Productivity Susceptibility Analysis (PSA) of bycatch in Yucatan Peninsula blue crab *Callinectes sapidus* trap fishery based on observed data

Fisheries Improvement Project Mexico Yucatan Peninsula blue crab-dipnet/pot/trap

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Content

Summary

This work applies the risk assessment method known as Productivity and Susceptibility Analysis (PSA) to the crustaceans: lesser blue crab, locally known as "pata seca" (*Callinectes similis*), sharptooth swimcrab (*Callinectes rathbunae*), hermit crab (*Clibanarius vittatus*), calico box crab (*Hepathus epheliticus*), stone crab (*Menippe mercenaria*), lognose spider crab (*Libinia dubia*), and to the fish: checkered puffer (*Sphoeroides testudineus*), hardhead catfish (*Ariopsis felis*), Western Atlantic seabream (*Archosargus rhomboidalis*), lined sole (*Achirus lineatus*), jenny mojarra (*Eucinostomus gula*) & mojarra (*Diapterus rhombeus*) species that have appeared as part of the accompanying fauna in the blue crab ring trap fishery in Isla Aguada and Sabancuy (Laguna de Términos) in Campeche.

Acronyms

CSIRO	Commonwealth Scientific and Industrial Research Organización
ERAEF	Environmental Risk Assessment for the Effects of Fishing
GMFMC	Gulf of Mexico Fishery Management Council
MSC	Marine Stewardship Council
PSA	Productivity-Susceptibility Analysis
RBF	Risk-Based Framework

Introduction

Productivity-Susceptibility Analysis (PSA) is a semi-quantitative method used to assess the vulnerability of species associated within data deficient fisheries. The method has been refined by the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia, based on the method developed by Stobutzki et al. (2001) to evaluate the probability of sustainability of the species of the companion fauna in a fishery. The PSA is part of a broader hierarchical methodology developed by CSIRO, called the Environmental Risk Assessment for the Effects of Fishing (ERAEF), which can be applied to species, habitats or communities with low fishing impact (Hobday et al., 2004; Hobday et al., 2007) and has been used to assess all fisheries managed by the Australian Fisheries Management Authority (Smith et al., 2007) and it is part of the Marine Stewardship Council (MSC) framework.

Data

A preliminary list of species that have appeared within the crab traps used in the fishery was made in the samplings carried out between October 2018 and December 2019. The samplings were carried out at the Reception Center located in Isla Aguada, Campeche where fishermen

take their catches in order to sell them to the organization. Many of the organisms observed were returned to the sea alive. Not all the accompanying fauna reaches the reception center because fishermen frequently release live species caught incidentally and of no commercial interest in the fishing area. This list of species was completed with the results of interviews with fishermen carried out during the same period. The identification of the species was carried out from Ayala-Perez, et al (2015), Perry and Larsen, 2004, Raz-Guzman, 1999, the FAO guide prepared by Fischer et al 1995) and the one prepared by Carpenter, (2002). A total of 12 species were identified as bycatch.

Methodology

In order to determine the risk level for each species, a bibliographic search was carried out in order to get the information available on the species in the region. When species-specific information was not available, information from similar species within the same genus or family was used. When this was not possible, a precautionary approach was considered by assigning the highest risk value.

Productivity and Susceptibility attributes were scored based in tables 1 & 2, and on the information gathered. Trophic level attributes were obtained from Fishbase (2020), Sealifebase (2020) or any other detailed information for crustaceans.

The score for each component of the PSA was recorded in the "MSC RBF Worksheet", and rationales were included when no specific information was found.

The PSA (Figure 1) is based on the assumption that the potential risk of fishing to a species that is directly or indirectly impacted depends on two main components (Stobutzki et al., 2001; Stobutzki et al., 2002; Hobday et al., 2007; Patrick et al., 2010; Hobday et al., 2011; Clarke et al., 2018):

- Its natural productivity, related to the recovery capacity of the species. This attribute is associated with the biology and ecology of the species..
- Its susceptibility to being fished, which reflects how exposed it is to fishing activities. This component is related to the characteristics of both the fishing gear and the spatial distribution of the fishery in relation to its natural distribution in the area.

The potential risk associated with the productivity or susceptibility of a particular species was determined with the tools provided by MSC (v 2.1) for applying the RBF.

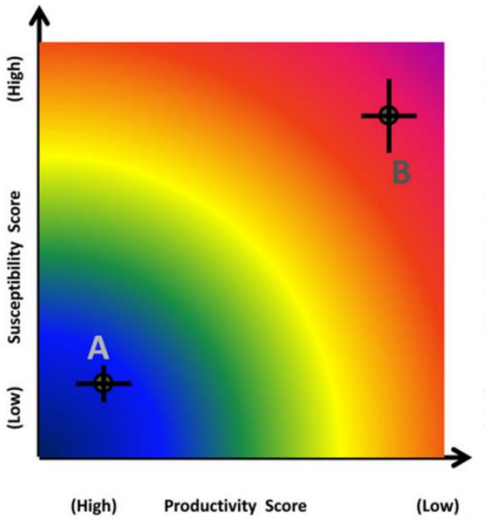

Figure 1. PSA graph with productivity and susceptibility axes, and the risk space divided into regions. If the vulnerability is <1.80, the risk is low; if the vulnerability is between 1.80 and 2.20, the risk is medium; and if the vulnerability is> 2.20, the risk is high. The graph has been modified from Stobutzki et al. (2001b), inverting the productivity scale that starts with 3 (high productivity) instead of 1 (low productivity).

