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Typology of small-scale fisheries of the Yucatan peninsula, Mexico: Recognizing complexity of mixed fisheries in assessment and management

Tipología de las pesquerías en pequeña escala de la península de Yucatán, México: Reconociendo la complejidad de las pesquerías mixtas en la evaluación y la ordenación

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Abstract
Since almost two decades ago, J. Caddy stated that the type of fisheries assessment undertaken defines the type of management established. In this line, classic input/output control management strategies based generally on traditional single species fisheries approaches have proved their limitations for the management of multispecies or mixed fisheries. In this research, we aimed to disentangle the complexity of mixed fisheries to identify similarities and differences among their fishing operations. We employed a typology analysis, having as a case study the Yucatan peninsula (YP). The fisheries in this region have been assumed homogeneous for management purposes despite their complexity and high flexibility in their fishing operations. The same assumption applies to several fisheries in the Gulf of Mexico and Caribbean (GMC). In this study, we examined data of 450 fishing trips, recorded in several fishing communities of the YP between 2017 and 2018. The information recorded includes fishing area and depth of operation of the boats, fishing methods/gear(s) employed, prices of the species captured, and operation costs; we also recorded the catch composition in each trip. We used multivariate statistical techniques to identify and characterize operational units using the *métiers* approach. The results showed that the fishing methods, target species, and Quasi-rent highly define the operational units in the study site. It was observed that less than six species dominated the catches in the analyzed fishing communities, despite 103 species were recorded during the study period, makings these few species highly vulnerable; fishers seem to adapt their fishing operations in time and space to balance their income from their trips. We observed variations among and within the fishing' operations in the analyzed fishing communities which highlights the relevance of recognizing the complexity of mixed fisheries for management purposes. Although slowly, the multispecies approach for fisheries assessment and management is gaining more space, since the first statements and work of J. F. Caddy.
Key words: Fisheries typology, *métiers*, small-scale fisheries, fisheries management units, fisheries monitoring and assessment.

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Resumen
Desde hace casi dos décadas, el Dr. John Caddy afirmó que el tipo de evaluación pesquera que se realiza, define el tipo de manejo que se establece. En este sentido, las estrategias clásicas de manejo de control por entrada/salida, basadas por lo general en las tradicionales pesquerías monoespecíficas, han demostrado sus limitaciones para la ordenación de pesquerías multiespecíficas o mixtas. El objetivo de este estudio es desentrañar la complejidad de las pesquerías mixtas para identificar las similitudes y diferencias entre sus operaciones de pesca. Se utilizó el análisis tipológico, teniendo como caso de estudio la península de Yucatán (YP). Las pesquerías en esta región se han supuesto homogéneas para efecto de manejo a pesar de su complejidad y su alta flexibilidad en sus operaciones de pesca. La misma suposición se aplica a varias pesquerías en el Golfo de México y el Caribe (GMC). En este estudio se examinan datos de 450 viajes de pesca, registrados en varias comunidades pesqueras en la YP entre 2017 y 2018. La información incluye área de pesca y profundidad de operación de los barcos, métodos/arte(s) de pesca utilizados, precios de las especies capturadas y costo de operación; también se registró la composición de la captura en cada viaje. Se utilizaron técnicas de estadística multivariada para identificar y caracterizar las unidades operacionales mediante el enfoque de *métiers*. Los resultados muestran que los métodos de pesca, especies objetivo y la cuasi-renta definen las unidades operativas en el sitio de estudio. Se observó que menos de seis especies dominaron la captura en las comunidades pesqueras analizadas, a pesar de que se registraron 103 especies durante el periodo de estudio, haciendo a estas pocas especies altamente vulnerables; los pescadores parecen adaptar sus operaciones de pesca en tiempo y espacio para balancear los ingresos de sus viajes. Observamos variaciones entre y dentro de las operaciones de pesca en las comunidades pesqueras analizadas, lo que destaca la relevancia de reconocer la complejidad de las pesquerías mixtas para fines de manejo. Aunque lentamente, el enfoque multiespecífico para la evaluación manejo de las pesquerías está ganando más importancia desde las primeras declaraciones y los trabajos iniciales de J. F. Caddy.
Palabras clave: Tipología pesquera, *métiers*, pesca artesanal, unidades de gestión pesquera, evaluación y seguimiento pesquero.

Introduction

The analysis of changes in fishing systems, including the characteristics of fleet operation, pressure on resources, and changes in the economic conditions of users in the face of different sources of stress, represent a challenge for fisheries management globally (Béné 2009, Teh & Sumaila 2013). Those challenges are even greater for artisanal fisheries, characterized by a great diversity of species that are caught with various fishing gears in different sites throughout the year. This complexity makes it difficult to establish appropriate and viable assessment, management, and monitoring schemes for these fisheries (Pelletier & Ferraris 2000, Salas *et al*. 2007, Ramírez-Rodríguez & Ojeda-Ruíz 2012). Along these lines, and given the inherent complexity of artisanal fisheries, several authors have used the *métiers* approach or management units in mixed fisheries (Tzanatos *et al*. 2006, Monroy *et al*. 2010, Ramírez-Rodríguez & Ojeda-Ruíz 2012, Ulrich *et al*. 2012, Quijano 2018, Salas *et al*. 2019a). This approach allows the identification of groups of vessels that share characteristics of fishing operations, which helps to define categories that are easier to distinguish and manage (Pelletier & Ferraris 2000, Monroy *et al*. 2010, Ramírez-Rodríguez & Ojeda-Ruíz 2012, Salas *et al*. 2019a).

As in many countries around the world, in Mexico most of the fishing fleet is artisanal in nature (Arreguín-Sánchez & Arcos-Huitrón 2011, Fernández *et al*. 2011, Galindo-Cortes *et al*. 2019). According to CONAPESCA's Statistical Yearbook (CONAPESCA 2019), nationally there are about 296 506 fishers (97% artisanal) and 74 863 artisanal vessels (<12 meters in length; 90% of the fleet), all heterogeneously distributed in multiple coastal communities. This fleet focuses its effort on more than 500 species (Carta Nacional Pesquera, DOF 2018), but, while species groups are referred to as management units (*e.g.*, demersal fishes defined locally as *escama*), the monitoring, assessment, and management schemes ignore the complexity that defines the artisanal fisheries in operation. Generally, and for long time the fisheries assessment, and monitoring programs have been based on a single species approach, *e.g.*, the resource-based approaches support the fisheries management decisions and the schemes and strategies implemented.

Considering this context, it is undeniable that a change of focus is required in the analysis and management of fisheries, moving from a resource-based perspective with a single species evaluation to understand mixed fisheries. As stated by Caddy and other authors (Caddy 1999, Arreguín-Sánchez 2022), in the context of these fisheries, the multispecies approach as one step to adopt the ecosystem approach to fisheries (EAF), can help to incorporate the diversity of the resources caught and the dynamics of the fleet that captures them, incorporating some economic aspects associated with the activity (Monroy *et al*. 2010, Torres-Irineo *et al*. 2017, Salas *et al*. 2019b, Coronado *et al*. 2020a). This knowledge can support the formulation of fishery management units that facilitate viable implementation of management strategies agreeing to the context of these fisheries (Ramírez-Rodríguez & Ojeda-Ruíz 2012, Saldaña *et al*. 2017, Torres-Irineo *et al*. 2017, Salas *et al*. 2019a).

To improve the management approaches, especially in the context of multispecies, multigear fisheries, Caddy (1999) called for a change of paradigms, by avoiding ignoring their complexity and promoting an integration of methods that could account for natural fluctuation, human induced changes, and socioeconomic factors. One way to move from the single species approach to multispecies approach has been using the *métiers* approach, helping to disentangle their complexity into more manageable units. This management unit approach or *métiers* approach, is beginning to be considered in the field of fisheries resource assessment mainly in Europe, but its application in case studies in Mexico are still limited: in the Mexican Pacific, Ramírez-Rodríguez & Ojeda-Ruíz (2012) assessed small-scale fisheries, Monroy *et al*. (2010) and Quijano *et al*. (2018) report the case of semi-industrial fleets in the Campeche Bank (CB), while Salas *et al*. (2019a) incorporate an analysis that integrates several fleets operating in the CB. On the other hand, Coronado *et al*. (2020b) typifies the diversity of fishing communities in the YP using attributes of the artisanal fleet to identify groups of communities with common characteristics, as well as the variables that define similarities and differences. To date, little attention has been placed on untangling the complexity of artisanal fisheries (within fishing communities) leading to identify management units based on their operational characteristics.

Homogeneity of the fisheries systems in the Yucatan peninsula has been assumed, and management strategies in the region have ignored the complexity and diversity of fishing strategies in fleets that appear to be similar. Furthermore, the objective of this study is to disentangling mixed fisheries by identifying units of operation of the artisanal fleet in the YP. We used two case studies as a contrast, to recognize similarities and differences in the fishing patterns associated with the attributes of fishing trips and the operational strategies of the fishers. The relevance of the analytical framework and the results are discussed in the frame of mixed fisheries management viability and the need to adapt the assessment, management, and monitoring schemes for these types of fisheries.

Background: Fisheries in the Yucatan peninsula

In the YP, Mexico, small-scale fisheries operate by a fleet with close to 10 000 boats and 16 274 thousand fishers; 90% of this fleet and fishing population is artisanal in nature. As stated by Coronado *et al*. (2020a), this number may be higher than officially recorded. The species captured include high-value species that contribute with foreign currency and a mix of other species of lower value, but also with high nutritional impact. In this region made up of three states (Campeche, Yucatan, and Quintana Roo), the artisanal fleet targets more than 140 species (Ramos *et al*. 2021), which are caught with different fishing gears and methods, spreading their landing in more than 20 fishing communities. In addition, these artisanal fleets sometimes coexist with semi-industrial fleets, operating sequentially targeting some resources of high value (Burgos & Defeo 2004, Quijano 2018).

