PESCA SUSTENTABLE

Risk Base Framework

RBF - Patagonian Red Octopus Fishery, Los Lagos Region

20/12/2021

1. Introduction

In recent years, stock assessments have been performed on the basis of various models that have served to draw conclusions on the population status of Patagonian Red Octopus. These assessments were carried out under the framework of projects funded by the Fisheries and Aquaculture Research Fund (Molinet *et al.*, 2018). Subsequently, IFOP performed a stock assessment under Benthic Fisheries Management Plans based on a production model and finally, the Sustainable Fisheries Center (Canales et al., 2021) carried out a management strategy assessment to condition the Operating Model for the fishery.

The assessment performed by IFOP implemented the bayesian function of the Froese *et al.* Model, 2017 with a state-space Schaefer model using Maximum Sustained Yield (MSY) as Biological Reference Point (BRP) defined as 50% of the virginal biomass. As a result, although captures are withing ranges of MSY, the fishing effort level has exceeded the limit reference point in 18% (F/FRMS= 1.18) and the stock biomass is presently in a state of over-exploitation at 42% with respect to its no fishing status, slightly below the management objective (B/BRMS= 0,84). This status is relatively in line with the results reported by Molinet et al., 2018, since it uses expert criteria derived from this study to condition the assessment.

On the other hand, in Canales et al. 2021, a fatigue model was used based on a simple delay difference proposed by Mangel *et al.* (2010), where the present spawning biomass depends on the biomass of the previous year, minus the harvests obtained during that fishing season, plus the annual latent production function. In such study, population scenarios are assessed, establishing that a lower fishing risk status is most probable by 2019 (65% of B_0).

Considering that these last assessments lead to very divergent conclusions, it was decided to carry out a Risk Assessment Framework for the target species, as well as an additional analysis to support the fisheries management decision making process.

2. Methodology

The ecological risk analysis method for a fishery was originally developed by the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO) in its "Ecological Risk Assessment of Fishing Effects" (ERAEF - Ecological Assessment for Effects of Fishing). For this methodology to be used in the MSC standard, in 2008 the method was tested in seven pilot fisheries worldwide. Once the results were obtained and consultations were held with risk-based evaluation experts, the Risk Assessment Framework (RBF) was established and later integrated in the MSC Fishing Standard in July 2009.

The methodology used in this work is used on a recurring basis in data por fisheries certification processes with the MSC Fishing Standard, that may be reviewed at the MSC Fisheries Certification

Process v2.2[1] (Date of publication: 25 March 2020) all tables cited in this document are part of Annex PF: Risk-Based Framework – guidelines contained in such document.

In PSA, CSA, and SICA analysis, the overlap of the fishery with the population distribution, habitat and ecosystem are estimated and respectively mapped in a Geographic Information System (GIS) using bathymetry from Nautical Chart 7000, from Corral Bay to Guafo Island (SHOA, 2001) building a bathymetry model of a zone situated between the coast of Maullín and Guafo Island, including the inland sea of Chiloé and the Corcovado Gulf. The ordinary Kriging interpolation method of interpolation was applied to bathymetry data, not accounting for anisotropy, using *Surfer* ® Software (Golden Software, 2021). All geographic data used in the model was previously standardized to datum WGS-84, UTM projection, time zone 18 south.

The bathymetric model obtained was used to establish the following zones of interest for the Risk Assessment Framework of the Octupus fishery:

- **Zone susceptible for exploitation using hooka diving equipment**: Defined as a Depth strata that stretches from the coast line to the *-20m* veril.
- **Octopus habitat**: defined as the habitat that is affected by the harvesting activity exerted on Octupus that takes place from the coast line to the *-40m* veril.
- **Resource distribution area**: A bathymetric distribution is considered from 0 to 300 m depth.

Once polygons with the bathymetric limits are constructed for each interest zone, the total surfaces of each area were calculated using the 'Field Calculator' tool of the geographic Information System QGIS (QGIS.org, 2022).

