Monterey Bay Aquarium SeafoodWatch

Blue swimming crab
Portunus pelagicus

© R. Swainston/www.anima.net.au

Sri Lanka

Set gillnets

Report ID 28177

January 9, 2023

Seafood Watch Standard used in this assessment: Fisheries Standard v4

Table of Contents

About Seafood Watch

Monterey Bay Aquarium's Seafood Watch program evaluates the environmental sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Seafood Watch's science-based ratings are available at www.SeafoodWatch.org. Each rating is supported by a Seafood Watch assessment, in which the fishery or aquaculture operation is evaluated using the Seafood Watch standard.

Seafood Watch standards are built on our guiding principles, which outline the necessary environmental sustainability elements for fisheries and aquaculture operations. The guiding principles differ across standards, reflecting the different impacts of fisheries and aquaculture.

- Seafood rated Best Choice comes from sources that operate in a manner that's consistent with our guiding principles. The seafood is caught or farmed in ways that cause little or no harm to other wildlife or the environment.

- Seafood rated Good Alternative comes from sources that align with most of our guiding principles. However, one issue needs substantial improvement, or there's significant uncertainty about the impacts on wildlife or the environment.

- Seafood rated Avoid comes from sources that don't align with our guiding principles. The seafood is caught or farmed in ways that have a high risk of causing harm to wildlife or the environment. There's a critical conservation concern or many issues need substantial improvement.

Each assessment follows an eight-step process, which prioritizes rigor, impartiality, transparency and accessibility. They are conducted by Seafood Watch scientists, in collaboration with scientific, government, industry and conservation experts and are open for public comment prior to publication. Conditions in wild capture fisheries and aquaculture operations can change over time; as such assessments and ratings are updated regularly to reflect current practice.

More information on Seafood Watch guiding principles, standards, assessments and ratings are available at www.SeafoodWatch.org.

Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished[1] or farmed, that can maintain or increase production in the long term without jeopardizing the structure or function of affected ecosystems.

The following guiding principles illustrate the qualities that fisheries must possess to be considered sustainable by the Seafood Watch program (these are explained further in the Seafood Watch Standard for Fisheries):

- Follow the principles of ecosystem-based fisheries management.
- Ensure all affected stocks are healthy and abundant.
- Fish all affected stocks at sustainable levels.
- Minimize bycatch.
- Have no more than a negligible impact on any threatened, endangered, or protected species.
- Managed to sustain the long-term productivity of all affected species.
- Avoid negative impacts on the structure, function, or associated biota of aquatic habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.

These guiding principles are operationalized in the four criteria in this standard.Each criterion includes:

- Factors to evaluate and score
- Guidelines for integrating these factors to produce a numerical score and rating

Once a rating has been assigned to each criterion, Seafood Watch develops an overall recommendation. Criteria ratings and the overall recommendation are color coded to correspond to the categories on the Seafood Watch pocket guides and online guide:

Best Choice/Green: Buy first; they're well managed and caught or farmed responsibly.

Good Alternative/Yellow: Buy, but be aware there are concerns with how they're caught, farmed or managed.

Avoid/Red: Take a pass on these for now; they're caught or farmed in ways that harm other marine life or the environment.

---

[1] "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates

Summary

This report includes recommendations for blue swimming crab (BSC) (*Portunus pelagicus*), a large-bodied, benthic crustacean caught by bottom-set crab net. The fisheries occur in Sri Lanka, specifically in the north, which is referred to as the Palk Bay fishery (Bay of Bengal/Northern Province, Districts of Jaffna, Kilinochchi, Mannar [north coast]), and in the northwest, which is referred to as the Gulf of Mannar fishery (Northwestern Province, Districts of Puttalam and Mannar [south coast]).

Recent stock assessments for the Palk Bay and Gulf of Mannar fisheries suggest that the blue swimming crab in all fisheries is above the recommended limit reference point ($SPR_{20\%}$) and, in Palk Bay, above the upper target reference point ($SPR_{40\%}$). In the Palk Bay and Gulf of Mannar fisheries, the percentage of catch that is mature is 100% and 99%, respectively, suggesting that crabs are able to spawn at least once before being caught. For blue swimming crab, there are two positive data-limited indicators in both regions, so abundance was deemed a low concern. Overfishing does not appear to be occurring; data suggest that fishing mortality is generally targeting larger, older crabs in the fishery, which somewhat protects the spawning potential of the stock; therefore, fishing mortality is scored a moderate concern.

The blue swimming crab bottom-set crab net fisheries typically have high levels of bycatch and interact with some species of concern (e.g., sharks, rays, sea turtles, and benthic invertebrates). Sharks, rays, sea turtles, and benthic invertebrates limit the Criterion 2 score for the bottom-set crab net fishery because of their high inherent vulnerability.

There are recently implemented formal procedures, measures, or regulations in place to specifically manage the fishery. In addition to the harvest control rules and tools, there is a "Voluntary Code of Conduct" (CoC), which was developed to ensure the sustainable use of resources by applying good management measures in maintaining the status of blue swimming crab stocks at healthy limits, and to minimize the impact on the marine environment and the associated species. Further, the Blue Swimming Crab Fishery Management Regulation is likely to soon replace the CoC, once it is approved by Parliament and becomes a law. Because management measures have been in place since 2014 and appear to be successful, management is deemed highly effective.

The fishery has an overall moderate impact on ocean habitats and ecosystems. Although there are no gear-specific modifications to reduce impacts to the seafloor, blue swimming crab fishers switch gears and fisheries throughout the year, depending on the availability and wholesale value of different fisheries, giving the crab stocks and their habitat a "break" from fishing.

Overall, the bottom-set crab net fisheries in Sri Lanka are rated Yellow or Good Alternative.

Final Seafood Recommendations

SPECIES | FISHERY	C 1 TARGET SPECIES	C 2 OTHER SPECIES	C 3 MANAGEMENT	C 4 HABITAT	OVERALL	VOLUME (MT) YEAR
Blue swimming crab | Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka	3.318	1.732	4.000	3.000	Good Alternative (2.882)	Unknown
Blue swimming crab | Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka	3.318	1.732	4.000	3.000	Good Alternative (2.882)	Unknown

Summary

Fisheries for blue swimming crab in Sri Lanka are considered a Good Alternative by Seafood Watch. Stock abundance is healthy and there is a new management system in place that is expected to effectively protect the crab stocks. There is some uncertainty regarding the impact of the fishery on other species.

Eco-Certification Information

There is a fishery improvement project (FIP) in place in each fishery. The FIPs were launched in 2013 and continue to work to improve the biological and ecological status and the management of the two fisheries, to the MBA Seafood Watch Standard for Fisheries. The FIPs are tripartite initiatives that bring together fishing communities, government authorities, and seafood processors to improve the biological and ecological status of each fishery and implement management measures that will ensure a sustainably managed fishery now and in the future.