The PSA considers eight productivity attributes: average age at maturity, average size at maturity, average maximum age, average maximum size, fecundity, reproductive strategy, trophic level and density dependence (only for invertebrates). The average maximum age and average maximum size are not used for the evaluation of invertebrates. For each of these attributes there are ranges associated with different levels of productivity as presented in Table 1. If the level of productivity associated with the attribute is high, a score of 1 (low risk) is given; if it is medium, 2 (medium risk); and if it is low, 3 (high risk).

Table 1. PSA productivity attributes and scores (from MSC V 2.0)

Productivity attribute	High productivity (Low risk, score = 1)	Medium productivity (medium risk, score = 2)	Low productivity (high risk, score = 3)
Average age at maturity	<5 years	5-15 years	>15 years
Average maximum age	<10 years	10-25 years	>25 years
Fecundity	>20,000 eggs per year	100-20,000 eggs per year	<100 eggs per year
Average maximum size (not to be used when scoring invertebrate species)	<100 cm	100-300 cm	>300 cm
Average size at maturity (not to be used when scoring invertebrate species)	<40 cm	40-200 cm	>200 cm
Reproductive strategy	Broadcast spawner	Demersal egg layer	Live bearer
Trophic Level	<2.75	2.75-3.25	>3.25
Density dependence !! (to be used when scoring invertebrate species only)	Compensatory dynamics at low population size demonstrated or likely.	No depensatory or compensatory dynamics demonstrated or likely.	Depensatory dynamics at low population sizes (Allee effects) demonstrated or likely.

In the case of susceptibility, there are four attributes: availability, which refers to the portion of the horizontal distribution of the species that coincides with the areas in which the fishery takes place; encounterability, which refers to the vertical overlap between the usual position of the fishing gear and the species in the water column; selectivity of fishing gear, and post-capture mortality (Hobday, 2007; Smith et al., 2007). Selectivity of the fishing gear is evaluated based on two criteria: the relationship between the size of immature individuals and the probability of their capture; and the possibility that these immature individuals may escape the fishing gear alive or may evade it.

Each attribute receives a score of 1, 2, or 3, depending on whether it is associated with low (low risk), medium (medium risk), or high (high risk) susceptibility, in accordance to criteria shown in the Table 2.

TABLE 2. Susceptibility attributes (MSC version 2.1)

Susceptibility attribute	High productivity (Low risk, score = 1)	Medium productivity (medium risk, score = 2)	Low productivity (high risk, score = 3)
Areal overlap (availability) Overlap of the fishing effort with a species concentration of the stock	<10% overlap	10-30% overlap	>30% overlap
Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Low overlap with fishing gear (low encounterability).	Medium overlap with fishing gear.	High overlap with fishing gear (high encounterability). Default score for target species (Principle 1).
Selectivity of gear type Potential of the gear to retain species	a Individuals < size at maturity are rarely caught.	a Individuals < size at maturity are regularly caught.	a Individuals < size at maturity are frequently caught.
	b Individuals < size at maturity can escape or avoid gear.	b Individuals < half the size at maturity can escape or avoid gear.	b Individuals < half the size at maturity are retained by gear.
Post-capture mortality (PCM) The chance that, if captured, a species would be released and that it would be in a condition permitting subsequent survival	Evidence of majority released post-capture and survival.	Evidence of some released post-capture and survival.	Retained species or majority dead when released. Default score for retained species (Principle 1 or Principle 2).

Discussion

Specific information for each species, references and information of each score is detailed as follows. Most of the scores were evaluated from bibliographic information. In some cases where specific information was not found, genus or family information was taken into consideration as reference. In cases where special criteria were used, a brief analysis is included. Fish trophic level was taken from Fishbase in all cases (Froese & Pauly, 2019).

Sphoeroides testudineus (Linnaeus, 1758)

Botete o Checkered puffer

Inhabits shallow waters up to 10 m in marine and brackish habitats (Shao et al, 2014). It is distributed from Rhode Island, USA to southern Brazil (Wester Atlantic to Southwest Atlantic). Commonly found in bays, tidal creeks and protected coastal waters, especially on seagrass beds, and in brackish water. Rare or absent on coral reefs. Does not form schools, but may form huge aggregates. Hides in the sand when frightened (Lieske & Myers, 1994). Feeds mainly on bivalves, gastropods, foraminiferans and several other benthic invertebrates specially crustaceans, which it crushes with its powerful teeth (Keith et al, 2000). To ward off predators, it inflates itself like a balloon. Highly toxic. (Pauly, 1991). Spawning season is from late spring to early fall at Biscayne Bay, Florida. Mean length at first maturity is over 13 cm TL. (Pauly, 1991)

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	< 1.53 y (Bonilla et al, 2012)	1
Average maximum age	1.53 /y (Bonilla et al 2012)	1
Fecundity	1.146 eggs/body weight Targett, T.E., 1979; 59 087 and 367 022 oocytes (mean 176 456) per spawning batch for *P. nephelus* (Peniche-Pérez, et al, 2019)	1
Average maximum size	38.8 cm (Claro, 1994)	1
Average size at maturity	10.8 cm or 13 cm. (Pauly, 1991)	1
Reproductive strategy	Batch spawning (Peniche-Pérez, et al, 2019), since it is a demersal fish it is considered	2
Trophic level	3.4	3
Density dependence (only for invertebrates)		

