liters. As the distance traveled, this variable significantly increased during the months of more significant nautical activity. This variability underscores the direct correlation between the distance navigated and the fuel consumed.
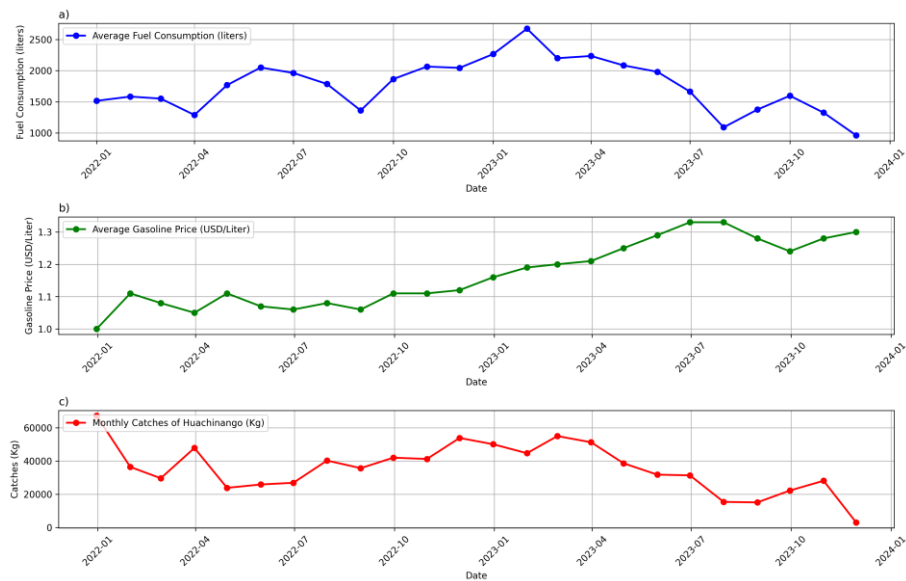
Figure 4. Time Series for a) Estimated Monthly Fuel Consumption in Liters Based on Operating Hours, b) Average Price per Liter of Gasoline in Dollars, and c) Monthly Catches of the Red Snapper Fishery Reported in Frontera, Tabasco.

In Figure 4(a), the average fleet fuel consumption, measured in liters and calculated from the operating hours of the vessels and their distance traveled, is shown. Throughout the year 2022 and up until December 2023, the consumption shows a generally stable trend with slight fluctuations, peaking in June 2022, with the highest peak in February 2023 at 2054 liters and decreasing towards January 2024 with a minimum of 1000 liters.

In contrast, Figure 4(b) shows the average price of gasoline in dollars per liter during the same period. A constant increase in the gasoline price is evident, starting in 2022 at approximately $1.00 per liter and rising to nearly $1.30 per liter by early 2024.

On the other hand, Figure 4(c) shows the monthly catches of red snapper reported at the fishing office in Frontera, Tabasco. The catches show monthly variations throughout the study period, with notable peaks in certain months and a general decreasing trend towards the end of the period, particularly noticeable from mid-2023 onwards.
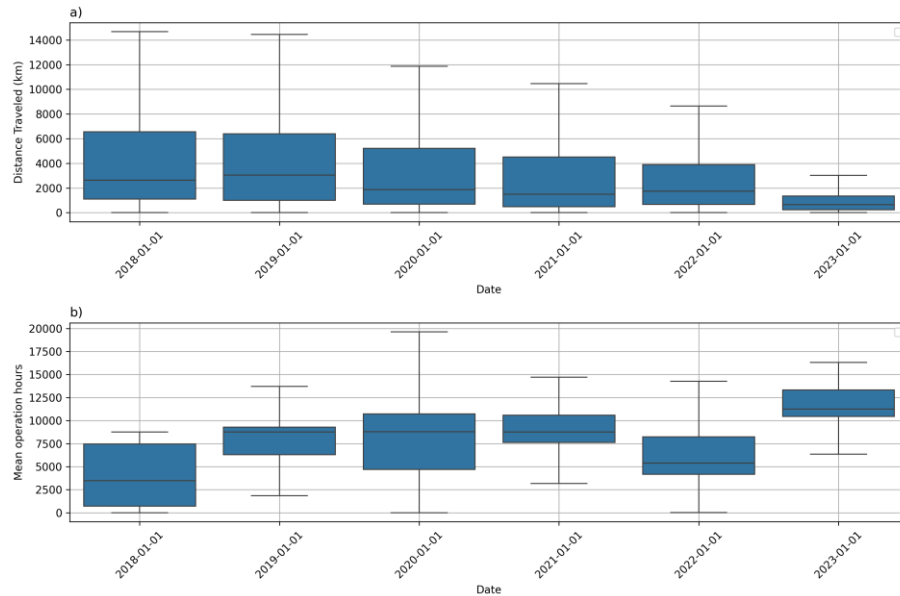
Figure 5. Monthly Distance Traveled (a) and Operating Hours (b) of the Deep-Sea Fleet.