Scoring Guide

Scores range from zero to five where zero indicates very poor performance and five indicates the fishing operations have no significant impact.

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

Best Choice/Green = Final Score >3.2, and no Red Criteria, and no Critical scores

Good Alternative/Yellow = Final score >2.2-3.2, and neither Harvest Strategy (Factor 3.1) nor Bycatch Management Strategy (Factor 3.2) are Very High Concern[2], and no more than one Red Criterion, and no Critical scores

Avoid/Red = Final Score ≤2.2, or either Harvest Strategy (Factor 3.1) or Bycatch Management Strategy (Factor 3.2) is Very High Concern or two or more Red Criteria, or one or more Critical scores.

---

[2] Because effective management is an essential component of sustainable fisheries, Seafood Watch issues an Avoid recommendation for any fishery scored as a Very High Concern for either factor under Management (Criterion 3).

Introduction

Scope of the analysis and ensuing recommendation

This report includes recommendations for blue swimming crab (*Portunus pelagicus*), a large-bodied, benthic crustacean caught by bottom-set crab net. The fisheries occur in Sri Lanka, specifically in the north, which is referred to as the Palk Bay fishery (Bay of Bengal/Northern Province, Districts of Jaffna, Kilinochchi, Mannar [north coast]), and in the northwest, which is referred to as the Gulf of Mannar fishery (Northwestern Province, Districts of Puttalam and Mannar [south coast]).

Species Overview

Blue swimming crab is a brachyuran crab that belongs to the Portunidae family. Crabs from this family are usually recognized by their flat, disc-shaped hind legs, used as paddles for swimming, and by the nine spikes (a.k.a. horns) along their carapace, on either side of their eyes (GWA DOF 2011). Males are bright blue in color with white spots and with characteristically long chelipeds; the females are a duller green/brown, with a more rounded carapace (BFAR 2013). Spawning occurs year-round: March to June in Kalpitiya (Puttalam estuarine complex, Gulf of Mannar fishery), January to April in Jaffna (Palk Bay), and November to February in Mannar (Palk Bay), with the end of the northeast monsoon and commencement of the second inter-monsoonal rains (Creech 2013). Female blue crabs mate only during molting, with the male crabs carrying and protecting them until molting and mating occur. Blue swimming crab is common throughout the Indo-Pacific in inshore and continental shelf habitats, including sand, mud, algae, and seagrass near reefs and mangrove areas, and is found from the intertidal zone to depths of 70 m {Ingles, 1988}{Germano et al. 2006}. Blue swimming crab is a focal point of fishery industries in the region, such as in Indonesia, the Philippines, Vietnam, Cambodia, Malaysia, Thailand, India, and Sri Lanka (Germano et al. 2006)(Creech et al. 2016)(FAO 2022); (Figure 1). They mature quickly (at about 1 year of age), have short lifespans (about 3 years), and are partial brooders (Josileen and Menon 2007)(Kangas 2000).
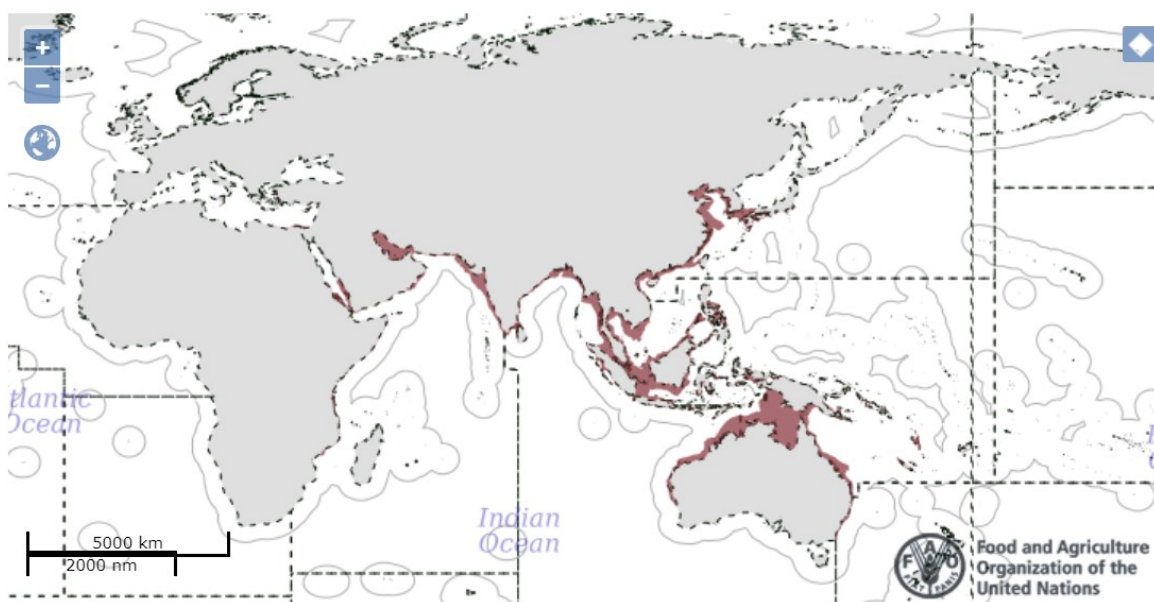

Figure 1: Global distribution of BSC. Taken from (FAO 2022).

SLSBC fishery locations and gear

The main area of the Sri Lankan blue swimming crab fishery (in terms of effort, production, purchasing, processing, and export) is in the districts of Mannar, Kilinochchi, and Jaffna on the Sri Lankan side of the Palk Bay (Palk Bay fishery; Figure 2) (Creech 2013). The Gulf of Mannar fishery, including the Gulf of Mannar and the Puttalam estuary complex, comprises Portugal Bay, Dutch Bay, and Puttalam Lagoon (Figure 3) (Wetland Conservation Project 1994).