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort with a species concentration of the stock	This species is found along the whole Laguna de Términos (Mallard et al, 1981) and it is distributed from Rhode Island to Brazil. Fishing effort is concentrated, it is considered as a precautionary approach 10-30% overlap	2
Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Since it is a demersal fish, it is considered a high overlap with fishing gear.	3
Ring traps Selectivity of gear type Potential of the gear to retain species	Individuals < size at maturity are regularly caught (from interviews with fishermen)	2
Post-capture mortality (Considers fishery under assessment)	Individuals < half the size at maturity can escape or avoid gear & Fishermen can free them alive since it has no commercial interest.	2

Ariopsis melanopus; Ariopsis felis, Bagre marinus
Hardhead sea catfish, locally known as bagre

Sea catfishes occur in marine, brackish, and fresh waters of warm-temperate and tropical regions. The marine representatives are mostly confined to the coastlines of the continent and continental islands such as Trinidad (only a single species has been reported from Cuba, for example). They may be locally abundant in the turbid waters of certain habitats, particularly large river estuaries and mangrove-lined lagoons. A few species may reach depths of 100 m or deeper. Sea catfishes' diets range from omnivorous, including detritus, to strongly carnivorous, including large bony fishes and crustaceans. Reproduction is highly specialized: the males incubate the eggs and vitelline young in their mouths. The sea catfishes include several species of high economic value. FAO statistics report landings ranging from 14 885 to 26 630 t from 1995 to 1999. They are captured with a variety of gear, including bottom trawls, longlines, seines, cast nets, traps, and hook-and-line.The flesh is usually of good quality, but the sharp and serrated dorsal- and pectoral-fin spines can inflict painful wounds. (Acero, A., 2002).

Wide distribution from the US to Venezuela, depending on the species. In the U.S. Gulf of Mexico, where marine catfishes remain common and can be found in such high local abundances that some fisheries reportedly avoid areas due to unwanted marine catfish bycatch (Armstrong et al. 1996). Winemiller & Rose (1992) consider this fish exhibit an equilibrium life history strategy. Armstrong et al. (1996) estimated maturity at around age 5.

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	5 years (Armstrong, et al, 1996).	2 As a precautionary approach, given the long life span of the species, a score of 2 is considered instead of 1.
Average maximum age	24 years (Flinn, et al, 2019)	2
Fecundity	15 eggs found in mouth, may bear up to 43, (Segura-Berttolini, 2011)	3
Average maximum size (not for invertebrate)	70 cm (Fishbase)	1
Average size at maturity (not for invertebrate)	13 cm (Fishbase)	1
Reproductive strategy	Bearers/external brooders (Fishbase)	3
Trophic level	3.2	3
Density dependence (only for invertebrates)		

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort	This species has a wide distribution in Laguna de	1

with a species concentration of the stock	Términos and it is important in terms of abundance (Ayala-Pérez, et al 2012). Fishing effort is concentrated, it is considered as a precautionary approach 10-30% overlap	
Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	This group of species feed on the seabed, having a strong interaction with fishing gear.	3
Ring traps Selectivity of gear type Potential of the gear to retain species	Individuals < 13 cm (average size at maturity) are rarely caught. It is not clear if they can escape or just avoid gear. As a precautionary approach it is rated as 3.	3
Post-capture mortality (Considers fishery under assessment)	Once in the boat, the fish dies. Fishermen release them since there is no commercial interest, although these are sometimes kept. They are very common in the area, a score of 3 was chosen as a precautionary approach.	3

Archosargus rhomboidalis

Commonly found over mud bottoms in mangrove sloughs and on vegetated sand bottoms, sometimes in brackish water and occasionally also in coral reef areas near mangroves. Feeds on benthic invertebrates (small bivalves, crustaceans), as well as on plant material.
Distribution USA and northeastern Gulf of Mexico to Argentina.

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	< 2 years (deduced from Av Max Age)	1
Average maximum age	2 years (Chavance, et al 1986)	1
Fecundity	485 eggs (Chavance et al 1986)	2
Average maximum size (not for invertebrate)	33 cm (Robins & Ray, 1986)	1
Average size at maturity (not for invertebrate)	Lm 8 cm (Fishbase)	1
Reproductive strategy	Non guarders open water/substratum egg scatterers (Chavance et al 1986)	2
Trophic level	2.9	2
Density dependence (only for invertebrates)		

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort with a species concentration of the stock	This is one of the most abundant species in Laguna de Términos. (Ayala-Pérez, 2003). As a precautionary approach it is scored 2.	2
Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Commonly found over mud bottoms in mangrove sloughs and on vegetated sand bottoms	3

Ring traps Selectivity of gear type Potential of the gear to retain species	Biological Monitoring Program suggests individuals < size at maturity (8 cm) are rarely caught. No information exists if Individuals < size at maturity can avoid or escape gear.	3
Post-capture mortality (Considers fishery under assessment)	Default score for retained species as fishermen use it as bait	3

Achirus lineatus

Lined sole

It is distributed along the Western Atlantic, from Florida and Northern Mexico to northern Argentina. Occurs mainly in brackish or hyper-saline lagoons, on sandy-muddy bottoms of estuaries and in the literal zone from 1 to 20m depths. Its growth rate is relatively slow (Keith, et al. 2000).