[1] https://www.msc.org/docs/default-source/default-document-library/for-business/program-documents/fisheries-program-documents/msc-fisheries-certification-process-v2-2.pdf?sfvrsn=9294350_9

Table 1 Principle 1 CA Scoring Template - Target Species

PRINCIPLE ONE: Stock status outcome	**Scoring element**	**Consequence subcomponents**	**Consequence Score**
	***Enteroctopus megalocyathus* Gould (1852)**	**Population size**	80
		Reproductive capacity	
		Age/size/sex structure	
		Geographic range	
Rationale for most vulnerable subcomponent	The Patagonian Octopus population possesses a high reproductive capacity and is considered a r strategist species, therefore, this aspect is not considered of greater vulnerability. On the other hand, historical records from biological monitoring performed on a yearly basis by IFOP do not deliver indications of considerable changes in the population structure not its geographic distribution range. Nevertheless, population size is considered the most vulnerable component of the population since significant fluctuations are observed in landings and fishing yields (Figure 1, Figure 2).		
Rationale for consequence score	**Catch Per Unit of Effort (CPUE)** IFOP keeps records of catches per unit of effort (CPUE) since 1996, at the onset of the fishery. Back then, standardized CPUE (Techeira et al., 2019) was under 13 (Kg/h/diver) remaining relatively stable during 10 years, an indicator that began to rise in 2006, reaching a peack of 28 (Kg/h/diver) in 2009, coincidentally with an increase in total catches. Presently, fishing yields are in the range of the levels observed at the beginning of the fishery (Figure 1).		

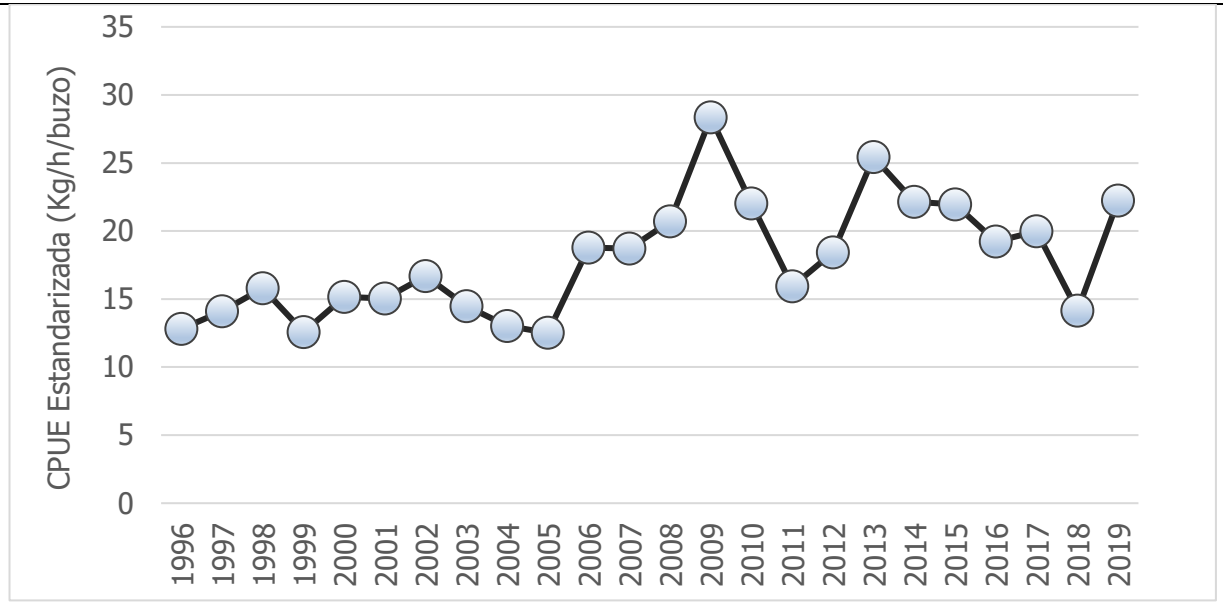


Figure 1. Historical CPUE for Patagonian Octopus in the Los Lagos Region. Modified from Techeira et al., 2019.

Considering the above, it may be assumed that the increase in catches during the first decade of the 2000s (Figure 2) was due to a population increase, given favorable environmental conditions, and therefore, the variation observed in abundance index values (CPUE) are rather related to environmental factors that condition population recruitment and somatic increase of Octopus than the influence of the fishery on the Octopus population in the Los Lagos Region.

As a result, it follows that it is possible that a detectable change exists in the size / growth rate (r), but the impact of fishing operations on the size of the population and its dynamics is minimal.