Fishing regulations in the country and the YP include management instruments that apply to the grouper (*Epinephelus morio* (Valenciennes 1828)) fishery, which includes: a closed season from February 1th to March 31st and a minimum legal fishing size for this species of 36.3 cm total length. The octopus' fishery targets *Octopus maya* Voss & Solis 1966 – by two fleets and the regulations include a closure from December 16th to July 31st, a variable quota that is defined annually, a minimum legal size of 11 cm of mantle length, and the prohibition on the use of a fishing method other than the *jimba* (DOF 2014a, 2018). *Octopus americanus* Froriep

1806 is captured by the semi-industrial fleet, but regulations defined for *O. maya* applies in that case as well (Avendaño *et al.* 2019). Caribbean lobster (*Panulirus argus* (Latreille 1804)) includes a closure from March 1st to June 30th, a legal minimum fishing size of 13.5 cm of abdominal length, and a prohibition of catching ovigerous females (DOF 2014b). Assessment methods are based on the most important resources and management schemes are top-down, and to date many resources have not been assessed despite being recorded in commercial and recreational fishing catches (Ramos *et al.* 2021, Cepeda-González & Salas 2021).

Some resources are exploited by fishers from the three states of the YP, such is the case of octopus, while lobster is captured in Quintana Roo and Yucatan; some species are caught exclusively in certain areas (macabí in Campeche, for example). Despite this diversity of species, fishery resources in YP (and throughout Mexico) have traditionally been managed with a single-species approach based on the resource-based approach considering the most important resources like those referred before (Fernández *et al.* 2011, DOF 2018, Galindo-Cortes *et al.* 2019). In addition, fisheries assessments have focused on biological aspects of the main target species such as octopus, lobster, shrimp, and grouper (Arreguín-Sánchez *et al.* 2000, Hernández & Seijo 2003, Velázquez-Abunader *et al.* 2013, López-Rocha & Velázquez-Abunader 2019). This assessment, although relevant, has shown to be insufficient to ensure the sustainability of the resources and the fisheries that support the livelihoods of multiple fishing communities (Monroy *et al.* 2010, Galindo-Cortés *et al.* 2019, Salas *et al.* 2019a). In general, little attention has been given to the socioeconomic factors and fishing strategies of users to understand their operational dynamics and seek ways to implement management schemes and strategies that are viable in relation to the context of the analyzed fisheries (Tzanatos *et al.* 2006, Ramírez-Rodríguez & Ojeda-Ruíz 2012, Leslie *et al.* 2015, Saldaña *et al.* 2017, Coronado *et al.* 2020a).

Study site and sources of information

We collected data for this study during monthly monitoring campaigns conducted in Rio Lagartos (Yucatan) and Puerto Morelos (Quintana Roo), during 2017 and 2018 (Fig. 1).

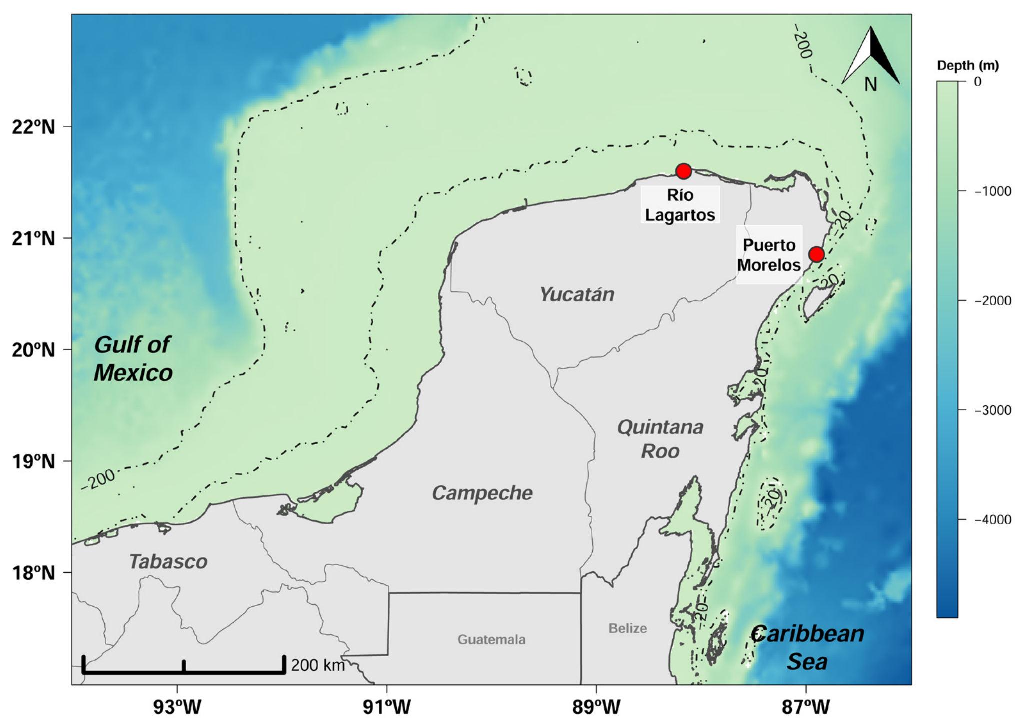

Fig. 1. Study area where the communities of Rio Lagartos Yucatan and Puerto Morelos, Quintana Roo are located (Image: Own design).

During the monthly visits, we got information from the fishing trips that arrived on the days of the visit and interviewed the captains of the vessels, obtaining data on the fishing gear used, the costs of the trip (in Mexican pesos, MX$), the time of the fishing trip (hours), and the number of crew members collaborating on the trip. Additionally, for each fishing trip, species were identified and volume per species (kg) recorded, and the beach price (price paid to the fishers) of those species (MX$/kg) was documented, including monthly variations in the prices if applicable. Interviews and data collection took place at the time of arrival of the boats and landing of the product at the docks or collection centers of the fishing cooperatives.

With the information collected, databases per community were integrated, comprising a total of 450 fishing trips in both ports during the study period. A matrix with information on those fishing trips was integrated. The number of trips analyzed is heterogeneous among localities, due to factors such as, the size of the fleet in each place, the number of boats that arrived at port on the day the research team was in the community (one or two days per month), the volume of catch per boat, and the willingness of the captains to accept the interviews were also important. The fleet of the only fishing cooperative in Puerto Morelos is composed of 13 vessels, while in Rio Lagartos there are two fishing cooperatives comprising about 250 vessels. Information from the entire fleet was not obtained because of its size and the wide dispersion of its arrival sites; the sampling effort was focused on the fishing cooperatives.

Data Analysis

The contribution of the different species to the catches was calculated to estimate the species composition associated with the fishing gear used, and average values of total catch (kg), fishing effort in hours of trip, average trip costs, total revenues derived from the fishing day expressed in pesos (MX), and the Quasi-rent per trip (MX).

To estimate the net income per trip, hereinafter referred to as Quasi-rent, we first calculated the total revenues (TR) generated in the fishing trips per boat (*j*) considering the monthly data (*t*) collected in the field. To do this, the catch volume (kg) of each species was multiplied by its respective price, using average prices per month per species (*1 to n*).

$$TR_{jt}=(CSp_{1jt}*PSp_{1jt})+(CSp_{2jt}*PSp_{2jt})+(CSp_{3jt}*PSp_{3jt})+\ldots(CSp_{njt}*PSp_{njt}) \quad \text{eq. 1}$$

Where: TR_{jt} = total revenues per $boat_j$ in the $month_t$; CSp_{1jt} = $Species_1$ average monthly catch; PSp_{1t} = Average monthly price of $species_{1t}$

Monthly travel total costs per trip of boat j (TC_{jt}) included: fuel costs (FC_{jt}), bait costs (BC_{jt}), and food for fishers' costs (F_{jt}).

$$TC_{jt} = FC_{jt} + BC_{jt} + F_{jt} \quad \text{eq. 2}$$

The Quasi-rent (QR_{jt}) per trip per boat *j* in time *t*, was estimated according to the following function. The calculation was made by each fishing community.

$$QR_{jt} = TR_{jt} - TC_{jt} \quad \text{eq. 3}$$

For the identification and characterization of the operational fishing units, following the approaches of Salas *et al.* (2019a), *a priori* the fishing gears were associated with the target species considered as *métier*, so an information matrix was generated with the relevant variables for each fishing community (Fig. 2). An exploratory analysis allowed to see the association between species and fishing gear used by fishers through a Principal Component Analysis (PCA).

The second analysis involved the integration of all fishing trips to group them in relation to similar characteristics based on fishing gear (*i* gear) and the variables: species caught, income per trip (Quasi-rent), gear, and fishing time (Fig. 2). Here it was assumed that fishing trips with similar characteristics should be associated, which was considered as a group (*métier*) that could potentially help define fishery management units (FMU). To do so, a Hierarchical Clustering Analysis on Principal Components (HCPC) was performed. According to Husson *et al.* (2010), this analysis can corroborate and describe the similarities between study individuals, in our case, fishing trips according to similar characteristics, in terms of the selected variables.

To ascertain the appropriate number of dimensions or PCs, the Kaiser criterion was used, which

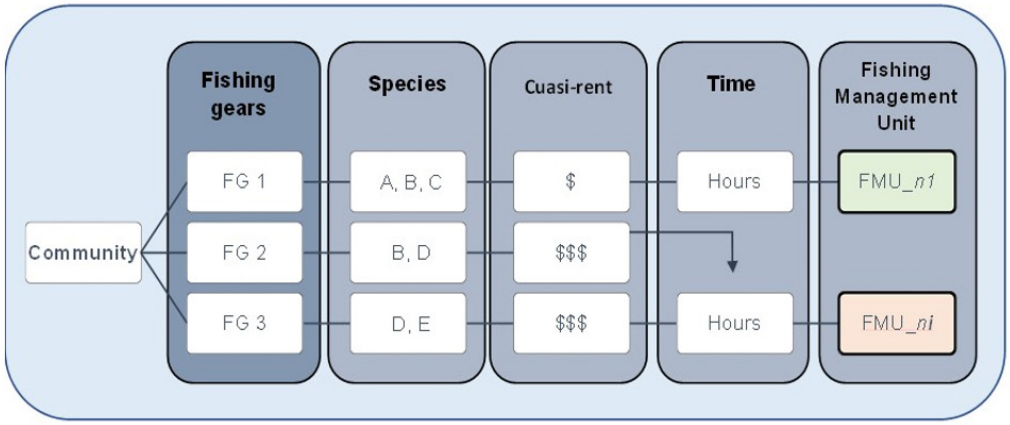

Fig. 2. Scheme for the configuration of fishery management units using fishing gear, species caught, economic income, and fishing time as attributes of analysis.

is based on the choice of all PCs with an eigenvalue >1 (Abdi & Williams 2010). The percentage of total variance explained was also considered; in this case, the number of PCs that together explained 70% or more of the observed variability was selected (Abdi & Williams 2010). The HCPC was run using Wards' method, based on multidimensional variance or inertia (Lê *et al*. 2008, Husson *et al*. 2010). The number of groups was chosen based on the general shape of the generated tree, this given by the optimal level of splitting suggested by the HCPC function (Husson *et al*. 2010). The resulting groups were labeled as Fishery Management Units (FMU).