Blue swimming crab is caught using bottom-set crab nets, which are nylon half-pieces of net that are set 3 feet above the bottom. Mesh sizes range from 3.5 to 6 in. and each crab net contains between 8 and 20 net pieces (Figure 4) (Creech 2013). Each boat may set up to five nets per trip, at depths of 3 to 5 fathoms, and at distances of 2 to 15 km from shore. Crab nets are set in the evening and hauled within 10 to 12 hours (Creech 2013). Most of the catch is not sorted at sea, except for a few species such as weaver fish and jellyfish (both venomous). Because all other catch is tangled in the net, which requires quite a bit of time to untangle, it gets hauled into the boat and brought back to the landing (Figures 5 and 6) (pers. comm., S. Creech, 10 May 2016).
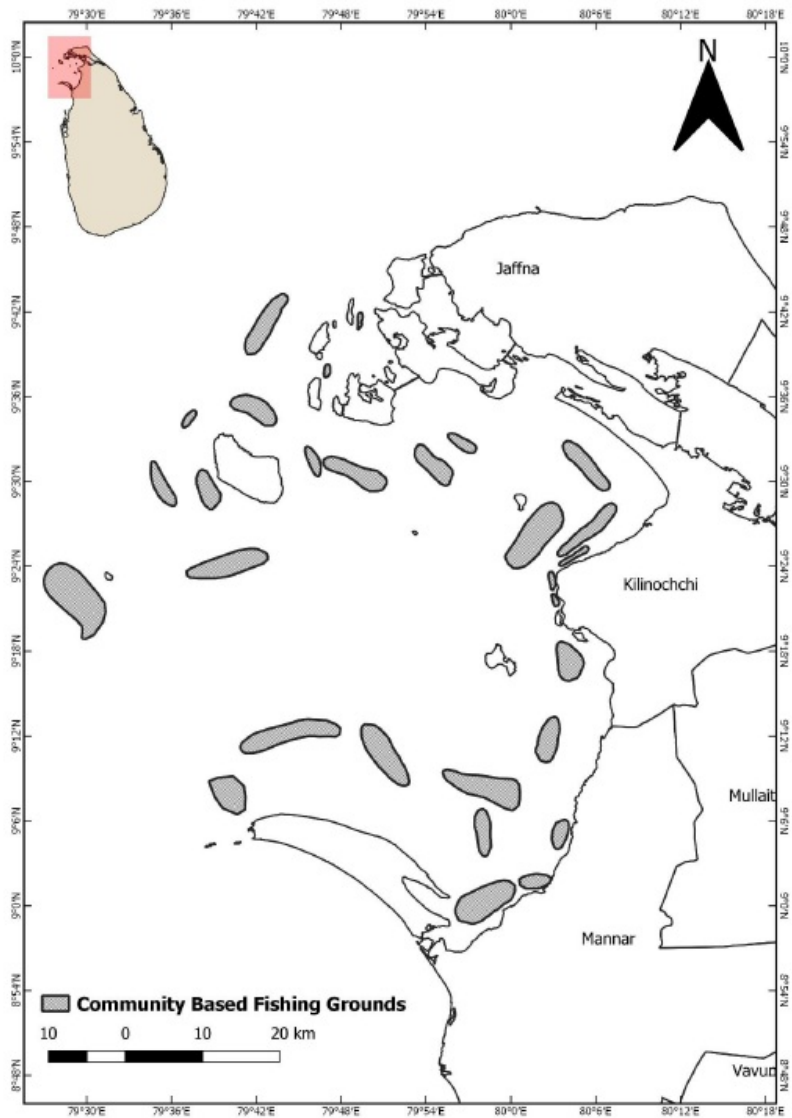
Figure 2: Fishing grounds in the Palk Bay blue swimming crab fishery as identified through GPS and community mapping studies conducted in 2021. Taken from (pelagikos Pvt ltd. 2022g).

Figure 3: Fishing grounds in the Gulf of Mannar blue swimming crab fishery as identified through GPS and community mapping studies conducted in 2020. Taken from {pelagikos Pvt ltd. 2022h}.

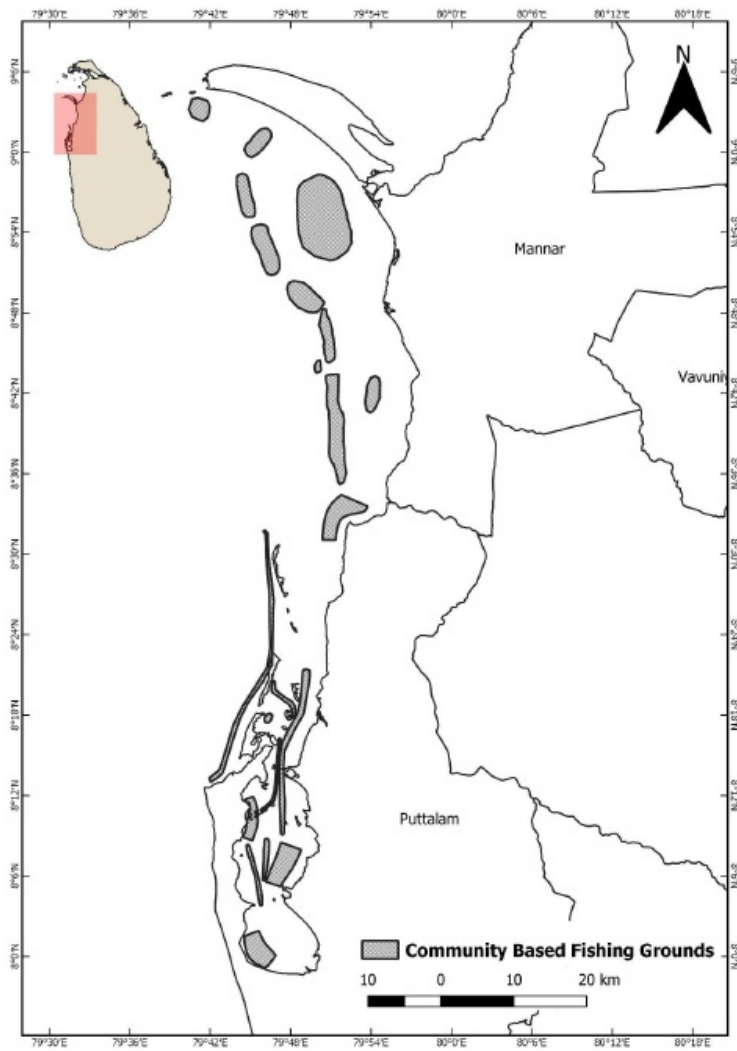Figure 4: Photo of BSC fishers from Baththalangunduwa hauling bottom-set crab nets in the Gulf of Mannar fishery. (Photo courtesy of Steve Creech.)

Figure 5: Photo of BSC bottom-set crab nets with catch entangled. (Photo courtesy of Steve Creech.)

Figure 6: Fiber-reinforced plastic (FRP) crab fishing boat and outboard engine loading a crab net at the landing centre at Soththupitiyawadiya, Puttalam District, Gulf of Mannar Fishery in 2014. (Photo courtesy of Steve Creech.)