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	Deducted from average maximum age, as a precautionary approach	2
Average maximum age	*Trinectes sp*. 6 years (Robins & Ray, 1986)	1
Fecundity		3
Average maximum size (not for invertebrate)	*Achirus lineatus* 33.1 cm; (Ayala-Pérez, et al 2015)	1
Average size at maturity (not for invertebrate)	< 33.1 cm (Ayala-Pérez, et al 2015)	1
Reproductive strategy	*Achirus* is dioicus; (Ayala-Pérez, et al 2015)	3
Trophic level	3.5 fishbase	3
Density dependence (only for invertebrates)		

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort with a species concentration of the stock	It has a wide distribution in Laguna de Términos and in the Western Atlantic (Ayala-Pérez et al, 2015)	1
Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Lives on sandy-muddy bottoms (Keith, et al 2000)	3
Ring traps Selectivity of gear type	Biological Monitoring Program suggests individuals < size at maturity (33.1 cm) may be frequently	3

Potential of the gear to retain species	caught. No information exists if Individuals < size at maturity can avoid or escape gear but this seems not probable since maturity size. As a precautionary approach it is considered the default score 3.	
Post-capture mortality (Considers fishery under assessment)	Fishermen release them since there is no commercial interest, but once in the boat it may die, since this fish does not represent a threat for fishermen they focus their attention in any spine-fish. As a precautionary approach it is considered the default score 3.	3

Eucinostomus gula

Jenny mojarra

Gerreidae family are chiefly marine. In brackish water, it is encountered occasionally; rarely, in freshwater. Very protractile mouth. Head scaly but with smooth upper surface. Dorsal and anal fins with a sheath of scales along base. Gill membranes not united to isthmus. Deeply forked tail; 24 vertebrae. Maximum length 35 cm, attained in *Gerres filamentosus*. Small silvery fishes with highly protrusible mouth. They feed by sorting benthic invertebrates from sand. Foodfishes. Assumed to be nonguarders. Most of the adult species occur in coastal lagoons with sandy or muddy bottoms bordered by mangroves; however, they occasionally enter river mouths. Juveniles enter estuaries until they reach maturity; spawning occurs at sea throughout the seasons. (Fishbase).

The mojarras were defined as second-order consumers, feeding on microcrustaceans (amphipods, copepods, tanaidaceous, ostracods) and significant amounts of detritus with variations in the proportion and frequency of different types of food according to their ontogeny and food availability (Chi-Espínola, 2018). Mojarras are omnivorous and euriphagous fishes, eating a wide spectrum of items, mainly small invertebrates as bivalves, gastropods, ostracods, copepods, polychaetes (Arenas-Granados & Acero, 1992).

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	No information found. Default score selected.	3
Average maximum age	No information found. Default score selected.	3
Fecundity	111 eggs (Mexicano-Cíntora)	3
Average maximum size (not for invertebrate)	25.5 cm (Amador, et al. 2015)	1
Average size at maturity (not for invertebrate)	11 cm (Amador, et al. 2015)	1
Reproductive strategy	Broadcast spawner	1
Trophic level	2.7 (Fishbase)	2
Density dependence (only for invertebrates)		

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort with a species concentration of the stock	Broad distribution	1

Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Inhabits shallow waters, being especially abundant over mud bottoms in mangrove-lined lagoons or creeks; larger individuals may also occur on vegetated sand grounds in marine areas.	3
Ring traps Selectivity of gear type Potential of the gear to retain species	Biological Monitoring Program suggests individuals < size at maturity (11 cm) may be rarely caught. No information exists if Individuals < size at maturity. As a precautionary approach it is considered the default score 3.	3
Post-capture mortality (Considers fishery under assessment)	Default score for retained species as fishermen use it as bait.	3

Diapterus rhombeus

Mojarra

Distributed from Gulf of Mexico, Central America and the Antilles to Brazil (Cervigón, F., 1993). Common in mangrove-lined lagoons, found over shallow mud and sand grounds in marine areas. Juveniles common in hypersaline lagoons and in brackish water (Cervigón, 1992). Lives from 9-70 m depth. Annual catches were estimated from 100-200 t (Claro, 1994).

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	No information found. Default score selected.	3
Average maximum age	No information found. Default score selected.	3
Fecundity	No information found. Default score selected.	3
Average maximum size (not for invertebrate)	40 cm (Randall y Vergara, 1978 in Ayala-Pérez et al, 2015)	1
Average size at maturity (not for invertebrate)	9 cm (Rodríguez da Costa, et al 2012)	1
Reproductive strategy	Its spawning most likely occurs in adjacent coastal waters, (Elliff et al, 2013). Previous observations made on *D. rhombeus* revealed that adults typically spawn in areas deeper than 10 m, whereas juveniles use the shallow waters of estuaries, bays and mangroves. Chaves et al (1998) suggested that smaller individuals (i.e.,<150 mm TL) present evidence of previous spawning events. Presents breeding aggregation & a unique nest-clearing behavior, the eggs potentially released over the cleared surfaces were nearly undistinguishable from sediment particles. (Reis-Filho, 2018)	2
Trophic level	3.0 (Fishbase)	2
Density dependence (only for invertebrates)		