To characterize each group, a hypergeometric v-test was performed according to the function proposed by Lê *et al*. (2008) and Husson *et al*. (2010). The test generates a score to evaluate the contribution of the analyzed variables. Variables with values of 1.96 and $p < 0.05$ are those that best represent the group, in this case FMU. The HCPC was performed through the hierarchical principal component clustering function (HCPC) of the FactoMineR library (Lê *et al*. 2008) of the R programming language (R Development Core Team 2019).[1] Finally, each identified group was considered as a *métier*/FMU and the average value of the variables within these groups was plotted to visualize the different patterns of operation.

1. R Development Core Team. 2019. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing.

Results

The results of the study are described below, separately for each of the fishing communities to discuss similarities and differences; later the results in relation to the implications for fisheries assessment, monitoring and management of artisanal fisheries in general and in the region are discussed.

Fishing gears/methods associated with target species

a) Rio Lagartos, Yucatan

In Rio Lagartos, information from 383 fishing trips was analyzed, where the use of six fishing gears was recorded during the study period. In this case, 54 different species were identified, but six stand out for their contribution to the catches and Quasi-rent including among the most important sea cucumber, octopus, hogfish, and lobster; those species that contributed less than 10% of the catches were included in a group named "others" (Fig. 3, Table 1). The fishing gears/methods recorded were used as the basis for the *a priori* definition of the respective *métier*/management unit as indicated earlier, including: *1)* pole, *2)* hookah (method/gear), *3)* jimba, *4)* fishing rode, *5)* longline, and *6)* nets. The fishing gears and species associated with the use of these fishing gears/methods are presented in *table 1*.

For the octopus' group, only *O. maya* was recorded, for lobster, *P. argus*, in the case of grouper, several species of the Serranidae family were included in the landings, where red grouper *Epinephelus morio* (Valenciennes 1828) stands out. The hogfish

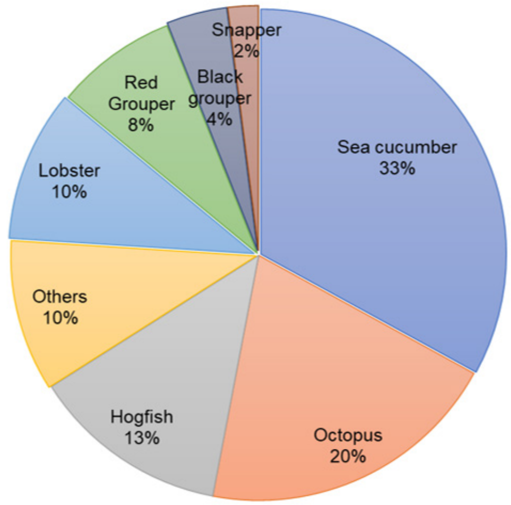

Fig. 3. Catch composition of landings of the small-scale fleet that operated in Rio Lagartos between 2017 and 2018.

Table 1.

Configuration of *métiers* in Rio Lagartos, Yucatan (RL) considering fishing gears and associated species captured by the artisanal fleet. RL (Rio Lagartos) and the following initials refer to the fishing gear/method

Métier /Gears	**RL_FR Fishing rod**	**RL_HHookah**	**RL_Ji Jimba**	**RL_Li Line**	**RL_HL Longline**	**RL_N Nets**
Depth (m)	50-100	3-30	50-100	50-100	80-180	12-50
Species	Catch composition (%)					
Sea cucumber		49.37				
Lobster		11.01				
Red Grouper		8.78	0.36	10.14	46.04	
Octopus		9.35	98.70			
Hogfish		16.2	0.55			
Black Grouper	48.04	1.26		23.07	4.00	
Others	51.96	4.03	0.40	66.78	49.97	100.0

(*Lachnolaimus maximus* (Walbaum 1792)) was observed in most of the landings in both fishing communities; this species has been increasing through the time across the region, especially when groupers decline, and its high price is also an incentive to catch it. Black grouper *(Mycteroperca bonaci* (Poey 1860)) was one of the largest and most expensive species landed. The fishing rod is a fishing gear that was introduced since 2016, as reported by fishers, and generally captures large fishes. This gear is generally used for recreational fishing, but its use in Rio Lagartos seems to be increasing for commercial fishing; it is selective towards large fishes that fetch a good price such as the gag (*Mycteroperca microlepis* (Goode & Bean 1879)) and the black grouper (*M. bonaci*).

The group of *others* includes species such as small sharks, Atlantic chub mackerel, and little tunny, as well as other demersal fishes such as speckled hind grouper (*Epinephelus drummondhayi* (Goode & Bean 1878)), mutton snapper (*Lutjanus analis* (Cuvier 1828)), grey snapper (*Lutjanus griseus* (Linnaeus 1758)), cubera snapper (*Lutjanus cyanopterus* (Cuvier 1828)), and a mixture of species known locally as *virula*. This last group includes organisms that due to their size are not accepted in the cooperatives or reception centers or that receive a low price because they are a mixture of low-value species; these species can be commercialized locally in restaurants or can be used for self-consumption.

The PCA performed considering the fishing gears and target species for Rio Lagartos explained 82.67 % of the total inertia in the first three dimensions of the PCs identifying four groups; the eigenvalues for each case were PC1 = 3.19 and PC2 = 1.35. These results show the mixture in the use of some fishing gears and the clear association between the fishing gears/methods used and the species caught. The following stand out: *1) jimbas-pulpo* with a high selectivity of fishing gear towards one species, and *2)* hookah targeting a diversity of species, but concentrating on species of high economic value (sea cucumber, lobster, anchovy, grouper, and black grouper) *3)* the use of lines (handline) and longline showed low selectivity, thus catching a mixture of species *4)* nets are generally used to fish for a combination of species, including sardine for bait and other fish that can be sold locally in restaurants. The results graphically illustrate the gear and species association referred to (Fig. 4, Table 1).

Integrating quasi-rent into the operational units

The hierarchical analysis that integrated in addition to species other variables associated with fishing operations, generated three groups or clusters instead of four as in the case of the

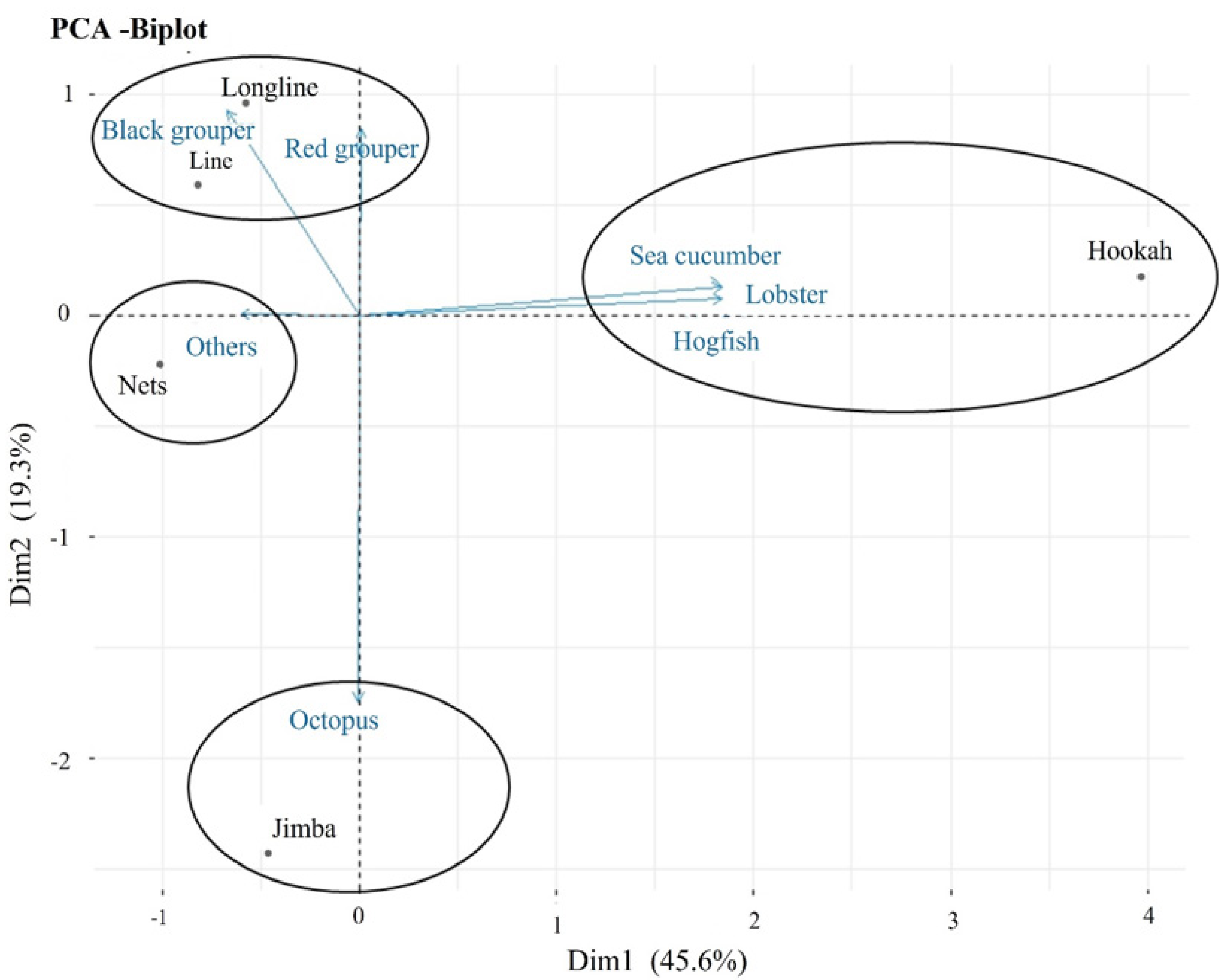

Fig. 4. Principal component analysis that integrates the relationship between fishing gears and target species in Rio Lagartos, Yucatan (Accumulated variance in percentage terms: PC1 = 46% y PC2 = 19.9%)

PCA, which shows that when adding Quasi-rent among the variables in the analysis, the grouping was allocated differently. These groups were defined in this study as Fisheries Management Units (FMUs) of the Rio Lagartos community (Fig. 5). The partitioning into the groups was confirmed by the results of the cluster diagram produced with the set of variables considered in the analysis, which explained 46% of variance in the first two dimensions; 70% of variance explained was reached in dimension 4.