History of SLBSC fishery

The blue swimming crab fishery is a new (and comparatively small) fishery in Sri Lanka (Creech 2013). Fishers in the north did not target the species until quite recently; the crabs were considered an annoyance when entangled in fishers' nets. The growth of the fishery is a result of a strong international demand for the its product, coupled with the end of the 30-year civil conflict in Sri Lanka, during which fishers were only allowed to fish between 6 a.m. and 6 p.m. daily. After the conflict ended, these fishing restrictions were lifted, and there was increased access for seafood companies to northern seafood resources (Creech 2013).

Management

In Sri Lanka, the chief authority for the regulation and management of all coastal and offshore fisheries is the MFAR, or the Honorable Minister of Fisheries and Aquatic Resource, with the legislative framework embodied in the Fisheries and Aquatic Resource Act of 1996 (to which new regulations and amendments have been added (Creech 2013). The Director General and staff of the Department of Fisheries and Aquatic Resources (DFAR), which comprises six divisions, undertake the task of implementing the regulations and managing the exploitation of fisheries and aquatic resources in Sri Lanka.

Along with the DFAR, there are 15 District Fisheries Offices (DFOs) located at each of the 14 coastal districts (2 for Puttalam District), which comprise numerous Fisheries Inspectorate Divisions, run by an Assistant Director. These Fisheries Inspectors (FIs) enforce the fishery regulations and implementations of the government's policies for the sector's management and development (Creech 2013).

Fishery Improvement Plan

The Sri Lanka blue swimming crab FIP was initiated by the Seafood Exporters' Association of Sri Lanka (SEASL) in May 2013, with the support of the National Fisheries Institute Crab Council, after receiving a request from representatives of Sri Lanka seafood companies, government authorities, researchers, and civil society organizations associated with the north blue swimming crab fishery (SEASL and NFICC 2013). SEASL acts as an essential focal point for engagement between seafood companies and the government of Sri Lanka. The aim of the FIP was to gather all those associated with the blue swimming crab fishery to create and implement a local plan to improve the economic, social, and ecological sustainability of the fishery. The FIP was officially launched by MFAR in November 2013 (Creech et al. 2016), and continues to work with fishing communities, seafood manufacturers, government agencies, and civil society organizations to improve the biological and ecological status and management of the two fisheries toward achieving a Green/Best Choice rating under the Monterey Bay Aquarium Seafood Watch Fisheries Standard.

Production Statistics

The increasing global demand for blue swimming crab and its wide distribution throughout the Indo-Pacific maks it an important species for a number of countries (Creech 2013)(FAO 2016a); nevertheless, there has been a steady increase in global blue swimming crab production from the 1960s until 2018, after which there has been a slight decline (Figure 7) (FAO 2022b). In 2020, the total global production of blue swimming crab was 251,915 tonnes (live weight); Indonesia, Thailand, and the Philippines were the largest contributors to global production volume (FAO 2022b). The contribution of Sri Lanka to the global blue swimming crab production volume was not specified in FAO data (FAO 2022b). No reliable production data on blue swimming crab are collected from Sri Lanka, because the species is caught in a small-scale fishery that is dispersed along 300 km of coastline and landed across 78 landing centers, and there is little capacity to collect production data (pers. comm., S. Creech).
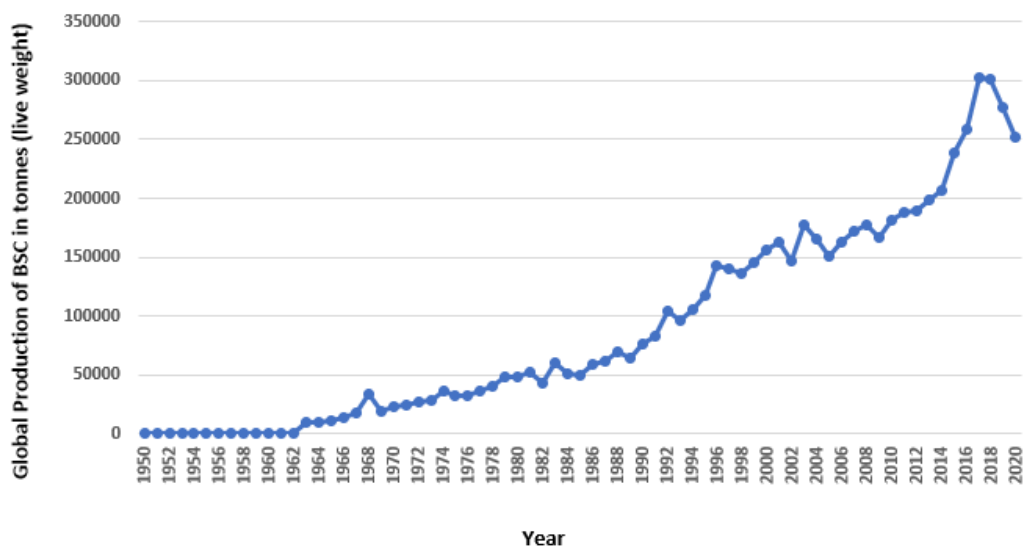
Figure 7: Global production of blue swimmer crab in tonnes (live weight). Taken from (FAO 2022b).

Importance to the US/North American market.

The total blue swimming crab exported from Palk Bay and the Gulf of Mannar in Sri Lanka in 2021 was 3,152.36 tonnes (pers. comm., Panduwawala P.). The total value of blue swimming crab exported from Sri Lanka in 2021 was USD 27.65 million (pers. comm., Panduwawala P.). The volume of Portunid crabs imported into the United States from Sri Lanka in 2021 was 467.10 tonnes (or 2% of all Portunid imports) (Figure 8), and the value of Portunid crabs imported into the United States from Sri Lanka in 2021 was USD 14,651,275 (Figure 9) (NMFS 2022).