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort with a species concentration of the stock	Broad distribution	1
Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Between 9 & 70 m (Gines & Cervigón, 1967). It is common to find it in coastal mangrove areas of coastal lagoons with muddy bottoms and in deep sea areas Sandy. (Froese y Pauly, 2009)	3
Ring traps Selectivity of gear type Potential of the gear to retain species	Biological Monitoring Program suggests individuals < size at maturity (9 cm) may be rarely caught. No information exists if Individuals < size at maturity. As a precautionary approach it is considered the default score 3.	3
Post-capture mortality (Considers fishery under assessment)	Default score for retained species as fishermen use it as bait.	3

Clibanarius vittatus

Cangrejo hermitaño

Adult crabs are commonly found inhabiting gastropod shells at least 10 cm long (Ruppert & Fox 1988). Thin stripe hermits are considered to employ an opportunistic trophic mode, feeding on a variety of plant and animal material. Diet studies involving gut content analysis revealed that crabs consumed 40% scavenged material, 40% detritus, and 20% substratum (Williams 1984).

Information on the predators of *C. vittatus* is scarce, but crabs are likely preyed upon by large benthic-feeding fishes and other crustaceans. Eggs and larvae are consumed by a variety of organisms, including some species that are considered to be commensals of the parent crab (Williams 1984).

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	No information found. Default score selected.	3
Average maximum age	No information found. Default score selected.	3
Fecundity	180,000 eggs (Turra & Leite, 2001)	1
Average maximum size (not for invertebrate)		
Average size at maturity (not for invertebrate)		
Reproductive strategy	Females carries eggs (sponge) Broadcast spawner	1
Trophic level	No information found. Default score selected.	3
Density dependence (only for invertebrates)	No depensatory or compensatory dynamics demonstrated or likely	2

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort with a species concentration of the stock	Wide distribution of the species (Crab data base)	1

Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Since they live on the bottom, there is a high probability of encounter	3
Ring traps Selectivity of gear type Potential of the gear to retain species	Individuals below size at maturity are regularly caught (5-50%)	2
Post-capture mortality (Considers fishery under assessment)	Evidence of majority released post-capture and survival	1

Callinectes similis

Lesser blue crab

Adult *Callinectes similis* occur in the oceanic littoral zone in salinities above 15‰ at a depth of 100 meters along the eastern seaboard from Delaware Bay to Key West, Florida and southern coasts of the United States, to the Yucatan, Colombia and northern Jamaica (Williams 1984, Piller et al. 1995). It is distributed throughout the lagoon independently of a particular type of habitat (Sánchez & Raz-Guzman, 1997). *Callinectes similis* was most frequently (92%) collected in salinities above 20%, in areas with macroalgae, sea grasses, and submerged aquatic vegetation (70%) and on unvegetated soft substrates (30%) (Sánchez & Raz-Guzman, 1997). *C. similis* is omnivorous; its diet includes detritus and invertebrates, and carrion (Britton & Morton, 1989). La jaiba Callinectes similis da soporte a la pesquería de plataforma. (Raz-Guzmán, 2005)

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Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	As of *Callinectes sapidus*, 12-18 months of age age (Rosas-Correa and Jesus-Navarrete 2008) (Estrada-Valencia, 1999) (Fischer & Wolff, 2006) (ADW, 2016)	1
Average maximum age	As of *Callinectes sapidus*, 4.5 years(Rosas-Correa and Jesus-Navarrete 2008)	1
Fecundity	277,886 ±136,270 (Chazaro-Olvera et al, 2000); 125,734 to 986,393 eggs García-Montes, et al.,1987)	1
Average maximum size (not for invertebrate)		
Average size at maturity (not for invertebrate)		
Reproductive strategy	Broadcast spawner	1
Trophic level	Unknown, 3.3 (as *C. sapidus*)	3
Density dependence (only for invertebrates)	No depensatory or compensatory dynamics demonstrated or likely	2

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort	Distributed throughout Laguna de Términos, found	3

with a species concentration of the stock	on all sorts of substrates along a wide range of salinity (Sánchez & Ráz-Guzmán, 1997), prefers salinities over 15°/oo. (Piller, et.al. 1995) Broad distribution, considered a precautionary approach since not much information found. Common in the Campeche area, specially in the coastal platform, sustains the platform fishery. (Raz-Guzmán, 2010)	
Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Since they live on the bottom, there is a high probability of encounter	3
Ring traps Selectivity of gear type Potential of the gear to retain species	Individuals below size at maturity are regularly caught (5-50%)	2
Post-capture mortality (Considers fishery under assessment)	FIP has evidence that fishermen release them, but when catches are scarce, they keep it, as a precautionary approach it is scored as default.	3

Callinectes rathbunae

Where no specific information for *C. rathbunae*, information of the genera is included.

Callinectes rathbunae was collected from all types of habitats along the margins of the NW, W, C-SE, and S-SW areas of the Laguna de Términos lagoon throughout wide ranges of salinity (3-34‰), on sand (5-99%), on mud (1-94%), as well as on habitats with and without submerged aquatic vegetation (Sánchez & Raz-Guzman, 1997). However, it is not frequently caught by fishermen, since they are looking for blue crabs (local fishermen information).