Each of the three groups identified in the Rio Lagartos community were defined as Fisheries Management Unit_Rio Lagartos 1 (FMU_RL1), Fisheries Management Unit_Rio Lagartos 2 (FMU_RL2), Fisheries Management Unit_Rio Lagartos 3 (FMU _RL3). The characteristics of the variables in the FMUs are presented in *table 2*, including the average values of these variables.

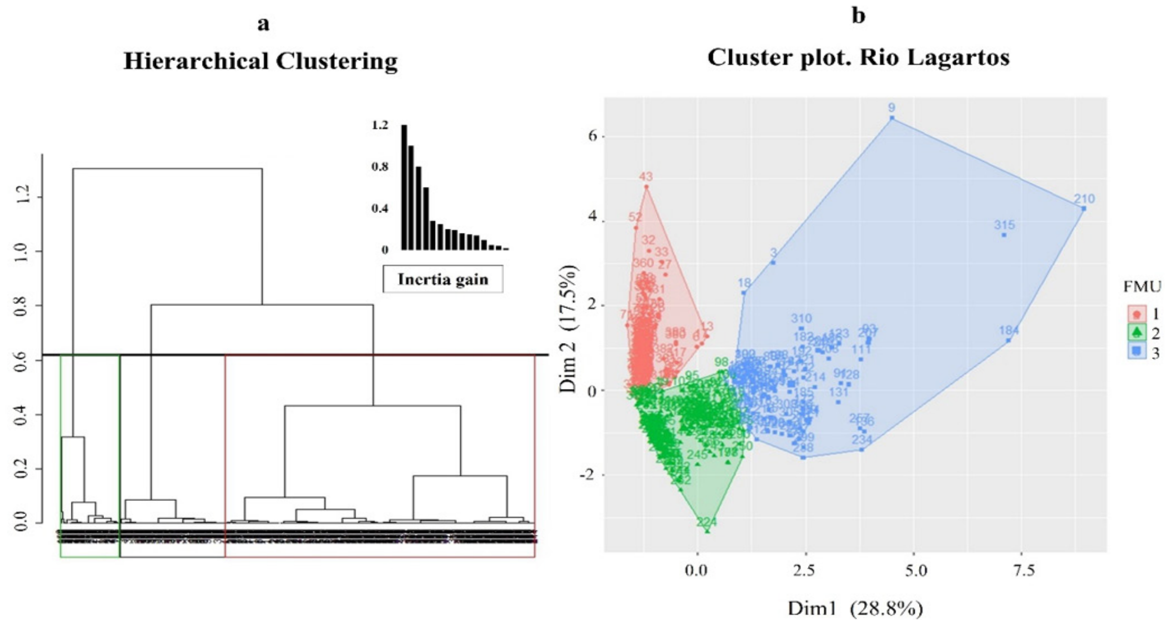

Fig. 5. Resulting hierarchical clustering for the Rio Lagartos community. a) dendrogram resulting from the HCPC, b) integration of Fishery Management Unit (FMU) depicted in a cluster plot. Red = FMU 1, Green = FMU 2; Blue = FMU 3.

Table 2.

Characteristics of the three fishery management units identified in the community of Rio Lagartos. The gears included in the management unit and the average value of each variable are shown. Notation of FMU has been referred in the text

FMU	FMU_RL1	FMU_RL2	FMU_RL3
Gears	**Hookah/Fishing Rod, Net**	**Jimba, Lines, Nets**	**Hookah and line, Line, Fishing Rod**
Catch (kg)	41.42	20.86	33.34
Crew (No.)	2.0	2.0	2.0
Costs/trip ($MX)	812.03	709.24	829.14
Quasi-rent/ Trip ($MX)	2 591.44	1 828.35	5 863.98
Time (hr)	10	8	8
CPUE (Kg/hr)	4.14	2.6	4.16

The results of the v-test and the dominant species representing each group are presented in *Appendix I*.

The FMU_RL1 grouped fishing trips that were identified using the hookah system in combination with other fishing gear such as the fishing rod. On average this FMU presents the highest catch volume and associated with the capture of sea cucumber, it registers the longest operation time with an average of 10 hours per trip during the study period (Fig. 6). FMU_RL2 encompasses fishing trips characterized using *jimbas* that catch octopus; this group showed the lowest average CPUE and Quasi-rent (Table 2). Trip costs ranged between $700 and $800 MX$ per trip in most cases, however, the highest Quasi-rent was reflected in FMU_RL3 defined by a high price of the species caught. The lowest catch per average unit effort (CPUE) corresponded to FMU_RL2 (Table 2, Fig. 6), which showed less diversification in the species captured.

The FMU_RL3, grouped fishing trips where the most common gear used was the longline, reporting a mixture of species (finfish, defined locally as *escama*), among them the black and red grouper stood out, although this group did not record the highest catch volume, it did record a higher Quasi-rent with respect to the other two identified groups (Fig. 6).

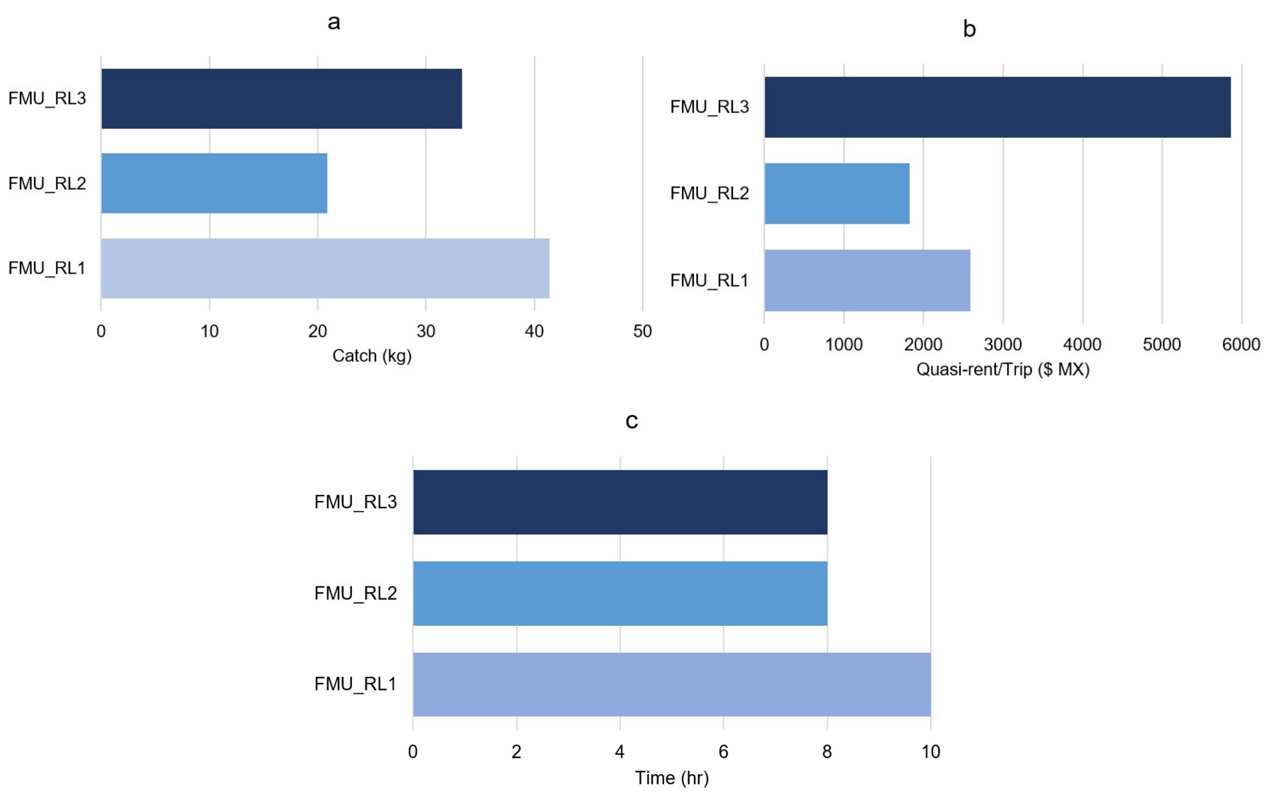

Fig. 6. Average values reported for each of the three fishery management units (FMU) identified in the community of Rio Lagartos. *a)* total catch (kg/trip), *b)* quasi-income per fishing trip (MX$/trip), *c)* average fishing time (hours/trip).

b) Puerto Morelos, Quintana Roo

In the community of Puerto Morelos, 67 fishing trips were analyzed, where 82 species in total were recorded in the landings, but five species dominated; like in Rio Lagartos, those species that contributed less than 10% of the landings were integrated into the group named "others".

During the study period, the use of four fishing methods/gear were recorded, including: *1)* line/string, *2)* longline, *3)* rosary, and *4)* snorkeling and free diving. The groups defined as *métiers* a priori included these fishing methods/gear. As can be seen in *table 3*, diving and longlining were the gears that recorded the most species in the catches; snappers were caught with all gears.