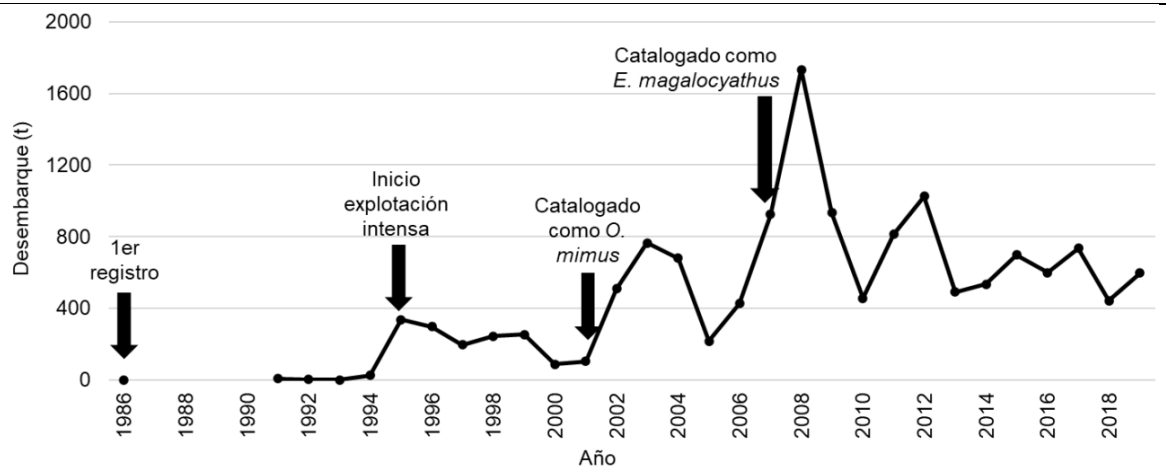


Figure 2. Landings (t) of Patagonian Octopus. Period 1986-2019 (Source: SERNAPESCA). Taken from Techeira et al., 2019.

2.1 Appendix 1.2.2 Productivity-Susceptibility Analysis (PSA) Reference: FCR Annex PF 4

Table 2: PSA Rationale Table

PI number	**1.1.1 Stock status**	
A. Productivity		
Scoring element (species)	Patagonian Octopus (*Enteroctopus megalocyathus*)	
Attribute	**Rationale**	**Score**
Average age at maturity.	Chong et al. 2001 establishes a maximum age for *Enteroctopus megalocyathus* in Chile between 1.4 and 2.5 years. And thus, it may be said with a considerable level of certainty that it meets the low risk criteria of RBF for maturity and longevity productivity properties	**1**
Average maximum age		**1**
Fecundity	Estimations of potential fecundity in natural populations recorded by Chong et al. (2001) up to 20.000 oocytes by female. Nevertheless, this estimation is far from those informed by Ortiz (2009; 2011) for the resource found in the Province of Chubut (Argentina), which varied between 1.429 and 6.940 oocytes, showed higher values for larger sized females. On the other hand, Uriarte et al. (2008), under laboratory conditions, reported fecundities of 3000-5000 eggs by females of *E. megalocyathus* the total weight varying from 1.7 to 3.3 kg, which were fed with a mixture of crab and fish, and maintained at a temperature of 12ºC. Whereas Farias et al. (2011), informed obtaining from 2.025 to 2.233 eggs in females fed on a mixture of fish and crab, a diet that in weight is equivalent to 10% of the body weight of octopus**.**	**2**
Reproductive strategy	The reproductive cycle of Patagonian Octopus follows patterns that are known for octopods cephalopods. In the mating process, the male passes sperm packets to the female (spermatophors) using a specialized arm called the hectocotylus arm (Gutiérrez et al., 2012), oviposture follows, during which the female places ovicapsules in natural caves and remains there to protect the eggs from potential predators (Pardo & Olguín, 2018).	**2**
Trophic level	Although specific studies that establish the trophic level of the Patagonian Octopus are not available, they are	**3**