Figure 8: Portunid crab imports into the U.S. (by tonnes) in 2021. Data from (NMFS 2022).
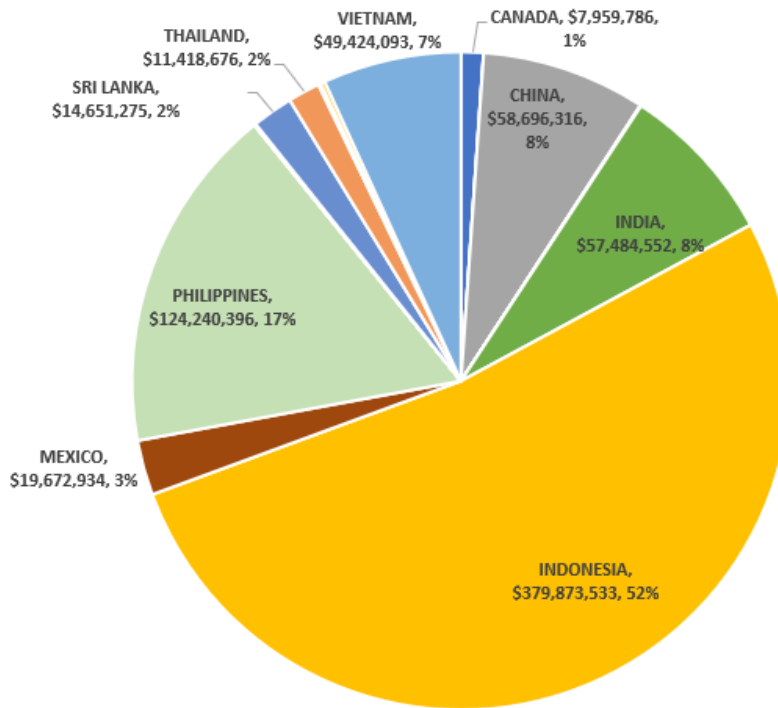
Figure 9: Portunid crab imports into the U.S. (by value) in 2021. Data from (NMFS 2022).

Common and market names.

Blue swimming crab is also known as flower crab, blue crab, blue swimmer crab, blue manna crab, horse crab, sand crab, and swimming crab (GWA DOF 2011)(FDA 2016){Fishsource 2016}.
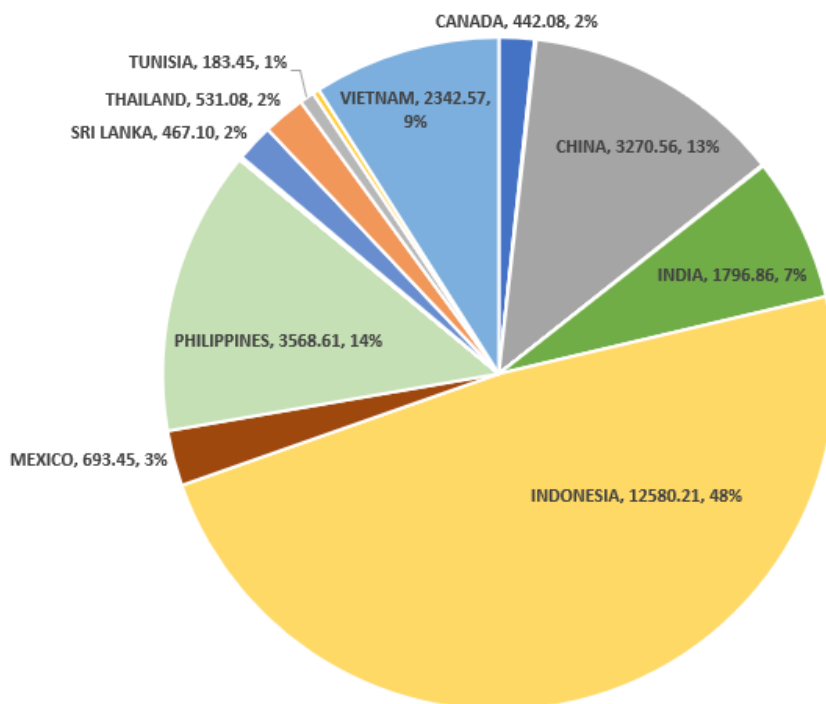
Primary product forms

Portunid crabs are sold interchangeably and these species can include red swimming crab, blue swimming crab, and others, such as *Portunis sanguinolentus* and *P. trituberculatus* (Lai et al. 2010)(Sea Fare Group 2011). Sri Lanka blue swimming crab is exported by seafood companies as fresh, frozen, and canned products. Fresh crab is either exported as "head on" or "cut crab" products. Cut crabs are processed by removing the top shell, guts, and gills, then brushing them clean and cutting into two sections. Canned crab is a pasteurized product that involves picking the meat from boiled crabs. Crab meat is graded according to type and size. Grades include colossal, jumbo, B jumbo, flower, lump, special, claw, B claw, and finger. Canned crab products include "fancy," "special," "jumbo lump," "back fin," "lump," "white," and "claw" (Creech 2013).

Assessment

This section assesses the sustainability of the fishery(s) relative to the Seafood Watch Standard for Fisheries, available at www.seafoodwatch.org. The specific standard used is referenced on the title page of all Seafood Watch assessments.

Criterion 1: Impacts on the species under assessment

This criterion evaluates the impact of fishing mortality on the species, given its current abundance. When abundance is unknown, abundance is scored based on the species' inherent vulnerability, which is calculated using a Productivity-Susceptibility Analysis. The final Criterion 1 score is determined by taking the geometric mean of the abundance and fishing mortality scores. The Criterion 1 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Factor 1.3 (Fishing Mortality) is Critical.

Guiding principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level*

Criterion 1 Summary

BLUE SWIMMING CRAB			
REGION / METHOD	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Gulf of Mannar	Indian Ocean, Eastern	Gillnets and entangling nets	Sri Lanka	3.670: Low Concern	3.000: Moderate Concern	Green (3.318)
Palk Strait and Palk Bay	Indian Ocean, Eastern	Gillnets and entangling nets	Sri Lanka	3.670: Low Concern	3.000: Moderate Concern	Green (3.318)

Criterion 1 Assessments

SCORING GUIDELINES

Factor 1.1 - Abundance

Goal: Stock abundance and size structure of native species is maintained at a level that does not impair recruitment or productivity.

- *5 (Very Low Concern) — Strong evidence exists that the population is above an appropriate target abundance level (given the species' ecological role), or near virgin biomass.*
- *3.67 (Low Concern) — Population may be below target abundance level, but is at least 75% of the target level, OR data-limited assessments suggest population is healthy and species is not highly*

vulnerable.

- *2.33 (Moderate Concern) — Population is not overfished but may be below 75% of the target abundance level, OR abundance is unknown and the species is not highly vulnerable.*
- *1 (High Concern) — Population is considered overfished/depleted, a species of concern, threatened or endangered, OR abundance is unknown and species is highly vulnerable.*

Factor 1.2 - Fishing Mortality
Goal: Fishing mortality is appropriate for current state of the stock.