Puerto Morelos is a community where tourism dominates and the cooperative's fleet is small, in some months when the cooperative was visited it matched with bad weather and the fishers did not go out fishing, so there were no data records and the number of trips incorporated in the data analysis of this community includes fewer trips than in the case of Rio Lagartos. The species recorded that made the greatest contribution to catches include different species of snappers, red snapper, lobster, different species of groupers, as well as a mixture of other species as shown in *figure 7*.

Table 3.

Métier configuration using fishing gear and associated species in the community of Puerto Morelos (PM). Species associated with the fishing gear and their catch contribution (%) are shown. PM (Puerto Morelos) and the following initials refer to the fishing gear/method

Métier/Gear	PM_Li Line	PM_HL Hook /Line	PM_Ro Rosario	PM _S SCUBA
Depth (m)	**20-40**	**40-100**	**100-150**	**9-25**
Catch composition (%)				
Hogfish		2		**25**
Lobster				**27**
Snappers	11	40	13	**5**
Groupers		10		
Red hind	16	12		**8**
Others	73	36	87	**35**

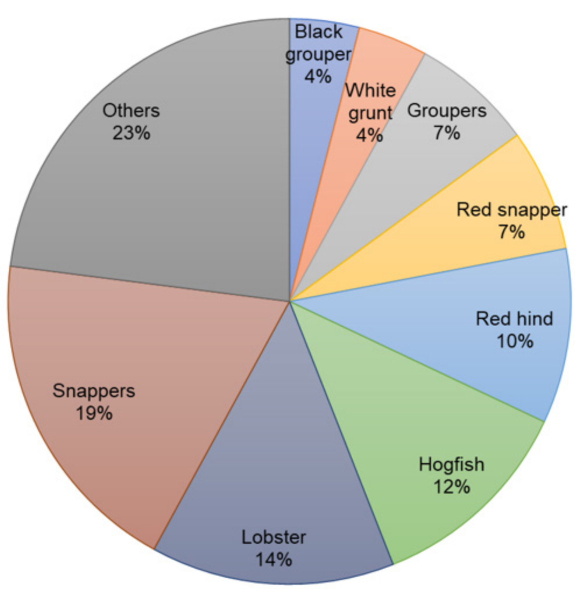

Fig. 7. Catch composition of landings of the small-scale fleet that operated in Puerto Morelos between 2017-2018.

The group of others (Table 3) includes yellow jack and blue runner, lionfish, blueline tilefish, jack mackerel, vermilion snapper, great barracuda, triggerfish, margate, and triggerfish fillet and other species used for this purpose that could not be identified (Table 3, Appendix II).

The PCA carried out considering the fishing gear and target species for the community of Puerto Morelos explained 94% of the total inertia in the first two dimensions of the PCs, showing association between fishing gear and species caught and showing two dominant groups, where diving associated with the capture of lobster (*P. argus*) and longline associated with the capture of various species of snappers stick out. Rosary, apnea, and line included few recorded trips and were separated from the scuba. The red grouper and the red hind (*Epinephelus guttatus* (Linnaeus 1758)) were the main species in this group, in addition to the rock hind (*Epinephelus adscensionis* (Osbeck 1765)), and coney (*Cephalopholis fulva* (Linnaeus 1758)) (Fig. 8)

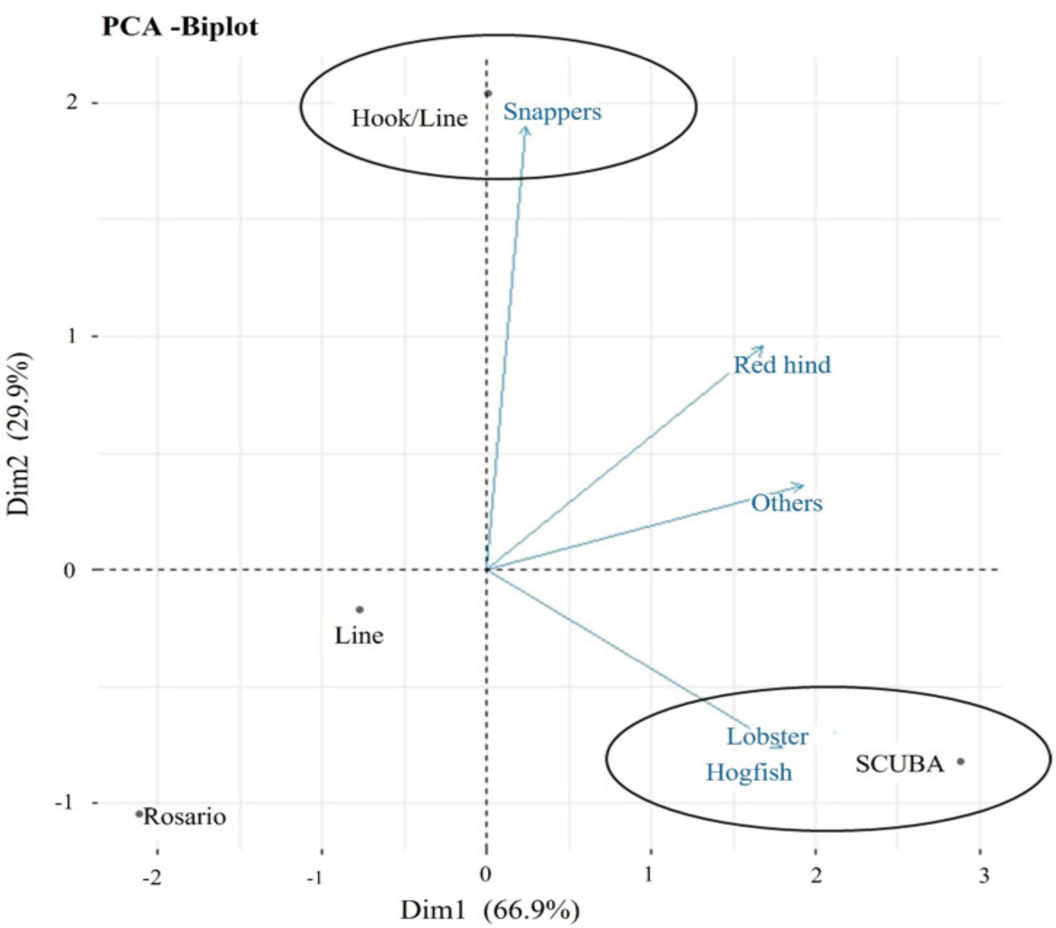

Fig. 8. Principal component analysis, fishing gear and target species in the community of Puerto Morelos (Percentage of variance accumulated in the first two dimensions of the PCA, PC1 = 66% and PC2 = 29%).

Incorporating economic contribution

The hierarchical analysis formed three groups or clusters, which were designated as the FMUs of the community of Puerto Morelos (Fig. 9). The partitioning into these groups was confirmed by the results of the clustering diagram produced with the set of variables considered with 54% of variance explained in the first two dimensions; seventy percent of the variance was reached in dimension 3.

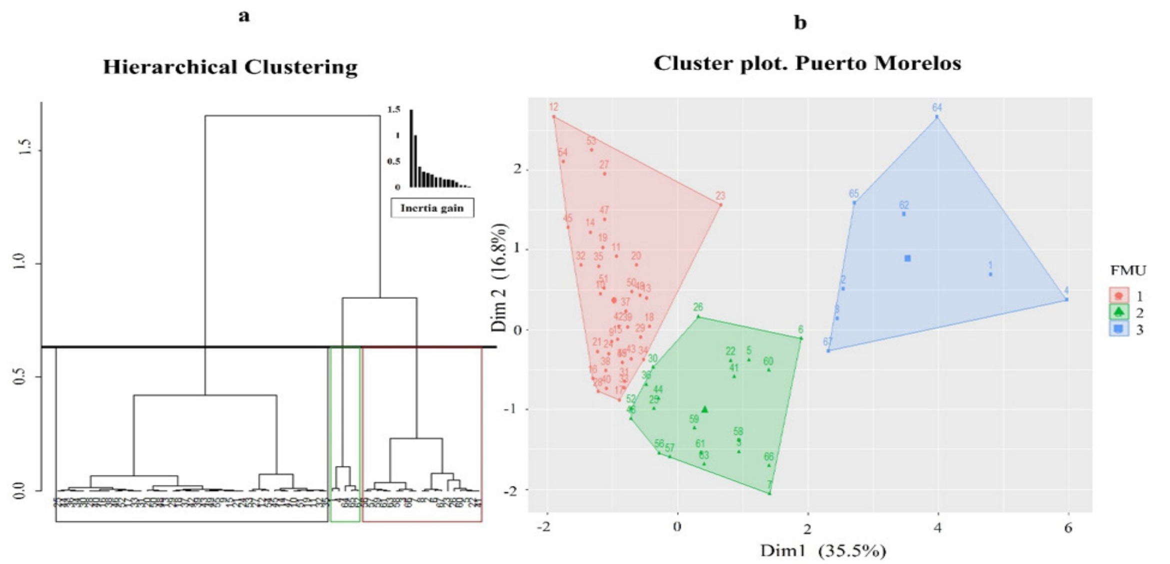

Fig. 9. Resulting hierarchical clustering for the community of Puerto Morelos, *a)* dendrogram resulting from the HCPC, *b)* shaped groups (FMU) shown in a cluster plot. Red = FMU 1, Green = FMU 2; Blue = FMU 3.

The three groups identified in the community of Puerto Morelos were named as Fisheries Management Unit Puerto Morelos 1 (FMU_PM 1), Fisheries Management Unit_Puerto Morelos 2 (FMU_PM2), Fisheries Management Unit Puerto Morelos 3 (FMU_PM3). The values of the variables in these FMUs are presented in *table 4*. FMU_PM1 grouped fishing trips characterized using scuba, highly selective for lobster; anchovy was included in the catches, but direct recording by on board observes indicated this as a bait captured with nets in the transit to the fishing grounds of lobster. These trips reported the lowest average catch volume, the second highest Quasi-rent value, and the shortest trip time compared to the other FMUs in this community. FMU_PM2 grouped fishing trips that were characterized using a diversity of gears that employ lines, including lines/string, rosary and longline, where the catch is diverse but mainly associated with low value species of demersal fishes (Table 4, Fig. 10).