Figure 5 analyses the deep-sea fleet's monthly distance traveled and operating hours from January 2018 to October 2023. The graph in Figure 5(a) depicts the monthly distance traveled in kilometers. Over the years, the average distance traveled shows significant variations, with a notable increase in 2019, when maximum distances were reached. In comparison, 2023 records a considerable decrease in distance traveled.

Figure 5(b) illustrates the deep-sea fleet's monthly operating hours. Like the distance traveled, operating hours show fluctuations throughout the study period. The year 2019 again stands out with a peak in operating hours, suggesting intense activity during that year. In contrast, the following years show a decrease in operating hours, reaching their lowest point in 2021 with a slight rebound in 2023.
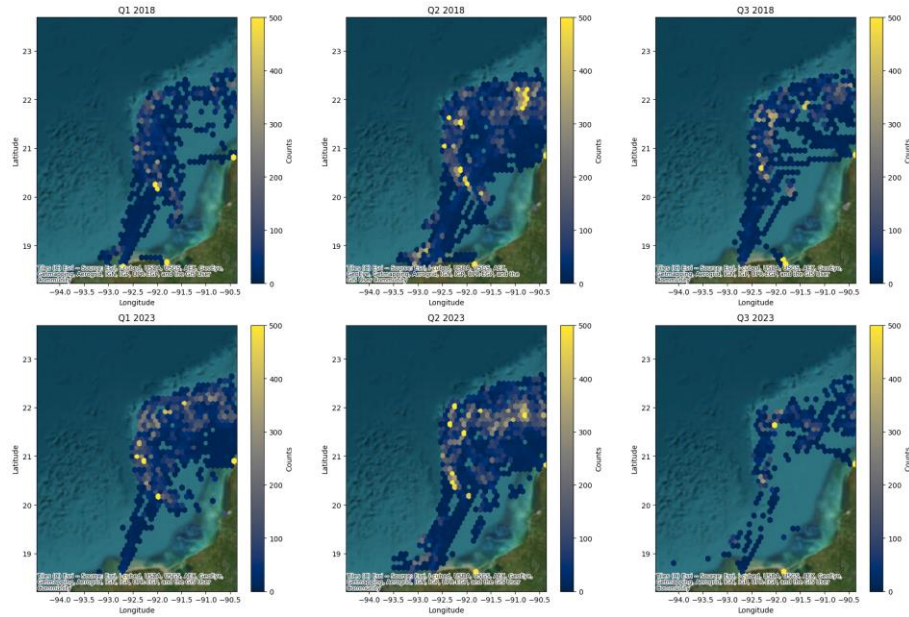
Figure 6. Quarterly Comparison of Navigation and Fishing Usage Area for the Years 2018 and 2023, Adjusted to a Maximum of 500.

Figure 6 displays heat maps of point density for the study region in the quarters of 2018 and 2023, utilizing vessel monitoring system (VMS) data. The 2018 maps show a higher concentration of points near the coast, especially in the second and third quarters.

The heat maps for 2023 also reveal similar patterns, with a notable density of points near the coast, particularly in the second and third quarters. Comparing both years, the corresponding quarters' intensity and distribution of points are consistent. However, a significant difference is that the density in the third quarter of 2023 appears more concentrated and less dispersed compared to 2018.