- *5 (Low Concern) — Probable (>50%) that fishing mortality from all sources is at or below a sustainable level, given the species ecological role, OR fishery does not target species and fishing mortality is low enough to not adversely affect its population.*
- *3 (Moderate Concern) — Fishing mortality is fluctuating around sustainable levels, OR fishing mortality relative to a sustainable level is uncertain.*
- *1 (High Concern) — Probable that fishing mortality from all source is above a sustainable level.*

Blue swimming crab

Factor 1.1 - Abundance

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Low Concern

The 2021 data-limited stock assessment of blue swimming crab from the Gulf of Mannar used the Length-Based Spawning Potential Ratio (LB-SPR) approach (pelagikos Pvt ltd. 2022). The estimated residual spawning potential ratio (SPR) of the Sri Lanka blue swimming crab stock in the Gulf of Mannar in 2019 was 29% (pelagikos Pvt ltd. 2022), which is above the recommended limit reference point ($SPR_{20\%}$) but slightly below the lower target reference point ($SPR_{30\%}$) (Prince et al. 2020). Stock assessments have been conducted annually for 8 years from 2014 to 2021, and in most years, the SPR was above the target reference point (pelagikos Pvt ltd. 2022). In addition, 99% of female blue swimming crab sampled in the Gulf of Mannar fishery were mature (pelagikos Pvt ltd. 2022). This shows that the fishery enables most blue swimming crab to mature (and potentially spawn) before entering the fishery. Because the data-limited indicators (SPR and percent maturity) are both positive, a score of low concern is awarded for abundance.

Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Low Concern

Although a quantitative stock assessment is lacking, an updated data-limited stock assessment using the LB-SPR method was conducted in 2021 on the blue swimming crab stock in the Palk Bay region (pelagikos Pvt ltd. 2022b); the analysis indicates that the SPR is 47% (pelagikos Pvt ltd. 2022b), which is above the upper target reference point of 40% (Prince et al. 2020). Stock assessments have been conducted for 7 years from 2015 to 2021, and the results of the SPR values in Palk Bay during this time have consistently been within or above the target reference points of 30% to 40%, indicating that the fishery is sustainably managed (pelagikos Pvt ltd. 2022b). In addition, 0% of female blue swimming crab sampled in the Palk Bay fishery were immature (pelagikos Pvt ltd. 2022b). This shows that the fishery enables all blue swimming crab to mature (and potentially spawn) before entering the fishery. Both the SPR and percent maturity indicators show conclusive results that a score of low concern is deemed appropriate for abundance.

Factor 1.2 - Fishing Mortality

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

The ratio of fishing mortality to natural mortality (F/M) for the Gulf of Mannar fishery (Puttalam Lagoon) was 3.76 (pelagikos Pvt ltd. 2022), which is higher than the generally accepted target value for F/M for a sustainable fishery (<1). Although the estimate of F/M ratio was higher than the generally accepted target F/M value for sustainable fisheries, other data suggest that fishing mortality (F) was generally targeting larger, older crabs in the fishery, which somewhat protects the spawning potential of the stock. F relative to F_{MSY} is unknown, but overfishing does not appear to be occurring. For this reason, fishing mortality for the Gulf of Mannar is deemed a moderate concern.

Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

In 2021, the ratio of fishing mortality to natural mortality (F/M) for the Palk Bay fishery (Jaffna, Kililnochchi, and Mannar districts) was 1.41 (pelagikos Pvt ltd. 2022b), which is higher than the generally accepted target value for F/M for a sustainably fishery (<1). Although the estimate of F/M ratio was a little higher than the generally accepted target F/M value for sustainable fisheries, other data suggest that fishing mortality (F) is generally targeting larger, older crabs in the fishery, which somewhat protects the spawning potential of the stock. F relative to F_{MSY} is unknown, but overfishing does not appear to be occurring. Therefore, fishing mortality for Palk Bay is deemed a moderate concern.

Criterion 2: Impacts on Other Species

All main retained and bycatch species in the fishery are evaluated under Criterion 2. Seafood Watch defines bycatch as all fisheries-related mortality or injury to species other than the retained catch. Examples include discards, endangered or threatened species catch, and ghost fishing. Species are evaluated using the same guidelines as in Criterion 1. When information on other species caught in the fishery is unavailable, the fishery's potential impacts on other species is scored according to the Unknown Bycatch Matrices, which are based on a synthesis of peer-reviewed literature and expert opinion on the bycatch impacts of each gear type. The fishery is also scored for the amount of non-retained catch (discards) and bait use relative to the retained catch. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard/bait score. The Criterion 2 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Factor 2.3 (Fishing Mortality) is Crtitical

Guiding principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level.*
- *Minimize bycatch.*

Criterion 2 Summary

Criterion 2 score(s) overview

This table(s) provides an overview of the Criterion 2 subscore, discards+bait modifier, and final Criterion 2 score for each fishery. A separate table is provided for each species/stock that we want an overall rating for.

BLUE SWIMMING CRAB			
REGION / METHOD	**SUB SCORE**	**DISCARD RATE/LANDINGS**	**SCORE**
Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka	1.732	1.000: < 100%	Red (1.732)
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka	1.732	1.000: < 100%	Red (1.732)

Criterion 2 main assessed species/stocks table(s)

This table(s) provides a list of all species/stocks included in this assessment for each 'fishery' (as defined by a region/method combination). The text following this table(s) provides an explanation of the reasons the listed species were selected for inclusion in the assessment.

GULF OF MANNAR | INDIAN OCEAN, EASTERN | GILLNETS AND ENTANGLING NETS | SRI LANKA			
SUB SCORE: 1.732	DISCARD RATE: 1.000		**SCORE: 1.732**
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Hook-nosed seasnake	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Indian mottled eel	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Rays	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Scaly whipray	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Sea turtles	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Sharks	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Blue-spotted stingray	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Spiral melongena	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Blue swimming crab	3.670: Low Concern	3.000: Moderate Concern	Green (3.318)

PALK STRAIT AND PALK BAY | INDIAN OCEAN, EASTERN | GILLNETS AND ENTANGLING NETS | SRI LANKA			
SUB SCORE: 1.732		DISCARD RATE: 1.000	SCORE: 1.732
SPECIES	ABUNDANCE	FISHING MORTALITY	SCORE
Benthic inverts	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Rays	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Scaly whipray	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Sea turtles	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Sharks	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Spider conch	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Blue swimming crab	3.670: Low Concern	3.000: Moderate Concern	Green (3.318)

Net fisheries targeting blue swimming crab in Sri Lanka typically land all the caught species to sort them on shore, which enables monitoring studies to identify the species caught. Studies have been conducted in recent years and are summarized below to identify the main species discussed in this assessment (pelagikos Pvt ltd. 2022c)(pelagikos Pvt ltd. 2022d). There are limitations to these bycatch studies because some species may not always be landed if they are encountered. To assess the risk to species identified using the Unknown Bycatch Matrix, we reviewed a study that uses a novel approach to determine the risk to megafauna in Sri Lanka (Hines et al. 2018).