FMU_PM3 grouped fishing trips associated with the use of longline and free diving, in these fishing trips a high catch volume, higher economic benefits, and longer trip duration were reported, compared to the other FMUs identified in this community. This management unit shows snapper and red grouper as its main targets (Fig. 10). The results of the v-test and the species that represent each of the groups are presented in *Appendix III*.

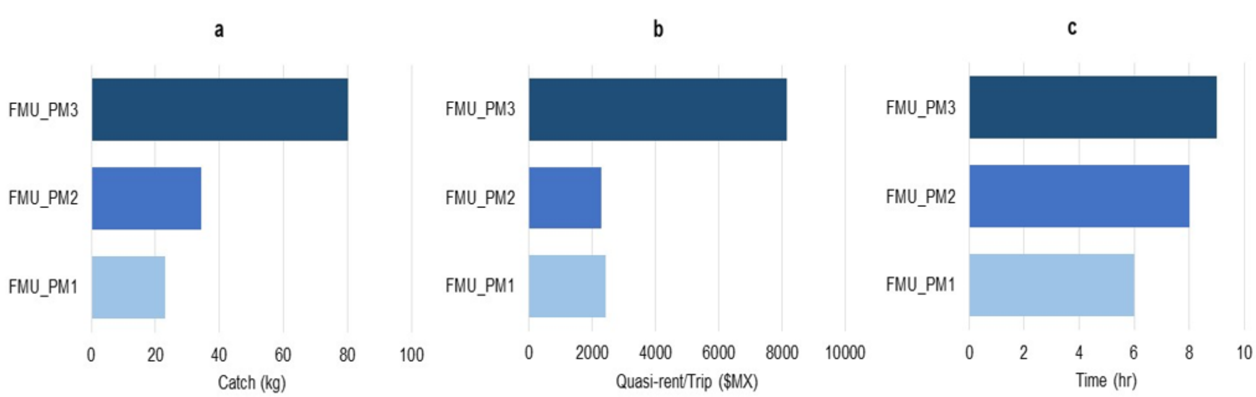

Fig. 10. Average values of some variables associated with the FMUs identified in Puerto Morelos community: *a)* catch (kg/trip), *b)* Quasi-rent per trip ($MX), *c)* Average time (hrs/trip).

Table 4.
Characteristics of the FMUs identified in the community of Puerto Morelos. Gears included in the management unit and the average value of the variables associated with the operating characteristics are shown

FMU	FMU_PMl	FMU_PM2	FMU_PM3
Gears	**SCUBA**	**Line, Rosario* Hook and line**	**Hook and line**
Catch (kg)	22.9	34.4	80.2
Crew (No.)	3.0	3.0	4.0
Costs/trip ($MX)	771.0	681.9	1 119.0
Quasi-rent/Trip ($MX)	2 439.91	2 296.5	8 158.3
Time (hr)	6.0	8.0	9.0
CPUE (Kg/hr)	3.8	4.3	8.9

*Rosario is a modified gear of the hook and line by adding hooks to increase exposition and expand effort.

c) Contrast between fishing comunities

In both communities, three groups defined as FMU were obtained by incorporating fishing gear, species, and other variables associated with fishing operations; *table 5* illustrates the differences in the characteristics of the *métiers* or FMU observed in both communities. The crew was larger in Puerto Morelos than in Rio Lagartos where diving dominates highly; the number of tanks and dives increased in this case, but the time spent diving was less extended than in Rio Lagartos, where hookah is used for diving, although their Quasi-rent was similar.

The species that contributed the most to the Quasi-rent in Rio Lagartos include sea cucumber, lobster, black grouper, and hogfish, while in Puerto Morelos it was lobster and large fish such as red grouper. The *jimba* generated the lowest Quasi-rent in Rio Lagartos and the mix of line gears fished a diversity of species in Puerto Morelos. Although, in both cases diving is used, the method differs between localities, particularly in the study period

Table 5.
Summary of the characteristics of each métier or fishery management unit identified in two communities of the Yucatan peninsula

FMU	Gears	Catch (kg)	Crew (#)	Costs ($MX)	Quasi-rent ($MX)	Time (hr)	Dominant Species (v-test)
Rio Lagartos, Yucatan							
FMU_RL1	Hookah, Fishing rod, nets	41.42	2	812.03	2 591.44	10	Sea cucumber and Others
FMU_RL2	Jimba, Fishing rod, nets	20.86	2	709.24	1 828.35	8	Octopus
FMU_RL3	Hook & Line, Line, Fishing rod	33.34	2	829.14	5 863.98	8	Grouper, Hogfish, Black grouper, Lobster
Puerto Morelos, Q. Roo							
FMU_PM1	SCUBA	22.97	3	771.00	2 439.91	6	Lobster and y Hogfish
FMU_PM2	Line, Rosario, Hook and Line	34.44	3	681.98	2 296.48	8	Others
FMU_PM3	Hook and Line	80.21	4	1 119.00	8 158.30	9	Snappers, Red hind, Others

the cucumber concentrated a large part of the fishing effort in Rio Lagartos during the study period. It should be clarified that, despite the moratorium for sea cucumber was defined since 2015 (DOF 2015), it was until 2018 when government and fishers came into agreement to the establishment of an indefinite closure of this fishery due to the high fishing pressure recognized as a problem that was affecting the resource and generating conflicts in different fishing communities.

On the other hand, it is worth to point out that the use of longlines proved to be economically efficient in both communities, and it is one of the most utilized fishing gears in these communities and across the coast of the Yucatan peninsula.

Discussion

Fishing operations and management units

Several authors refer that fishers' adaptive strategies respond to regulatory schemes, market demands, and resource behavior, reflected in their forms of operation (Cambiè *et al.* 2017, Saldaña *et al.* 2017, Coronado *et al.* 2020b). These operational processes generally occur seasonally. Ulrich & Andersen (2004) and Salas *et al.* (2019a) state that those adaptive processes are developed by fishers to balance the volume and value of the available species to which they have access, to maintain stable income from their activity. These processes were evident in the case studies presented here, where a certain selectivity of fishing gear was observed, such as the *jimbas* for octopus in the case of Rio Lagartos, as well as the rosary and the fishing rod to capture large demersal fishes with a higher price, resulting in higher fishers' profits. The catches obtained by diving showed to be more diverse in catch composition, but targeted species that fetch high prices, while the line and hook gears, caught a mix of species, which, although not high priced, in volume compensated for the revenues obtained from the trips. This diversification of fishing strategies is what maintains the activity of the artisanal fleet.

Smith and McKelvey (1986), as well as Salas (2000), refer to generalists and specialists fishing strategies. In the first case, diversification of species is observed to compensate catch volume for value, *i.e.*, multiple low-value species can be included in the catch, which as a whole and in volume compensate for trip costs, generating the expected income (Smith & McKelvey 1986, Coronado *et al.* 2020b). On the other hand, some fishers may concentrate on higher value species, even if this demands special skills such as diving, or going to specific fishing grounds (Salas *et al.* 2004; Cambiè *et al.* 2017, Saldaña *et al.* 2017, Salas *et al.* 2019b). In this study it was possible to identify both types of strategies. Adaptive strategies of fishers have been reported previously in the area (Salas *et al.* 2004, Monroy *et al.* 2010, Saldaña *et al.* 2017, Quijano 2018). As described above, fishers showed high economic dependence derived from the capture of few profitable and highly demanded species, these exploited populations are highly vulnerable, being subject to increasing fishing pressure.

This study highlighted the concentration of diving effort on sea cucumbers in Rio Lagartos during the study period, which stop due to a moratorium defined to control the overexploitation conditions of the stock. Several authors have mentioned that due to the biological characteristics and low mobility of holothuroids, the existence of exploitation patterns with high levels of fishing effort is alarming for these species, running the risk of unsustainable fisheries (Purcell *et al.* 2018, López-Rocha & Velázquez-Abunader 2019). This resource went from being the target species that supported an FMU in Rio Lagartos before 2017 to being listed as a species at risk and a moratorium for the fishing activity.

For the case of octopus, the selectivity of the *jimba* and its effectiveness in ensuring the sustainability of the resource has been reported by several authors (Velázquez-Abunader *et al.* 2013, Duarte *et al.* 2018, Avendaño *et al.* 2019, López-Rocha *et al.* 2021). In this *métiers* study, a selective management unit defined by *jimbas* was identified and hence confirm previous reports regarding selectivity of the authorized gear for this fishery. Nonetheless, the use of diving for octopus' extraction was observed occasionally, which could affect not only the resource, but even the commercialization processes, given that the fishery is being evaluated for certification (Coronado *et al.* 2020b). This fishery is an important contributor of volume and value at the local, national, and international levels, and greater vigilance is required to reduce these practices and eventually eliminate them.

It is also worth noting, that in Rio Lagartos some boats defined as travelers, which spend between two-three days fishing; this autonomy increases their potential catch volumes and hence economic performance. However, in terms of safety, they require attention, as trips of this duration with artisanal boats can be particularly risky for fishers, especially if they do not have safety equipment (Salas *et al*. 2011) or in cases where diving is employed with long hours of immersion, as reported in the case of the sea cucumber fishery (Huchim-Lara 2015, Salas *et al*. 2019b). During the study period, low catches of octopus resulted in Rio Lagartos due to the great attraction towards sea cucumber, more recent years have reported higher volume of octopus in the region (Ramos *et al*. 2021).

Identifying management units for artisanal fishing

Although in Yucatan and Quintana Roo, some resources are shared and the management schemes for some fisheries are common, the lessons learned during this study on how the artisanal fleet in the communities analyzed operates, displays similarities and differences mirrored in their fishing patterns, resulting in differences in *métiers* or FMU identified in each community. It is assumed that these differences respond to adaptations in fishing operations based on the availability of resources, biogeographic conditions, and the skills and preferences of fishers regarding the use of different fishing gears and methods. This diversity in fishing patterns observed in the area has been reported by several authors, both in semi-industrial (Monroy *et al*. 2010, Quijano *et al*. 2018) and artisanal fisheries (Salas *et al*. 2004, Saldaña *et al*. 2017) or a combination of them (Salas *et al*. 2019a). Although, the information generated seems complex, once these units are identified it is easier to summarize, analyze, and understand (Ulrich *et al*. 2012, Cambiè *et al*. 2017). Although it demands detailed information that is not always easy to obtain, due to logistics or economic problems when developing assessment and monitoring plans.