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	As of *Callinectes sapidus*, 12-18 months of age age (Rosas-Correa and Jesus-Navarrete 2008) (Estrada-Valencia, 1999) (Fischer & Wolff, 2006) (ADW, 2016)	1
Average maximum age	As of *Callinectes sapidus*, 4.5 years(Rosas-Correa and Jesus-Navarrete 2008)	1
Fecundity	As of *Callinectes sapidus*, 872,000 eggs/year (Estrada-Valencia, 1999; ADW, 2016)	1
Average maximum size (not for invertebrate)		
Average size at maturity (not for invertebrate)		
Reproductive strategy	Brooder	2
Trophic level	As of *Callinectes sapidus,* 3.3 (Morales-Zarate, et al. 2004); 3.73 (Mancinelli, et al, 2016)	3
Density dependence (only for invertebrates)	As of *Callinectes sapidus,* No depensatory or compensatory dynamics demonstrated or likely	2

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort with a species concentration of the stock	Broad distribution. Frequently found in freshwater mouths or close to them. (Sánchez & Raz-Guzman, 1997)	1

Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Since it inhabits bottom a precautionary approach is scored.	3
Ring traps Selectivity of gear type Potential of the gear to retain species	No information found. Default score	3
Post-capture mortality (Considers fishery under assessment)	Since species is kept when caught, default score for retained species	3

Hepatus epheliticus

Cangrejo fuente o calico box crab

Hepatus epheliticus. is an abundant crab commonly found in shallow and continental shelf waters of the Atlantic coast of USA, Mexico (Negreiros-Fransozo, 2008; Hernáez, 2012) Cuba, Jamaica and Dominican Republic (Williams, 1984). It lives buried in sandy substrate between depths of 2 to 91 m (Franks et al., 1972). Hernáez (2012) suggests that ovigerous females may migrate to other areas away from the fishing area in the Campeche Bank or since baited traps were used in their study, that ovigerous females do not enter in them as recorded by other authors. This crab is caught to be used as bait for the octopus fishery in the Campeche Bank, Mexico (Hernáez, 2012).

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	No information found. Default score selected.	3
Average maximum age	Longevity for *H. pudibundus* was estimated at 1.91 and 2.40 years for males and females, respectively (Fernandes-Miazaki, 2018)	1
Fecundity	75,615 +/- 30,120 eggs/female/spawn. (Reigada, 1995)	1
Average maximum size (not for invertebrate)		
Average size at maturity (not for invertebrate)		
Reproductive strategy	Members of the order Decapoda are mostly gonochoric. Mating behavior: Precopulatory courtship ritual is common (through olfactory and tactile cues); usually indirect sperm transfer (Ruppert et al, 2004). Broadcast spawner (De Lima, 2014).	1
Trophic level	2.75 to 3.25 (Mantellano, 1997 in Seafood Watch, 2019)	2
Density dependence (only for invertebrates)	No evidence for compensatory or depensatory dynamics	2

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort with a species concentration of the stock	It is an abundant subtidal crab that lives buried in sandy substrate between depths of 2 to 91 m 8Franks, et al., 1972) lives in shallow water in the western Atlantic Ocean from the Chesapeake Bay to the Dominican Republic (Felder, et al, 2009), common in the Campeche area (Raz-Guzmán, 2010)	1
Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	This is a benthic organism (sealifease) commonly found in the ringtraps. The fishing gear is directed to a very similar species so a Default score is considered.	3
Ring traps Selectivity of gear type Potential of the gear to retain species	Default score. Species is not targeted but caught incidentally regularly. As a precautionary approach it is scored 3. The absence of ovigerous females suggests that they did not enter into the traps during embryogenesis. (Hernáez, 2012)	3
Post-capture mortality (Considers fishery under assessment)	Evidence of some released post-capture & survival from local fishermen, but when octopus fishery (aug-mid dec) sometimes used as bait for this fishery.	2

Libinia dubia

Longnose Spider Crab or maxkil

This crab is commonly referred to as decorator crabs. It is found in a variety of coastal and estuarine habitats to approximately 50 m depth (Williams 1984). The native range of *L. dubia* extends from Cape Cod to southern Texas, Bahamas, Cuba and Yucatan Peninsula (www.inaturalist.org). In Florida, *L. dubia* has been documented as a common inhabitant of Florida Bay (Tabb & Manning 1961), and the most prevalent spider crab in Tampa Bay (Dragovich & Kelly 1964). In Laguna de Términos it was distributed within a narrow salinity range 24-33‰ (Sánchez & Raz-Guzman, 1997). In Indian River Lagoon adults may inhabit more open sandy-bottom areas (Tunberg & Reed, 2004 in http://.naturalhistory2.si.edu). Commonly used as bait for the Yucatan Peninsula fishery (Bravo-Calderón, et al. 2016). Local populations of *L. dubia* have declined due to overexploitation (CONABIO, 2010) as it is used as bait for the octopus fishery.