The November 2022 bycatch assessment indicated that scaly whipray (*Brevitrygon imbracata*) was caught in both the Palk Bay and Gulf of Mannar blue swimming crab fishing areas in Sri Lanka and represented 12.9% of the total catch in the Gulf of Mannar fishery (pelagikos Pvt ltd. 2022c). Scaly whipray is classified as "Vulnerable" on the IUCN Red List (Sherman et al. 2021), so it has been included as a Criterion 2 species. Blue-spotted stingray (*Neotrygon kuhlii*) was also recorded as 13.9% of the total catch in the Gulf of Mannar fishery (pelagikos Pvt ltd. 2022c) and is seasonally targeted by blue swimming crab fishers.

The most recent bycatch assessment for the Gulf of Mannar fishery (2022) stated that approximately 88.5% of the total catch, which comprised both targeted species and other capture species, was retained (sold or consumed), and 11.5% was discarded (pelagikos Pvt ltd. 2022c). For the Palk Bay fishery, approximately 83% of the total catch of targeted and other capture species was retained, and 17% was discarded (pelagikos Pvt ltd. 2022d).

Sea turtles and dugong are known to reside within Palk Bay and the Gulf of Mannar {DSCP 2016}. In a 2008 study, where gillnet fishers in Sri Lanka were interviewed about the incidental bycatch of dugong in fishing nets, all fishers responded that dugong is incidentally caught and likely killed for its meat (even though it is a protected species) (Ilangakoon et al. 2008). But, it appears that trawlers and shark/ray nets, not crab nets, are the gear that capture the most dugong (Hines et al. 2018). Further, a recent social survey was conducted in both Palk Bay (n = 330 fishers across 44 landing centers) and the Gulf of Mannar (n = 293 across 39 landing centers), and in both regions, fishers said that dugong did not interact with blue swimming crab gillnets and that shark/ray gillnets were the greater threat to dugong in the region (pelagikos Pvt ltd. 2022c)(pelagikos Pvt ltd. 2022d). Fishers stated that the small mesh size, low height, and lower-strength yarn ply of the crab nets were why dugong did not interact with blue swimming crab gillnets (pelagikos Pvt ltd. 2022c)(pelagikos Pvt ltd. 2022d), so dugong was excluded as a Criterion 2

species. Incidental capture of sea turtles in crab nets occurs occasionally (they are released alive when possible), but because the extent of their incidental capture is unknown, they are scored a moderate concern for fishing mortality.

Long-tailed butterfly ray (*Gymnura poecilura*; "Vulnerable"), spotted eagle ray (*Aetobatus narinari*; "Endangered"), sharpnose stingray (*Himantura gerrardi*; "Endangered"), honeycomb stingray (*Himantura uarnak*; "Endangered"), Bleeker's whipray (*Pateobatis bleekeri*; "Endangered"), numbray (*Narke dipterygia*; "Vulnerable"), Annandale's guitarfish (*Rhinobatos annandalei*; "Critically Endangered"), blacktip reef shark (*Carcharhinus melanopterus*; "Vulnerable"), grey bamboo shark (*Chiloscyllium griseum*; "Vulnerable"), great hammerhead shark (*Sphyrna mokarran*; "Critically Endangered"), bignose shark (Carcharhinus altimus; "Near Threatened"), and sandfish (*Holothuris scabra*; "Endangered") have also been included (in broad groupings) as Criterion 2 species because of their high vulnerability and unknown stock status. Species that did not constitute more than 5% of the catch have been grouped into broad taxonomic groups to streamline the assessment.

For bottom-set crab nets in both the Palk Bay and Gulf of Mannar blue swimming crab fisheries, sharks, rays, sea turtles, benthic invertebrates, hook-nosed seasnake, and Indian mottled eel limit the score for Criterion 2.

Criterion 2 Assessment

Factor 2.1 - Abundance
(same as Factor 1.1 above)

Factor 2.2 - Fishing Mortality
(same as Factor 1.2 above)

Factor 2.3 - Modifying Factor: Discards and Bait Use
Goal: Fishery optimizes the utilization of marine and freshwater resources by minimizing post-harvest loss. For fisheries that use bait, bait is used efficiently.

Scoring Guidelines: The discard rate is the sum of all dead discards (i.e. non-retained catch) plus bait use divided by the total retained catch.

Ratio of bait + discards/landings	Factor 2.3 score
<100%	1
>=100	0.75

Benthic inverts

Factor 2.1 - Abundance

Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

High Concern

A number of known and unknown benthic invertebrates were found in the catch. One of the species found in the catch—the sea cucumber (*Holothuria scabra*)—is listed as "Endangered" on the IUCN Red List {Hamel et al. 2020}. Hence, abundance of benthic invertebrates has been scored a high concern.

Factor 2.2 - Fishing Mortality

Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

According to the SFW Unknown Bycatch Matrix, benthic invertebrates caught using bottom-set gillnets score a 3 out of 5. Hence, fishing mortality is considered a moderate concern.

Blue-spotted stingray

Factor 2.1 - Abundance

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

There is no stock assessment for blue-spotted stingray (*Neotrygon [Dasyatis] kuhlii*) in Sri Lankan waters. But, according to the SFW productivity-susceptibility analysis (PSA score = 3.03), blue-spotted stingray is deemed moderately inherently vulnerable. Because there is no stock information for this species and it is considered moderately inherently vulnerable, we have scored its abundance a moderate concern.

Justification:

Productivity-Susceptibility Analysis:

Productivity Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Average age at maturity	3 to 6 years (Jacobsen and Bennett 2010)	1
Average maximum age	10 to 13 years (Pierce and Bennett 2009)	2

Von Bertalanffy growth Coefficient (K)	0.13–0.20 (Froese and Pauly 2022)	2
Fecundity	1 to 7 pups (Froese and Pauly 2022)	3
Average maximum size (fish only)	<70 cm (Froese and Pauly 2022)	1
Average size at maturity (fish only)	19 cm (Froese and Pauly 2022)	1
Reproductive strategy	Live bearer (ovoviviparous) (Froese and Pauly 2022)	3
Density dependence (invertebrates only)	—	—
Total Productivity (average)		**2**

Susceptibility Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Areal overlap (Considers all fisheries)	Most (70%–90%) of species concentration is unfished by any fishery; species of the family Dasyatididae are mostly found in the north and northwestern coast of Sri Lanka, from 0 to 170 m {Pelagikos Pvt ltd. 2022c}.	2
Vertical overlap (Considers all fisheries)	High degree of overlap between bottom-set gillnet fishing depths and depth range of species {Pelagikos Pvt ltd. 2022c}.	3
Seasonal availability (considers all fisheries)	Fisheries overlap with species 3–6 months/year {Pelagikos Pvt ltd. 2022c}.	2
Selectivity of fishery (Specific to fishery under assessment)	The mesh sizes used to catch blue-spotted stingray and blue swimming crab range from 5" (127 mm) to 6" (152.4 mm), but no data have been collected to assess the selectivity of bottom-set crab nets for blue-spotted stingray {Pelagikos Pvt ltd. 2022c}.	2
Post-capture mortality (Specific to fishery under assessment)	Almost all blue-spotted stingray is retained as salted, dry fish {Pelagikos Pvt ltd. 2022c}.	3
Total Susceptibility (multiplicative)		**2.4**

PSA score for blue-spotted stingray in Sri Lanka crab net fisheries is calculated as follows:

Vulnerability (V) = $\sqrt{(P^2 + S^2)}$

V = $\sqrt{(2^2 + 2.4^2)}$

V = 3.03

Factor 2.2 - Fishing Mortality

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

The impact of the blue swimming crab fishery on the blue-spotted stingray stock is unclear; therefore, fishing mortality is scored a moderate concern.