This research shows the relevance of the fishing gears used in their association with the target species for the definition of FMUs, but also highlights the differences between these units, considering other variables associated with fishing operations that have to do with fishing time and travel costs, which will ultimately be reflected in the Quasi-trip rent. The economic component associated to the fishers' operations has been highlighted by several authors (Salas & Charles 2008, Caddy 2009, Coronado *et al*. 2013). As observed patterns can change over time, it is relevant to define monitoring programs that recognizes those patterns and track them; this approach can also help to adapt management programs when required.

It is worth noting here, that the *jimbas* showed high selectivity for octopus's capture, confirming the claims of Duarte *et al*. (2018) regarding the advantages of using this selective fishing gear in this fishery, which makes it an operational unit that can remain in a monitoring program of the resource. However, given the use of other ilegal fishing methods for the capture of the mollusk, like diving occasionally, it is important to analyze the impacts that these non-selective gears/methods could have on the population in the long term, especially if this practice tends to increase.

The use of line gears shows the diversity of species captured, and the integration of groups of species targeted seems to be associated highly by the demand of products and the value of those species, in addition to the skills of the fishers, as observed in previous studies in the area (Salas 2000, Saldaña *et al*. 2017, Salas *et al*. 2019a). Hence the revenues derived from a trip can be defined more in terms of the selection of the fishing grounds (areas and depth), time fishing, and access to the selected resources (Salas *et al*. 2004). On the other hand, the virula, provides a source of additional income if sold, or it can be for used for self-consumption, up lifting the relevance of artisanal fisheries in the coastal areas, its relevance as provision of jobs and food is evident.

Understanding artisanal fisheries through the fishing operations and management units: a change of paradigms

In the past two decades, several authors, including Caddy, have drawn attention to the ineffectiveness of using theory and models for unspecific fisheries to understand and manage multispecies fisheries (Ault *et al*. 1998, Caddy & Agnew 2004, Caddy 2009, González-Alvarez *et al*. 2016). In this frame, the ecosystem approach (Caddy & Agnew 2004, Caddy 2009, Arreguín-Sánchez 2022) became highly relevant. This approach offers a snapshot of the ecosystem and changes in the system when outputs change (catches), *i.e.*, it considers, to a large extent, the output controls used for fisheries management (catches, Caddy 2009, Hoff *et al*. 2010). Approaches such as the *métiers* employed in several regions for the case of mixed fisheries, provides an important weight to input control (*e.g.*, effort allocation). This approach allows to analyze the exploitation patterns defined by the fishing operations in place, considering several variables, such as type of fishing gear, spatial distribution of species, fishing effort associated with assemblages of resources, etc. (Tzanatos *et al*. 2006, Ulrich *et al*. 2012, Salas *et al*. 2019a). Indeed, it could be a difficult task to track the gears and methods employed in the artisanal fisheries, as it is difficult to assess the fishing effort exerted over the resources, but definition of management schemes in agreement with fishers could be easier to explain when considering their fishing strategies and dynamics, so they can be involved into the implementation of management tools.

In this line, artisanal fisheries of multiple species that operate in the coasts of Yucatan and Quintana Roo, demand attention in terms of management processes, especially because different species are caught with multiple fishing gears, therefore, as evidenced in this study, it is necessary to maintain control of fishing effort associated with fishing gear, which significantly define the groups of species landed. The list of fishing methods and gear does not exceed ten types, however, there are modifications to the designs to adapt them to the conditions of the fishing zones and the skills of the fishers (López-Rocha *et al*. 2021), therefore, regulatory measures must go beyond effort control based on fishing permits and recognize the complexity in species caught, gears, and fishing operations of the fleets working in the study area (Saldaña *et al*. 2017, Salas *et al*. 2019a, Coronado *et al*. 2020a).

The *métiers* approach allows to understand changes in fishing patterns associated with the behavior of fishers in response to changes in the fishing system such as resources, markets, and other factors of change (Salas *et al*. 2004, Ulrich *et al*. 2012, Cambiè *et al*. 2017, Saldaña *et al*. 2017). It also reports the assemblages of species caught, for instance in this study the increase of some species like *Lutjanus synagris*, that have increased in landings, but do not have specific updated stock assessments to support management decisions (Ramos-Miranda *et al*. 2021).

In this context, artisanal fisheries given their complexity, diversity, and dynamism (Salas *et al*. 2007, FAO, 2015, Chuenpagdee & Jentoft 2019) are defined in terms of exploitation patterns. The inherent complexity of artisanal fisheries, coupled with the risks faced by fishers within fishing communities, emphasize the need for attention to this fishing sector with assessment and management approaches in line with their context (Salas *et al*. 2019b).

As stated by Caddy (2009), in the review of assessment approaches for Mediterranean and Black Sea fisheries, the type of data defines the type of assessment, and the type of assessment has been defined by the type of control or management instrument, which in the fisheries analyzed here have been sustained by single species approaches and biased input-control tools (fishing permits; with limitations in records). The lack of detailed information on fishing operations at the level of fishing communities and with limitations to account for input-control information (fishing effort), this situation has generated restrictions to employ different evaluation and management approaches, such as the case of *métiers*. To be able to keep with these approaches, it is necessary an adjustment in field monitoring programs to collect relevant information in space and time, that allow different assessment approaches as well allowing to follow up relevant variables of changing processes. All this will help to adjust the management schemes associated with the resources exploited by the artisanal fleets, especially given the multispecies nature of these fisheries. The implementation of such strategies could be better supported if the context of the fishery is recognized and if the information associated to these complex fisheries can be disentangled for better understanding. It is also relevant to involve stakeholders in the monitoring programs which can facilitate the access to more precise information and the buy-in the implementation of management programs (FAO 2014, 2017, González-Alvarez *et al*. 2016, Fulton *et al*. 2019).

There are information gaps that need attention to be filled in (no-assessed resources, social and economic data, and governance issues) to strength management capacities to deal with complex multispecies artisanal fisheries. In this sense, the *métiers* approach helped in this study to identify management units and the results are encouraging to promote a change of paradigms in the region, moving from a resource-based approach to a more comprehensive approach, recognizing the complexity of the species assemblages targeted by the fleets, allowing to disentangle groups within the fisheries systems that are easier to characterize and understand, thus facilitating management processes.

Finally, it is worth to mention that the integration of information on exploitation patterns and their ecological, technological, social, and economic components, are fundamental to support decision making, but it this necessarily demand for a systematic, comprehensive, and transdisciplinary evaluation of the fisheries, requiring expertise from different disciplines.

Conclusions

- Several authors refer to the importance of considering the diversity of gears and species exhibited in fishing operations when evaluating artisanal fisheries. The differences between the Yucatan and Quintana Roo communities are evidenced by this analysis.
- The results obtained, made it possible to identify patterns of operation, considering fishing gear, target species, economic benefits, and travel time. These groupings help to describe the fishing activity, in terms of the characteristics of operation and use of resources in the analyzed fishing communities, highlighting the complexity and diversity of the activity of the artisanal fleets and their exploitation patterns.
- The mix of gear in the fishing journeys can be alternated according to climatic conditions for instance in the case of diving, or according to market demands as was the case of the sea cucumber boom at the end of the year the study took place. Grouper, lobster, and hogfish were common species targeted by fishers in both communities, but the gears employed and the seasonality in the use were different. Some particularities were also observed during the study period, *e.g.*, red hind was only reported in Puerto Morelos and octopus only in Rio Lagartos; octopus in Quintana Roo is captured by a semi-industrial fleet.
- This study highlights the need and relevance of reviewing the current approach to monitoring, assessment, and fisheries management, which has been mainly based on controlling the number of permits as a measure of fishing effort, which does not necessarily result in a real control of fishing pressure while it does not acknowledge the dynamics of fishing strategies of fishers and adaptation of methods and gears, that could change the fishing power.
- The results of this study are meant to be of support for decision-makers in the definition of public policy implementation and can aid to define a monitor, assessment and management programs that aligns with the observed exploitation patterns and its changes, including cases such as those of the FMUs reported here (Hookah-sea cucumber). Gathering information related to changes in key species targeted, or changes in fishers' operation patterns over time and space can be of great help to ensure sustainable and viable fisheries.
- A change of vision is needed, considering complementary approaches and tools of analysis to the current context, and defining monitoring and management programs accordingly. In addition, it is important to stress that the dynamics of the fisheries and the uncertainty that new stressors can generate impacts on the fisheries systems call for a new assessment and management vision. The methodological approach used here, allows for replication in other regions of the country or as a base to assess changes in the analyzed case studies.
- It is also worth to say the caveats the *métiers* approach and the multispecies approaches can potentially hold. The field work to obtain detailed information could be one of the limitations, hence working in cooperation with fishers is important, they can contribute with relevant data like prices, costs and personal data of their fishing trips, this could not be the case in some fishing communities as they can perceive that the studies could reveal information that could in the future go against them but gaining trust through time can make this possible. Financial support for long-term monitoring programs is relevant; this is especially important for research centers associated with the National Institute of Fisheries and Aquaculture (INAPESCA, Spanish acronym); recently this institute and others have faced a reduction in financial support for research. The implementation of management approaches derived from studies like the one presented here may not be straight forward implementable, but adaptations could be made as an approximation. Recognition of the dynamic changes that the fisheries systems are facing is necessary to make the necessary adaptation in research and management.

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Appendix 1.