	considered to belong to the same common Octopus family in Morocco, which estimate a trophic level of 3.35 north of Boujador Cape and 2.67 southeast (Hounaida et al, 2016). On the Atlantic coast of Morocco, on the other hand, a trophic level general value of 3.5 for cephalopod group was estimated (Stanford, 2001). To this end, a precautionary criterion was used to score its trophic level as high risk.	
Density dependence	Without data. Score by defect.	**3**
B. Susceptibility		
Fishery only where the scoring element is scored cumulatively	Scoring element, as required in PF4.4.3. • Octopus fishery with the use of hooka diving equipment • Crustacean fisheries are not considered due to low catch levels	
Attribute	**Rationale**	**Score**
Areal Overlap	Shellfish divers in the Los Lagos region declare harvesting this resource at depths ranging from 1 - 48 m (Barahona et al., 2007) Nevertheless, diving at depths above 20 m are not authorized by the maritime authority and do not take place on a regular basis. Fishing grounds in Los Lagos region reported in biological monitoring performed by IFOP, are located from the coast of Calbuco in the Llanquihue Province, the Gulf of Ancud, and the inland sea of Chiloe in the Province of Chiloe, and to a lower extent, the coast off the Province of Palena (**¡Error! No se encuentra el origen de la referencia.**).	**2**

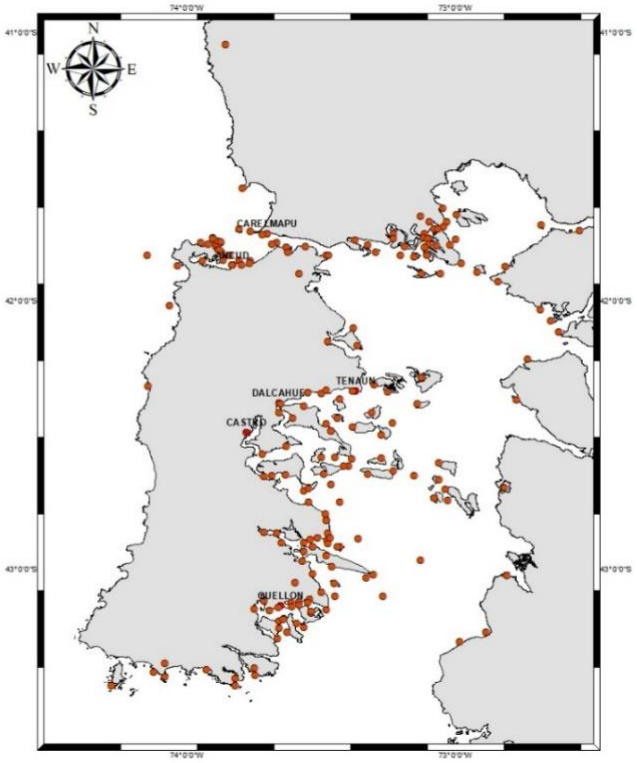


Figure 3: Fishing grounds located in the Los Lagos Region used by the small-scale fleet to harvest E. megalocyathus. Period 1995-2017. (Source: IFOP).

As to the spatial distribution of this species, Patagonian Octopus is considered an intertidal and subtidal species that lives in caves, crevices and overhangs (Ortiz, 2009). The deepest sightings of this species have been recorded in by-catch reports from crab and king crab fisheries included in IFOP's Benthic Crustacean Monitoring (Olguín & Mora, 2018). These fisheries operate up to 300 m depth, which is consistent with the description by (Osorio et al., 2006) reporting the presence of octopus at depths up to 220 m.