Table 3. Comparison of Catches and Catch Value for the Main Landing Sites

| Landing Site	Catches (tons)		Value (MXN)	
	2017	2023	2017	2023
Malecon Sansores Perez	6474	4712	240,703	133,839
Isla Aguada	5955	872	167,036	65,531
Malecom Seybaplaya	5247	4903	267,420	117,093
Sabancuy	2881	3004	129,303	145,984
Barra De San Pedro	2605	1435	146,684	122,043
Isla Arena	2278	2712	289,374	252,111
Arroyo Grande	2240	1204	390,819	103,117
Costa Blanca	1702	232	73,594	4,920
Frontera	1499	1616	109,459	55,558
Sanchez Magallanes,Tab.	1337	1514	84,359	78,619
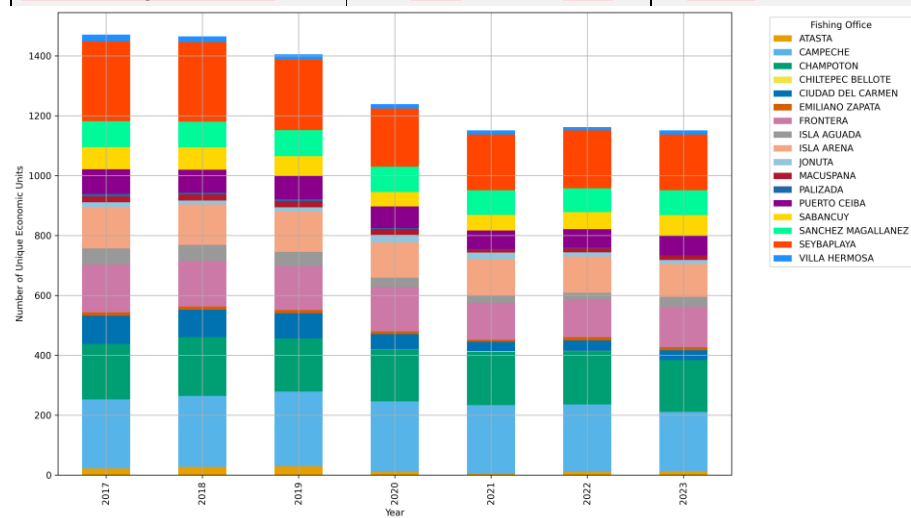
Figure 7. Number of Unique Economic Units Registered per Year (2017-2023) in Each Fishing Office.

Table 3 compares catches (in tons) and the catch value (in pesos) for the main landing sites in 2017 and 2023. Malecon Sansores Perez shows a decrease in catches, from 6474 tons in 2017 to 4712 tons in 2023. The value of the catches also decreased from 240,703 pesos in 2017 to 133,839 pesos in 2023. Isla Aguada shows a notable reduction in catches, from 5955 tons in 2017 to 872 tons in 2023, with a corresponding decrease in value from 167,036 pesos to 65,531 pesos.

Malecon Seybaplaya reflects a decline in catches, from 5247 tons in 2017 to 4903 tons in 2023, and in value, from 267,420 pesos to 117,093 pesos. Sabancuy shows a slight increase in catches, from 2881 tons in 2017 to 3004 tons in 2023, while the value of the catches increased from 129,303 pesos to 145,984 pesos. Barra De San Pedro shows a decrease in catches from 2605 tons in 2017 to 1435 tons in 2023 and a reduction in value from 146,684 pesos to 122,043 pesos.

> **Comentado [RC15]:** Y si eliminamos esta parte? Jejeje

Discussion

This is evident in the observed trends in the catches reported in Tabasco and Campeche, particularly in the main fisheries.

While Campeche experienced an increase in catches up until 2017, reaching a peak of 69,026 tons, the average annual catch has since stabilized at around 53,800 tons over the following five years, according to the Statistical Yearbook of Fisheries and Aquaculture. In contrast, Tabasco has shown a clear downward trend since 2018, with a significant reduction in catches, dropping from 50,000 tons that year to 18,000 tons in 2022(Comisión Nacional de Acuacultura y Pesca, 2022).