Results of the v.-test for each management units identified in Rio Lagartos, Yucatán. Variables highlighted in bold represent those that represent the FMU by the significance of the variables in the analysis with values of v-test > 1.96 y p < 0.05. > 1.96 y p < 0.05

Fisheries Management Unit	*Variables*	*v-test*	*p. value*
FMU _RL1	**Sea Cucumber kg**	**14.73**	**0.00**
	Others kg	**2.66**	**0.01**
	Quasi Rent $MX	-2.51	0.01
	Red Grouper kg	-7.12	0.00
	Lobster kg	-7.23	0.00
	Octopus kg	-7.82	0.00
	Hogfish kg	-8.90	0.00
FMU _RL2	**Octopus kg**	**9.82**	**0.00**
	Red Grouper kg	-2.26	0.02
	Black Grouper kg	-2.77	0.01
	Lobster kg	-4.56	0.00
	Quasi rent $MX	-7.72	0.00
	Sea Cucumber kg	-8.88	0.00
FMU _RL3	**Lobster kg**	**13.23**	**0.00**
	Quasi rent $MX	**11.65**	**0.00**
	Red Grouper kg	**10.46**	**0.00**
	Hogfish kg	**10.43**	**0.00**
	Black Grouper kg	**4.19**	**0.00**
	Octopus kg	-2.66	0.01
	Sea Cucumber kg	-6.06	0.00

Appendix II.

Common and scientific names of species captured and recorded in Rio Lagartos (RL) and Puerto Morelos (PM)

Common Spanish name	*Common English name*	*Scientific name*	*Fishing community*
Abadejo	Gag	*Mycteroperca microlepis*	PM, RL
Anjova	Bluefish	*Pomatomus saltatrix*	RL
Armado	Pigfish	*Orthopristis chrysoptera*	RL
Balá	Southern stingray	*Hypanus americanus*	RL
Barracuda	Great barracuda	*Sphyraena barracuda*	PM, RL
Besugo, orijuelo	Vermilion snapper	*Rhomboplites aurorubens*	PM
Blanquillo	Blackline tilefish	*Caulolatilus cyanops*	PM
Blanquillo	Bankslope tilefish	*Caulolatilus dooleyi*	PM
Bonito	Atlantic chub mackerel	*Scomber colias*	PM
Bonito, bacoreta	Little tunny	*Euthynnus alletteratus*	PM, RL
Boquinete	Hogfish	*Lachnolaimus maximus*	PM, RL
Botete	Checkered puffer	*Sphoeroides testudineus*	RL
Burro	Black margate	*Anisotremus surinamensis*	PM
Burro payaso	Porkfish	*Anisotremus virginicus*	PM
Cabrilla, payaso verde	Rock hind	*Epinephelus adscensionis*	PM, RL
Calamar	Squid	*Loligo sp.*	RL
Canané	Yellow snapper	*Ocyurus chrysurus*	PM, RL
Cangrejo araña	Channel clinging crab	*Mithrax spinosissimus*	PM
Carito	King mackerel	*Scomberomorus cavalla*	RL
Cazón de ley	Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	PM, RL
Chac-chi	White grunt	*Haemulon plumieri*	PM, RL
Chac-chi dorado	Bluestriped grunt	*Haemulon scirius*	PM
Cherna	Jewfish	*Epinephelus itajara*	RL
Cojinuda amarilla	Yellow jack	*Carangoides bartholomaei*	PM, RL
Cojinuda negra	Blue runner	*Caranx crysos*	PM, RL
Conejo	Blueline tilefish	*Caulolatilus microps*	PM
Coronado	Amberjack	*Seriola rivoliana*	PM
Coronado	Greater amberjack	*Seriola dumerili*	PM, RL
Corvina pinta	Spotted seatrout	*Cynoscion nebulosus*	RL
Corvinato	Sand tilefish	*Malacanthus plumieri*	PM
Dorado	Dolphinfish	*Coryphaena hippurus*	RL
Escochin, cochinito	Ocean triggerfish	*Canthidermis sufflamen*	PM
Escochin, cochinito	Queen triggerfish	*Balistes vetula*	PM

Continues Appendix II

Common Spanish name	*Common English name*	*Scientific name*	*Fishing community*
Escochin, cochino gris	Gray triggerfish	*Balistes capriscus*	PM, RL
Esmedregal	Cobia	*Rachycentron canadum*	RL
Fiat, mero negro,	Warsaw grouper	*Hyporthodus nigritus*	RL
Gallina	Yellowmouth grouper	*Mycteroperca interstitialis*	PM, RL
Garropa	Scamp	*Mycteroperca phenax*	PM, RL
Guacamayo	Yellowfin grouper	*Mycteroperca venenosa*	PM, RL
Huachinango aleta negra	Blackfin snapper	*Lutjanus bucanella*	PM
Huachinango de castilla	Red snapper	*Lutjanus campechanus*	PM
Huachinango de seda	Queen snapper	*Etelis oculatus*	PM
Huachinango navaja	Wenchman	*Pristipomoides aquilonaris*	PM
Huachinango ojo amarillo	Silk snapper	*Lutjanus vivanus*	PM
Jaiba azul	Blue crab	*Callinectes sapidus*	RL
Jurel común	Crevalle jack	*Caranx hippos*	PM, RL
Langosta del Caribe	Caribbean spiny lobster	*Panulirus argus*	PM, RL
Langosta pinta	Spotted spiny lobster	*Panulirus guttatus*	PM
Langosta verde	Smoothtail spiny lobster	*Panulirus laevicauda*	PM
Lenguado	Peacock flounder	*Bothus lunatus*	PM
Lenguado moreno	Dusky flounder	*Syacium papillosum*	RL
Macarela	Rainbow runner	*Elegatis bipinnulata*	PM, RL
Medregal listado	Lesser amberjack	*Seriola fasciata*	PM
Mero colorado, Payaso rojo	Red hind	*Epinephelus guttatus*	PM, RL
Mero del Caribe, Cherna criolla	Nassau grouper	*Epinephelus striatus*	PM
Mero lenteja	Speckled hind	*Epinephelus drummondhayi*	PM
Mero payaso, Cabrilla roja	Coney	*Cephalopholis fulva*	PM, RL
Mero rojo	Red grouper	*Epinephelus morio*	PM, RL
Mojarra burra		*Calamus spp.*	PM, RL
Mojarra negra	Grass porgy	*Calamus arctifrons*	PM
Mojarra pluma	Knobbed porgy	*Calamus nodosus*	PM, RL
Mojarra pluma	Pluma porgy	*Calamus pennatula*	PM
Mojarrón	Jolthead porgy	*Calamus bajonado*	PM

Continues Appendix II

Common Spanish name	*Common English name*	*Scientific name*	*Fishing community*
Morena pinta	Spotted moray	*Gymnothorax moringa*	PM
Morena verde	Green moray	*Gymnothorax funebris*	PM
Negrillo	Black grouper	*Mycteroperca bonaci*	PM, RL
Ojón	Bigeye	*Priacanthus arenatus*	PM
Ojotón, macarela	Round scad	*Decapterus punctatus*	PM
Pámpano amarillo	Florida pompano	*Trachinotus carolinus*	RL
Pargo boquilla	Sailor´s grunt	*Haemulon parra*	PM
Pargo canchix	Schoolmaster	*Lutjanus apodus*	PM
Pargo criollo, lunarejo	Mutton snapper	*Lutjanus analis*	PM, RL
Pargo cubera	Cubera snapper	*Lutjanus cyanopterus*	PM
Pargo llorón, pargo perro	Dog snapper	*Lutjanus jocu*	PM
Pargo mestizo, Lamparita	Black snapper	*Apsilus dentatus*	PM
Pargo mulato	Grey snapper	*Lutjanus griseus*	PM, RL
Pargo ojón	Mahogany snapper	*Lutjanus mahogoni*	PM
Pargo ronco	Cottonwick grunt	*Haemulon melanurum*	PM
Pepino de mar café	Chocolate chip sea cucumber	*Isostichopus badionotus*	RL
Peto	Wahoo	*Acanthocybium solandri*	PM
Pez león	Red lionfish	*Pterois volitans*	PM
Pluma calamo	Saucereye porgy	*Calamus calamus*	PM, RL
Pluma jorobada	Littlehead porgy	*Calamus proridens*	PM
Pluma manchada	Sheepshead porgy	*Calamus penna*	PM
Postá	Sea bream	*Archosargus rhomboidalis*	PM, RL
Pulpo rojo	Mexican four-eyed octopus	*Octopus maya*	RL
Raya pinta	Spotted eagle ray	*Aetobatus narinari*	PM, RL
Robalo blanco	Common snook	*Centropomus undecimalis*	RL
Ronco	Tomtate	*Haemulon aurolineatum*	PM, RL
Ronco amarillo	Barred grunt	*Conodon nobilis*	PM
Rubia, villajaiba	Lane snapper	*Lutjanus synagris*	PM, RL
Sardina escamuda	False pilchard	*Harengula clupeola*	PM
Sardina rayada	Redear sardine	*Harengula humeralis*	PM, RL
Sargo	Sheepshead	*Archosargus probatocephalus*	RL
Sargo rojo, besugo	Red porgy	*Pagrus pagrus*	PM

Continues Appendix II

Common Spanish name	*Common English name*	*Scientific name*	*Fishing community*
Serrano	Saddle bass	*Serranus notospilus*	PM
Sierra	Spanish mackerel	*Scomberomorus maculatus*	PM, RL
Tintorera	Tiger shark	*Galeocerdo cuvier*	PM
Vivita de hebra	Atlantic thread herring	*Opisthonema oglinum*	RL
Vivita escamuda	Scale sardine	*Harengula jaguana*	RL
Zapatero	Margate	*Haemulon album*	PM
Zote, ronco Carbonero	Caesar grunt	*Haemulon carbonarium*	PM

Appendix III.

Results of the v-test for each management units identified in Puerto Morelos, Quintana Roo. Variables highlighted in bold represent those that represent the FMU by the significance of the variables in the analysis with values of v-test > 1.96 y p < 0.05

FMU	*Variables*	*v-test*	*p. value*
FMU_PM1	Lobster	5.99	0.00
	Hogfish	3.23	0.00
	Quasi-Rent	-2.43	0.02
	Cabrilla	-2.52	0.01
	Snappers	-3.72	0.00
	Others	-4.96	0.00
FMU_PM2	Others	3.57	0.00
	Hogfish	-2.30	0.02
	Lobster	-4.32	0.00
FMU_PM3	**Snappers**	**6.71**	**0.00**
	Quasi-Rent	**6.23**	**0.00**
	Cabrilla	**4.51**	**0.00**
	Others	2.47	0.01
	Lobster	**-2.98**	**0.00**