With these considerations in mind, a SIG map was drawn up (

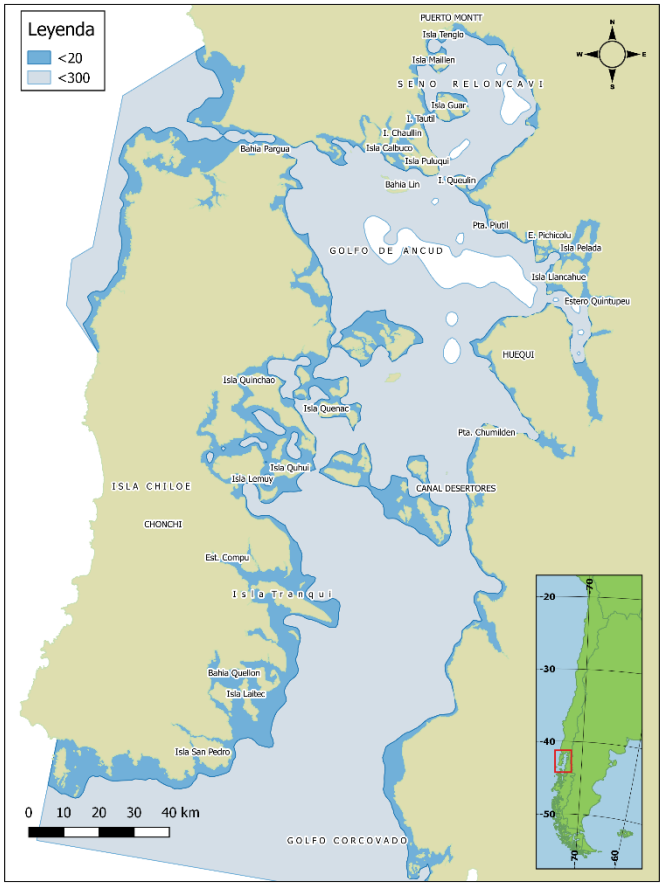
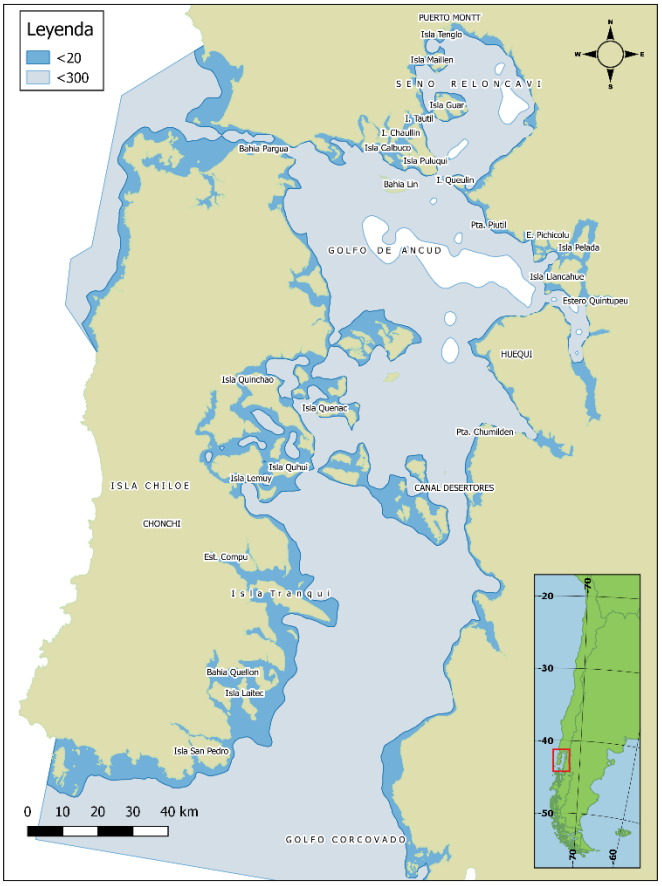
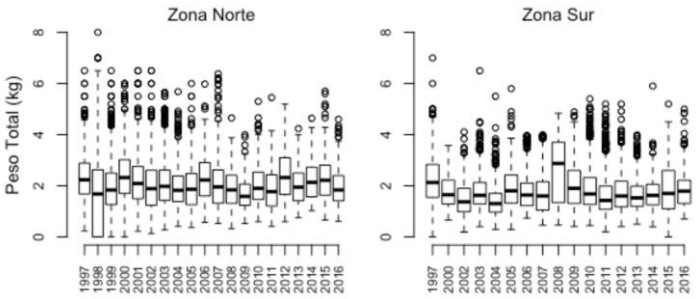


Figure 4: Area overlap. In grey: 20-300 m; in blue: 0-20 m depth.

) depicting the area at depths ranging from 0 - 300m as the habitat used by the Patagonian Octopus and the area ranging from 0 - 20m where the fishing effort takes place.

	 Figure 4: Area overlap. In grey: 20-300 m; in blue: 0-20 m depth. With this GIS analysis, the area that provides habitat to the Patagonian Octopus was calculated in 1.596.630 ha and the fishing effort area in 365.937 ha, thus, the overlap percentage of the population with the fishing effort is 23%. Considering the latter, this element of susceptibility is scored as medium risk.	
Encounterability	Scoring element, as required in PF4.4.7.3 This aspect is scored by defect since it is the target species.	**3**
Selectivity of gear type	The total weight of sampled individuals ranges from 0.13 kg - 8 kg, with an average of 2 Kg, while the mantle length ranges from 5 cm - 30 cm, with an average of 15 cm (**¡Error! No se encuentra el origen de la referencia.**). Mantle sampling in weight and length by zone indicates that the northern area shows the	**2**