Small Scale Fisheries

The octopus fishery emerges as the most significant, as previously highlighted by other authors and documented in fisheries statistical yearbooks. In 2018, octopus catches reached 14,900 tons, most originating from the State of Campeche. However, our analysis indicates that octopus holds a Relative Importance Index (RII) of 21.16, significantly surpassing snook and amberjack, which rank second and third, respectively, with RII values of approximately 5. Snook, amberjack, Mojarra, are reported by fisheries identified as métiers, where multiple species classified as "Escama" are captured using the same fishing gear (Monroy et al., 2010). This suggests these species are likely caught when octopus fishing is not the primary activity. Additionally, the observed changes in catch volumes may be influenced by environmental factors, particularly in the case of red grouper(Oribe-Pérez et al., 2023; García-Rodríguez et al., 2024)

In the case of the smaller fleet, the red snapper is in eighth place according to its index of relative importance, with 707 economic units participating in this fishery. However, this species represents 6% of the economic value of the catch and contributes 2.6% of the total catch.

Regarding prices, the results are mixed. Some species have experienced significant declines in value, such as octopus, which decreased from 58 to 45 pesos, and snook, which dropped from 75 to 58 pesos. Conversely, other species, such as crab, snail, weakfish, red snapper, and bluewing searobin, have seen price increases. Interestingly, no scientific studies analyzed these price variations and the potential factors influencing them in the study area. However, the observed price increases can be attributed to two main factors: first, inflation, and second, the removal of government fuel subsidies (Chávez-Sánchez,Sara, 2022; Causa Natura, 2024), which may shift operational costs to the price per kilogram. It is important to remember that for fisheries with catch shares—a rights-based management system that can reduce costs and increase revenues by allocating individual or group quotas—this shift allows more efficient operation, reducing costs and eliminating redundant fishing capacity, especially when quota trading is permitted (Birkenbach et al., 2023).

In the context of spatial analysis, it is crucial to understand how fishing operations are conducted and to identify potential impacts on exploited stocks, particularly considering the interactions between co-occurring species and different types of fishing gear. Knowledge of the spatial distribution of fishing effort and the dynamics of gear usage, influenced by fishers' behavior, is essential for this understanding (Monroy et al., 2010; Torres-Irineo et al., 2021). The fleet equipped with NEMO transmitters showed increased distances traveled towards the end of the first year of study. In 2023, there were significant variations in the monthly average distances traveled, likely reflecting changes in the spatial distribution of the target species, which in this case is the red snapper. However, due to the limited number of transmitters installed, it is challenging to draw more definitive conclusions about the behavior of this fleet. The importance of using high-resolution monitoring systems to support fisheries management decisions cannot be overstated (Hernández-Álvarez et al., 2023: 934). While the deep-sea fishing fleet benefits from satellite monitoring systems like VMS, the small-scale fleet faces significant challenges accessing such technology. Enhancing access to monitoring technology for the small-scale fleet could be crucial for achieving more effective and equitable fisheries management.

Deep-sea Fisheries

The relative importance ranking highlights the shrimp fishery, which contributes 17.38% of the total catch volume and represents 84.8% of the economic value of the same, responsible for 45% of the arrival notices. This fishery supports 54 economic units and has a relative importance index of 67.92. However, it is notable that the Statistical Yearbook of Fisheries for Tabasco does not consider shrimp as one of the most important fisheries, while Campeche ranks fourth, with maximum catches of 7,182 tons in 2015, decreasing to 3,269 tons in 2022 (Comisión Nacional de Acuacultura y Pesca, 2022).

On the other hand, for the deep-sea fleet, the red snapper ranks second in relative importance, with an index of 5.75. In this category, the species represents 3.77% of the total volume of catches and 3.06% of the economic value and involves 42 economic units. The Red Snapper (*Lutjanus campechanus*) has increased production from 2015 to 2020 (Secretaría de Agricultura y Desarrollo Rural, 2023); in contrast, the red snapper time series shows a negative trend from 2018 to 2023 in catch volumes, this coincides with forecast done by the fisheries authority, that point a possible negative trend form 2018 (Secretaría de Agricultura y Desarrollo Rural, 2023). Another approximation of the negative trends into best practices in fisheries management implemented in recent years has influenced stock trends in small-scale multispecies fisheries in Mexico (García-Rodríguez et al., 2024). It is pointed out that *L. campechanus* is one of the few species that is not overexploited or overfished, with a 62% probability of not being in these categories, which could be contributing to its increase in recent catches (García-Rodríguez et al., 2024). On the other hand, the prices of species caught by the deep-sea fleet have shown significant increases in the average price per kilogram, which, as previously argued, is likely due to changes in subsidy policies. Another factor that may be affecting prices is the opening of foreign markets for fishery exports (Coronado et al., 2020).Analyzing the spatial dynamics of the deep-sea fleet, we observe that the average distance traveled has decreased in recent years since 2022, but the sea operation hours have increased during this time. This indicates a concentration of the fleet in specific areas, which aligns with the findings of Monroy et al. (2010) and Torres-Irineo et al. (2021). From May to August, fishing activity is more dispersed, while from October to December, the main concentration zones are located off the coast of Campeche and along the continental slope.