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	About 12 months for *L. ferreirae* (Gonçalves, et al. 2020)	1
Average maximum age	For *Libinia ferreirae* 4.68 to 5.91 years (Gonçalves, et al. 2020)	1
Fecundity	20,637 (±SD 12,683.33), with an 81% (±SD 4.62) viability until hatching Carmona-Osalde & Rodríguez-Serna, 2012)	2
Average maximum size (not for invertebrate)		
Average size at maturity (not for invertebrate)		
Reproductive strategy	Broadcast spawner	1
Trophic level	No specific information found. Estimated values after Morales-Zárate, (et al., 2004), considered as "Crab" trophic level 3.30	2
Density dependence (only for invertebrates)	No information found. Default score	3

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort	This species has a broad distribution from Massachusetts, USA to Cuba and Peninsula de	1

with a species concentration of the stock	Yucatan. It is preferentially distributed in carbonated environments (Soto, 1980). FIP effort overlaps in <10% of its distribution.	
Encounterability The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	No information found. Default score	3
Ring traps Selectivity of gear type Potential of the gear to retain species	No information found. Default score	3
Post-capture mortality (Considers fishery under assessment)	Retained species when octopus fishery is open	3

Menippe mercenaria

There is a commercial fishery for Stone crab in the state of Campeche, however, according to NOM-045-SAG / PESC-2015, no place in the Laguna de Terminos appears within the landing areas, therefore its capture is not allowed. . However, with some frequency, some fishermen are observed with the characteristic claw, due to its high commercial value and the custom of self-consumption. The distribution of the Stone crab in the Laguna de Terminos is observed associated with the distribution of underwater vegetation (Sánchez & Raz-Guzmán, 1997) and is reflected in the figure below.

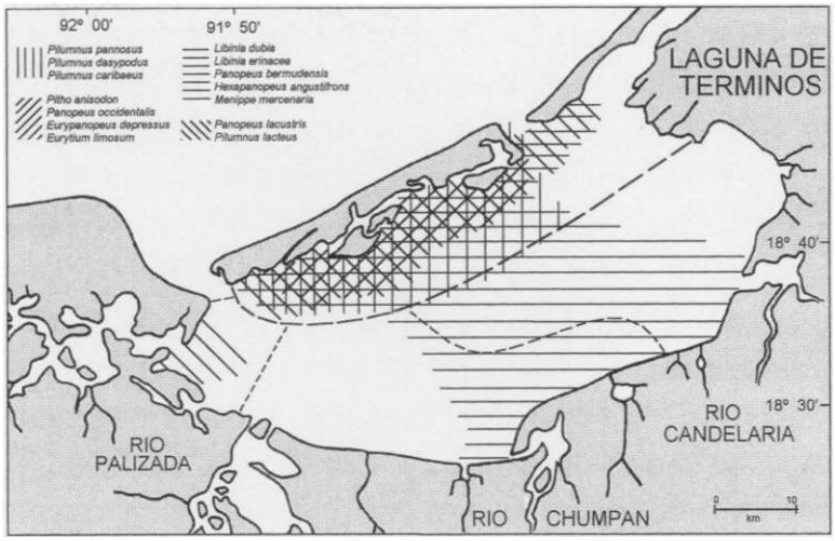

Fig. *Menippe mercenaria* distribution in Laguna de Términos after Sánchez & Raz-Guzmán, 1997)

Productivity Attribute	Relevant information	Score (1 low risk, 2 medium risk, 3 high risk)
Average age at maturity	2 years (GMFMC, 1979), <5 years (Crowley, 2018)	1
Average maximum age	2 years (GMFMC, 1979); < 10 years (Gerhart & Bert, 2008)	1
Fecundity	The number of eggs per batch depends on carapace widths, increased with increasing size-class. Number of eggs per batch was found between 40,438 & 836,644 eggs. Additionally, batch fecundity was 39% lower for crabs with no claws, indicating that claw removal by the fishery negatively affects reproductive output. (Crowley, et al, 2019;	1

	Carmona-Osalde & M. Rodríguez-Serna, 2012)	
Average maximum size (not for invertebrate)		
Average size at maturity (not for invertebrate)		
Reproductive strategy	Demersal egg brooder (Crowley, 2019)	2
Trophic level	2.75 to 3.25 (Abeels, et al 2012; Thera et al, 2014)	2
Density dependence (only for invertebrates)	No depensatory or compensatory dynamics demonstrated or likely	2

Susceptibility Attribute	Relevant Information	Score (1 low risk, 2 medium risk, 3 high risk)
Aerial overlap (availability) Overlap of the fishing effort with a species concentration of the stock	Broad distribution, fishery overlaps between 10-30% of its habitat in the coastal lagoon.	2
Encounterability. The position of the stock/species within the water column relative to the fishing gear, and the position of the stock/species within the habitat relative to the position of the gear	Benthic, burrows in mudflats, rocks offshore reef areas or grass clumps. (Froese & Pauly, 2019) Targeted species so default score is used.	3
Ring traps Selectivity of gear type Potential of the gear to retain species	Default. Since stone crabs are a targeted species.	3
Post-capture mortality (Considers fishery under assessment)	Stone crabs although illegal, are a targeted species but released alive after removal of the claws. (Gandy, 2016 & fishermen information)	1

Results

The final table that includes the scores for each attribute is presented below. According to this results, the MSC score for PI 2.2.1 would be 90 points (Unconditional Pass).