	presence of larger individuals in average, with a total weight of 2 kg and 16 cm mantle length, with respect to the lengths observed in the southern area, at 1.8 kg and 14 cm.  Figure 5: Monthly time series of total mantle weight of Octopus individuals by fishing ground in Los Lagos Region. Taken from Molinet et al., 2018. On the other hand, Barahona *et al* (2010) reported that the weight of first maturity ranges from 1200 - 1600 grams in females. Although this information source is useful to establish that the average catch is above the size of first sexual maturity, it is not possible to ascertain that individuals below this reference weight are rarely captured. As a result, a medium risk is considered for fishing gear selectivity.	
Post capture mortality	Considering that the gear used in the Los Lagos region does not allow selectivity by size, and therefore, a Minimum Legal Size does not exist as management measure, all harvested octopus have a commercial objective. As a result, this aspect is scored as high risk.	**3**

Final Score for Stock Status (PI 1.1.1)

From the PSA and CA scores for target species, a result score equivalent to the MSC scoring ranges was generated. They were 77 for PSA and 80 for CA. The results show a final MSC score for the performance Indicator (PI) 1.1.1 featuring a medium vulnerability. This stands for a conditional pass (SG 79).

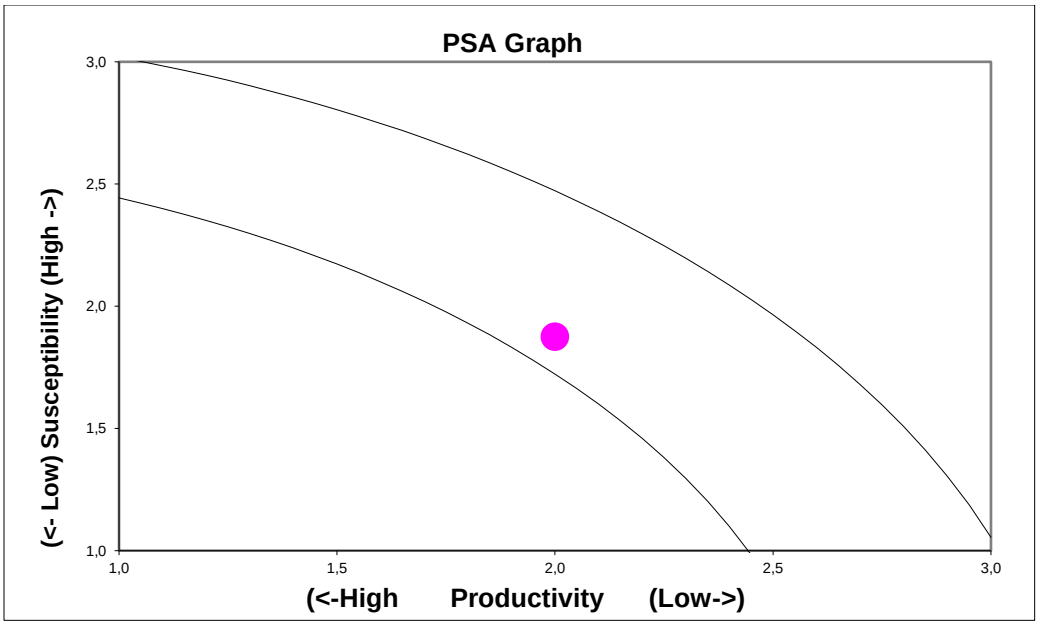


Figure 6: PSA diagnostic plot for Patagonian red octopus in Los Lagos Region.

2.2 Appendix 1.2.3 Consequence Spatial Analysis (CSA) (Reference: FCR Annex PF 7)

The operation area of this fishery extends from the coast of Calbuco, to the Gulf of Ancud, the inland sea of Chiloe, and to a lesser extent, the coast of Palena Province. Fishing activities take place over this area up to 20 m depth, confined to a single habitat in the coastal margin areas of the rocky reef.