Findings from fishing offices

When examining the temporal evolution of fisheries offices where arrival reports are registered, it becomes clear that most sites have experienced a significant reduction in catches from 2017 to 2023, except for Sacunbay, Sanchez Magallanes, and Frontera who increased the catches. For example, Malecon Sansores Perez decreased from 6,474 tons in 2017 to 4,712 tons in 2023, indicating a substantial decline. This trend is also evident in locations such as Isla Aguada and Malecon Seybaplaya, where catches dropped by more than 80% and 50%, respectively. This suggests a shift in the economic focus of these localities that face a reduction of the catches; it is also necessary to point out that the number of economic units has decreased since 2019. A case to point is the Isla Aguada offices, which have reduced their reliance on fishing income while expanding their tourism sector (Peña-Puch et al., 2023).

Concurrently, the economic value of catches at some sites has also shown a downward trend. For example, at *Malecon Seybaplaya*, the total value decreased from 267,420 MXN in 2017 to 117,093 MXN in 2023, reflecting a substantial reduction. However, not all sites exhibit this trend; *Sabancuy*, for instance, shows an increase in economic value despite a modest increase in catches, which had a shift in the species caught or an increase in market prices.

Conclusions

Hallazgos Flota de pequeña escala:

- Pulpo, Robalo y Jurel son las especies más importantes.
- En general hay una tendencia negativa para las capturas.
- En cuanto a los precios el resultado es variado, hay especies que perdieron mucho su valor y otras que han podido incrementar el precio.
- En cuanto al análisis espacial, las distancias recorridas tuvieron variaciones interesantes para la segunda mitad del año ¿qué pesquería está abierta para ese periodo? El consumo de gasolina tiene un periodo máximo hacia la mitad del año, lo que indica que pasan un mayor tiempo en una misma zona. El precio del combustible subió para final del año encareciendo la operación, lo cual debiera promover el incremento del precio de la gasolina, lo cual no se observa por lo corto del periodo de tiempo analizado. La operación y las capturas de guachinango siguen la misma tendencia estacional, lo cual tiene sentido porque es una flota especializada.

Hallazgos de la flota de altura:

- La flota de altura está altamente especializada en camarón, posteriormente le sigue el guachinango (hay que ver si se tienen referencias de flota multiespecífica)
- Las capturas de la flota no han variado por excepción del camarón, y por el contrario de la flota menor, los precios han aumentado significativamente, posiblemente a la inflación o el acceso a mercados internacionales.
- En cuanto a la distancia recorrida en promedio no han variado hasta el año 2023, aquí se tiene que se concentraron en una zona, ya que las horas de operación subieron para el mismo año. La tendencia es incrementar las horas de operación.
- La flota disminuye las áreas de pesca concentrándose hacia el final del año, esto es más notable para el año 2023.

Hallazgos de las comunidades

- Hay oficinas que han disminuido significativamente las capturas y los ingresos por la pesca ¿las comunidades que reportan ahí han cambiado su vocación?
- Hay una tendencia general en la disminución de unidades económicas que reportan pesca

References

Comisión Nacional de Acuacultura y Pesca. (2022). *Anuari Estadistico de Acuacultura y Pesca 2022*. https://nube.conapesca.gob.mx/sites/cona/dgppe/2022/ANUARIO_ESTADISTICO_DE_ACUACULTURA_Y_PESCA_2022.pdf