				Productivity Scores [1-3]								
Family name	Scientific name	Common name	Fishery descriptor	Average age at maturity	Average max age	Fecundity	Average max size	Average size at Maturity	Reproductive strategy	Trophic level	Density Dependance	Total Productivity (average)
Tetraodontidae	Sphoeroides testudineus	Botete	Ringtraps	1	1	1	1	1	1	3		1.29
Ariidae	Ariopsis felis	Bagre	Ringtraps	2	2	3	1	1	3	3		2.14
Sparidae	Archosargus rhomboidalis	Postá	Ringtraps	1	1	2	1	1	2	2		1.43
Achiridae	Achirus lineatus	Lenguado	Ringtraps	2	1	3	1	1	3	3		2.00
Diogenidae	Clibanarius vittatus	Cangrejo hermitaño	Ringtraps	3	3	1			1	3	2	2.17
Portunidae	Callinectes similis	Jaiba pata seca	Ringtraps	1	1	1			1	3	2	1.50
Portunidae	Callinectes rathbunae	Jaiba negra o café	Ringtraps	1	1	1			1	3	2	1.50
Aethridae	Hepathus epheliticus	Cangrejo fuente	Ringtraps	3	1	1			1	2	2	1.67
Menippidae	Menippe mercenaria	Cangrejo	Ringtraps	1	1	1			3	3	3	2.00
Epialthidae	Libinia duvia	Maxquil	Ringtraps	1	1	2			1	2	3	1.67
Gerreidae	Eucinostomus gula	Mojarra	Ringtraps	3	3	3	1	1	1	2		2.00
Gerreidae	Diapterus rhombeus	Mojarra	Ringtraps	3	3	3	1	1	2	2		2.14
Ariidae	Bagre marinus	Bagre 2	Ringtraps	2	2	3	1	1	3	3		2.14
Ariidae	Ariopsis melanopus	Bagre 3	Ringtraps	2	2	3	1	1	3	3		2.14

				Susceptibility Scores [1-3]					Cumulative only							
Family name	Scientific name	Common name	Fishery descriptor	Availability	Encounterability	Selectivity	Post-capture mortality	Total (multiplicative)	PSA Score	Catch (tons)	Weighting	Weighted Total	Weighted PSA Score	MSC PSA-derived score	Risk Category Name	MSC scoring guidepost
Tetraodontidae	Sphoeroides testudineus	Botete	Ringtraps	2	3	2	2	1.58	2.03	10000	1.00	2.03	2.03	95	Low	≥80
Ariidae	Ariopsis felis	Bagre	Ringtraps	1	3	3	3	1.65	2.70	10000	1.00	2.70	2.70	81	Low	≥80
Sparidae	Archosargus rhomboidalis	Postá	Ringtraps	2	3	3	3	2.33	2.73	10000	1.00	2.73	2.73	81	Low	≥80
Achiridae	Achirus lineatus	Lenguado	Ringtraps	1	3	3	3	1.65	2.59	10000	1.00	2.59	2.59	84	Low	≥80
Diogenidae	Clibanarius vittatus	Cangrejo hermitaño	Ringtraps	1	3	2	1	1.13	2.44	10000	1.00	2.44	2.44	87	Low	≥80
Portunidae	Callinectes similis	Jaiba pata seca	Ringtraps	3	3	2	3	2.33	2.77	10000	1.00	2.77	2.77	80	Low	≥80
Portunidae	Callinectes rathbunae	Jaiba negra o café	Ringtraps	1	3	3	3	1.65	2.23	50000	1.00	2.23	2.23	92	Low	≥80
Aethridae	Hepathus epheliticus	Cangrejo fuente	Ringtraps	1	3	3	2	1.43	2.19	50000	1.00	2.19	2.19	92	Low	≥80
Menippidae	Menippe mercenaria	Cangrejo	Ringtraps	2	3	3	1	1.43	2.46	30000	1.00	2.46	2.46	87	Low	≥80
Epialthidae	Libinia duvia	Maxquil	Ringtraps	1	3	3	3	1.65	2.35	50000	1.00	2.35	2.35	89	Low	≥80
Gerreidae	Eucinostomus gula	Mojarra	Ringtraps	1	3	3	3	1.65	2.59	10000	1.00	2.59	2.59	84	Low	≥80
Gerreidae	Diapterus rhombeus	Mojarra	Ringtraps	1	3	3	3	1.65	2.70	200	1.00	2.70	2.70	81	Low	≥80
Ariidae	Bagre marinus	Bagre 2	Ringtraps	1	3	3	3	1.65	2.70	10000	1.00	2.70	2.70	81	Low	≥80
Ariidae	Ariopsis melanopus	Bagre 3	Ringtraps	1	3	3	3	1.65	2.70	10000	1.00	2.70	2.70	81	Low	≥80

Conclusions

Compared to other coastal lagoons in the Gulf of Mexico, Laguna de Términos has a high species richness that responds to the environmental heterogeneity in terms of salinity and types of substrate that characterizes this lagoon (Raz-Guzman, 2010). Through the Biological Monitoring Program 14 species were identified as species associated to the blue crab fishery and its fishermen. **The Productivity Susceptibility Analysis results show a low risk score to all of them which allows a score of 90 in the Performance Indicator 2.2.1**. of the MSC standard. Specially attention should be taken to species that are part of other fisheries such as *Menippe mercenaria* and *Libinia duvia*.

Menippe mercenaria has a specific fishery with 783 fishing permits (783 traps) in Campeche (www.pescandodatos.org, updated August, 2019) none of them in Laguna de Términos or Isla Aguada. Even though, when found it is targeted as of the high value of its chelae. This fishery does not pose a mortality risk since most fishermen only take one chelae, but it is demonstrated this practice diminishes its fecundity.

Libinia duvia is used as bait for the octopus's fishery. This fishery takes place from August to mid- December, representing a threat only during this period of the year.

Less information is available on crustaceans.

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