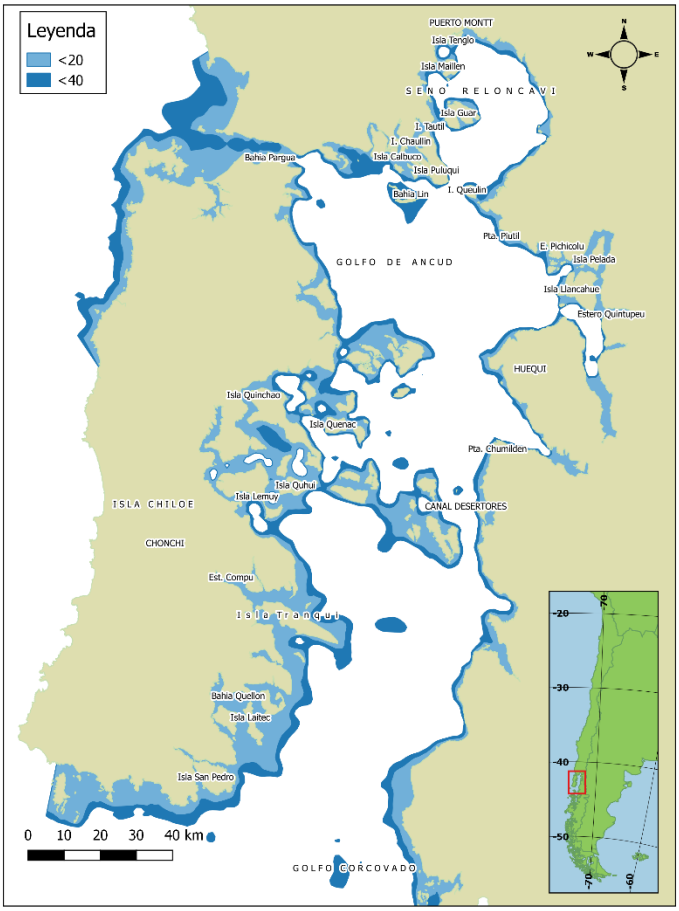
According to the habitat nomenclature used by the MSC Fisheries Certification Process v2.2, the fishery is linked to a **large** Substratum, **high relief** Geomorphology and **small erect** Biota. It is a **coastal Biome (0-25 m)**, **coastal margin** Sub-biome **(<25 m) large rocky Banks** Feature**.**

Table 3: CSA Rationale Table

PI number	**2.4.1**	**Habitat**	Coastal margin of the inland sea of Chiloe and depths less than 40m.
Consequence	**Rationale**		**Score**
Habitat-productivity attributes			
Regeneration of biota	Considering that information on age, growth, and recolonisation of associated biota is not available for the UoA proxies from Table PF12 of the MSC Fisheries Certification Process v2.2 were used. The following biota is found in this coastal habitat: Small erect/encrusting, Large erect (sponges), Large erect (ascidians and bryozoans) and to a lower extent Crinoids/solitary/mixed communities. All of these biota are scored as high risk.		**1**
Natural disturbance	According to the table, the habitat is coastal margin and shallow inner shelf (<60 m) which could be a proxy of having a regular or severe natural disturbance, nevertheless, given that a mixed substrate ranging from hard to soft is found in these shallow depths. Thus, intermediate-sized rock fragments (6 cm to 3 m) that form attachment sites for sessile fauna can be permanently removed. While soft sediment is less resistant to impact, it is generally more resilient because it accumulates relatively rapidly and is altered by burrowing fauna.		**2**

	As a result, a precautionary score of moderate natural disturbance is assigned.	
Gear-habitat interaction attributes		
Removability of biota	Based on Table PF14, octopus harvests with the use of hookah diving equipment is considered a Hand collection and therefore a score of low Removability of biota is assigned.	**1**
Removability of substratum	In general, hooks used as fishing gear does not affect habitat, nevertheless, under the framework of the management committees, some fishers have mentioned fishers with les experience use practices that modify octopus shelters to a certain degree, which could prevent their reuse. Either way, this practice does not remove the substrate but rather modifies it, and thus has a low Removability of substratum.	**1**
Substratum hardness	Since the interaction between substrate and fishing gear is Hard (igneous, sedimentary, or heavily consolidated rock types) and the gear is considered Hand collection, it is scored with a low risk by defect.	**1**
Substratum ruggedness	The ruggedness of the substratum is between low (<1.0 m) and high (>1 m) relief, therefore the score is high risk.	**3**
Seabed slope	The seabed slope is considered low degree (<1) since the fishery is located in the coastal margin area and reaches higher depths in terraces in the outer shelf or upper slope.	**1**