Coronado, E., Zepeda-Domínguez, J. A., Espinoza-Tenorio, A., Cupido Santamaria, D., Ramos Muñoz, D., & Monzón-Alvarado, C. (2024). Institutional mapping and implementation of the sustainable development goals across co-existing industries:

The case of the fisheries-oil system in Mexico. *The Extractive Industries and Society, 17*, 101390. https://doi.org/10.1016/j.exis.2023.101390

Espinoza-Tenorio, A., Millán-Vásquez, N. I., Vite-García, N., & Alcalá-Moya, M. G. (2019). People and Blue Carbon: Conservation and Settlements in the Mangrove Forests of Mexico. *Human Ecology*, 47(6), 877–892. https://doi.org/10.1007/s10745-019-00123-6

Espinoza-Tenorio, A., Ehuan-Noh, R. M., Cuevas-Gómez, G. A., Narchi, N. E., Ramos-Muñoz, D. E., Fernández-Rivera-Melo, F. J., Saldívar-Moreno, A., Zepeda-Domínguez, J. A., Pérez-Jiménez, J. C., Oliveto-Andrade, A., & Torre, J. (2022). Between uncertainty and hope: Young leaders as agents of change in sustainable small-scale fisheries. *Ambio*, 51(5), 1287–1301. https://doi.org/10.1007/s13280-021-01639-2

FAO. (2024). *El estado mundial de la pesca y la acuicultura 2024. La transformación azul en acción,*. FAO. https://doi.org/10.4060/cd0683es

García-Rodríguez, E., Saldaña-Ruiz, L. E., Sosa-Nishizaki, O., Fajardo-Yamamoto, A., Cisneros-Soberanis, F., & Flores-Guzmán, A. (2024). From bottom to up: Effects of fishery improvement projects on the stock trends of multi-specific small-scale fisheries from Mexico. *Marine Policy*, *168*, 106292. https://doi.org/10.1016/j.marpol.2024.106292

Machado, A. M. S., Giehl, E. L. H., Fernandes, L. P., Ingram, S. N., and Daura-Jorge, F. G. Alternative data sources can fill the gaps in data- poor fisheries. –ICES Journal of Marine Science, 78:1663-1671.

Peña-Puch, A.,Rivera-Arriaga E.,Williams-Beck, L., (2023) Exploring governance challenges in coastal communities through key informant perceptions in Campeche, Mexico. *Ocean and Coastal Management*. https://doi.org/10.1016/j.ocecoaman.2023.106722

Peña-Puch, A. del C., Pérez-Jiménez, J. C., & Espinoza-Tenorio, A. (2019). Advances in the study of Mexican fisheries with the social-ecological system (SES) perspective and its inclusion in fishery management policy. *Ocean and Coastal Management*. https://doi.org/10.1016/j.ocecoaman.2019.105065}

Pérez-Sánchez, E., & Muir, J. F. (2003). Fishermen perception on resources management and aquaculture development in the Mecoacan estuary, Tabasco, Mexico. *Ocean & Coastal Management*, 46(6-7), 681–700. https://doi.org/10.1016/S0964-5691(03)00041-3

Ramos-Muñoz, Dora E.; Ramos-Reyes, Rodimiro; Zamora-Cornelio, Luis Felipe; Hernández-De la Cruz, Armando; Espinoza-Tenorio, Alejandro. (2019). "Exclusión en el Golfo de México: una visión desde los pescadores sobre la industria petrolera en Tabasco." Cuadernos de Geografía: Revista Colombiana de Geografía 28 (2): 357-372. doi: 10.15446/rcdg.v28n2.73511

Ramos-Muñoz, D. E., Zepeda-Domínguez, J. A., & Espinoza-Tenorio, A. (2020). La reforma energética mexicana en el marco de la pesca y el petróleo en el Golfo de México. *Revista Costas*, 2(1), 67–80. https://doi.org/10.26359/costas.0402

Secretaría de Agricultura y Desarrollo Rural. (2023, July 21). *Carta Nacional Pesquera 2023*.

Secretaría de Energía. 2017. Sistema de Información Energética

Zalik A. 2009. Zones of exclusion: Offshore extraction, the contestation of space and physical displacement in the Nigerian delta and the Mexican Gulf. Antipode. 41(3):557–582. doi:10.1111/j.1467-8330.2009.00687.x