Spatial	**Rationale**	**Score**
Gear footprint	Hand collection	**1**
Spatial overlap	In accordance with the classification of chilean ecosystems in the exclusive economic zone by the Ministry for the Environment in 2015-16, the coastal ecosystem extends from the coast up to 40 meters depth. The ocean in this area is closely related to terrestrial phenomena: soil temperatura, rain water, sedimentation, etc. In addition to other coastal phenomena such as waves, wind effects, tides, etc. Based on this classification, the habitat where Patagonian Octopus harvests take place is considered to extend from the coast up to 40m. As mentioned above, fishing gear affects a fraction of this habitat, only reaching a depth of 20 m. Thus, the habitat's surface was estimated in 530.085 ha using SIG (Figure 7) and a 33% UoA overlap with Habitat.	**1.5**

	 Figure 7. UoA overlap with Habitat. In light blue: 0-20 m; in blue: 20-40 m Depth.	
Encounterability	In general, this fishing gear is made manually and therefore does not have a significant impact on the habitat. Nevertheless, Octopus shelters may suffer certain impacts. As a result, a precautionary assessment is made, considering the possibility of up to 30% encounterability.	**1**

Final Score for Habitats outcome (PI 2.4.1)

As well as the habitat productivity, the interaction with the fishing gear, and the spatial attributes of the fishery scores have a low risk upon the habitat, which entails a very low total risk and a MSC score of 98 for the Habitats outcome (PI 2.4.1)

2.3 Appendix 1.2.4 Scale Intensity Consequence Analysis (SICA (Reference FCR Annex PF 8)

Tabla 4: SICA Scoring Template for PI 2.5.1 Ecosystem (Reference: CR Table PF19)

	Spatial scale of fishing activity	Temporal scale of fishing activity	Intensity of fishing activity	Relevant subcomponents	Consequence Score
PRINCIPLE TWO: **Ecosystem outcome**	4	4	3	**Species composition**	
				Functional group composition	
				Distribution of the community	
				Trophic size/structure	100
Rationale for spatial scale of fishing activity	In accordance with the classification of chilean marine ecosystems in the exclusive economic zone (Rovira & Herreros, 2016), the coastal ecosystem extends from the coast up to a depth of 40 meters. This information is used to estimate an 33% overlap of the ecosystem with the fishing activity of the UoA using GIS.				
Rationale for temporal scale of fishing activity	One of the main management measures for the Patagonian Octopus fishery is a biological closure that is effective from October 15th to March 15th of every callendar year, meaning that Octopus harvest are allowed during 214 days a year. Nevertheless, given the climate conditions in this region, small-scale fishing activities are suspended during an important number of days throughout the year. In general, fishers comply with this closure and ilegal fishing actdivities during the closure is minimal given the scarce availabillity of this resource during this period of the year. As a result, it is estimated that the				

	largest number of actual fishing days never exceed 200 days. Following the ranges established in Table PF21 of the MSC, annual fishing days range from 101 – 200, obtaining a score of 4.
Rationale for intensity of fishing activity	Although the overlap of the ecosystem with the fishing activity of the UoA was estimated in 33%, with respect to the spatial scale, it is noted that the most significant fishing activities take place in the communes of Quellón, Castro, Calbuco and Ancud, while Puerto Montt and the Provinde of Palena present low and sporadic landing levels (Molinet et al, 2018). As to the time scale, climate conditions in the region contribute to a significantly low number of actual fishing days than those allowed during the fishing season. As a result, a moderate detectability of fishing activity at broader spatial scale, or obvious but local detectability is considered.
Rationale for Consequence score	Cephalopods are characterized by short lifespans, high metabolic rates, and rapid growth. Their growth rates and maturation, as well as life cycle phenology, are highly variable. Although much of this variation seems to be environmentally driven, it also reflects phenotypic plasticity and possibly a genetic component (Arkhipkin et al., 2020). Although there is no clear evidence, in the case of Patagonian Octopus apparently fishing mortality is not the principal factor affecting fishing yields and harvest variations. As described in cephalopod populations, there is also a high environmental influence in the population dynamics of Patagonian Octopus. Therefore, given the environmental variability constant, it is highly complex to establish the isolated effects of fishing mortality in the population, thus it is inferred that changes that affect the internal dynamics are unlikely to be detectable against natural variation. It is important to note that it was considered that the overlap of the ecosystem with the fishing activity was overestimated as a precautionary criterion, mainly because the fishery occurs scarcely in the province of Palena.

3. References

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