Hook-nosed seasnake

Factor 2.1 - Abundance

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

High Concern

The hook-nosed sea snake (*Hydrophis schistosus*) is listed as "Least Concern" by the IUCN Red List (Rasmussen et al. 2018). But, the species is protected in Sri Lanka under the Fauna and Flora Protection (Amendment) Act No. 22 of 2009 {Pelagikos Pvt ltd. 2022c}, and it is an offense to kill, wound, or injure this species even if it is not targeted and incidentally caught in activities such as fishing (GDSRSL 1993)(GDSRSL 2009). Because the species is protected under Sri Lankan law, we assume that there are concerns about the population, so abundance has been scored a high concern.

Factor 2.2 - Fishing Mortality

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

Because there is no information on the susceptibility of hook-nosed sea snake to gillnets in the blue swimming crab fishery, and fishing mortality of sea snakes in gillnets in Sri Lanka is unknown, a score of moderate concern has been assigned.

Indian mottled eel

Factor 2.1 - Abundance

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

High Concern

Per the IUCN Red List, the Indian mottled eel (*Anguilla bengalensis*) is "Near Threatened" {Pike et al. 2020}. Therefore, abundance for this species has been scored a high concern.

Factor 2.2 - Fishing Mortality

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

The impact of the blue swimming crab fishery on the blue-spotted stingray stock is unclear; therefore, fishing mortality is scored a moderate concern.

Rays

Factor 2.1 - Abundance

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

High Concern

Many of the rays caught in the blue swimming crab fishery are listed on the IUCN Red List as "Vulnerable," "Endangered," or "Critically Endangered" (IUCN 2022), as shown in the table below. For these reasons, their abundance is ranked a high concern.

Justification:

Species name	IUCN status	Reference
Long-tailed butterfly ray (*Gymnura poecilura*)	Vulnerable	(Sherman et al. 2021b)
Honeycomb stingray (*Himantura uarnak*)	Endangered	(Sherman et al. 2021c)
Spotted eagle ray (*Aetobatus narinari*)	Endangered	(Dulvy et al. 2021)
Sharpnose stingray (*Maculabatis gerrardi*)	Endangered	(Sherman et al. 2020)
Bleeker's whipray (*Pateobatis bleekeri*)	Endangered	(Sherman et al. 2020b)
Numbray (*Narke dipterygia*)	Vulnerable	(VanderWright et al. 2021)
Annandale's guitarfish (*Rhinobatos annandalei*)	Critically Endangered	(Dulvy et al. 2021b)

Factor 2.2 - Fishing Mortality

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

The impact of the blue swimming crab fishery on ray stocks of various species that are caught in smaller proportions in the catch is unclear, so fishing mortality is scored a moderate concern.

Scaly whipray

Factor 2.1 - Abundance

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

High Concern

There is no stock assessment for scaly whipray (*Brevitrygon imbricata*) from Sri Lanka. But, the species is globally "Vulnerable" per the IUCN Red List (Sherman et al. 2021). Therefore, abundance has been scored a high concern.

Factor 2.2 - Fishing Mortality

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern
The impact of the blue swimming crab fishery on the scaly whipray stock is unclear, so fishing mortality is scored a moderate concern.

Sea turtles

Factor 2.1 - Abundance

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

High Concern
Sea turtles are listed as "Endangered" or "Threatened" throughout the world {NOAA 2016}, and are nationally protected in Sri Lanka under the Fauna and Flora Protection Ordinance, No 2 of 1937 (GDSRSL 2009). Therefore, sea turtles scored a high concern, using the Seafood Watch criteria.

Justification:
Five of the world's seven sea turtle species—green turtle, leatherback turtle, olive ridley turtle, hawksbill turtle, and loggerhead turtle—come to nest on Sri Lankan beaches (Deraniyagala 1953). But, the concern is for the two species that migrate through the waters around the northwest of Sri Lanka (olive ridley turtle and green turtle), rather than those that nest in the south of Sri Lanka.

Factor 2.2 - Fishing Mortality

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern
For bottom gillnet fisheries in Southeast Asia, sea turtle fishing mortality is scored a 1 out of 5, or high concern, using the SFW Unknown Bycatch Matrix. There is no clear evidence that the crab fishery does not interact with turtles (low concern, or removal); however, expert opinion suggests that, although gillnets are a threat, flying fish nets, ray nets, shark nets, and surface-set gillnets are a greater threat in the region (pers. comm., R. Nanayakkara and T. Kapurusinghe, February 20, 2017) {Pelagikos Pvt ltd. 2022c}{Pelagikos Pvt ltd. 2022d}.

This information was corroborated by a bycatch study of megafauna in northwestern Sri Lanka, where researchers found that marine turtles were mentioned on a number of occasions as being present in the study areas and are commonly caught in nets in unsustainable numbers. It was reported that olive ridley turtle (*Lepidochelys olivacea*) and leatherback turtle (*Dermochelys coriacea*) stay closer to shore, so bycatch risk is higher along the shore and in swimming crab nets throughout Palk Bay (Hines et al. 2018). For green turtle (*Chelonia mydas*) and hawksbill turtle

(*Eretmochelys imbricata*), which stay closest to seagrass beds and coral reefs, nearshore shark/ray, swimming crab, and trawler fisheries showed the most risk throughout the study area (Hines et al. 2018). Although there are reports of capture in the swimming crab fishery and of overfishing across all fisheries, the available information suggests that the blue swimming crab fishery is a minor contributor to overall mortality of sea turtles, so we have rated fishing mortality a moderate concern.

Justification:
The incidental capture of sea turtles in certain fisheries along the northwestern coast (one area where blue swimming crab is fished), western coast, and southwestern coast of Sri Lanka has been reported (Kapurusinghe and Saman 2001) and is thought to be the leading cause of sea turtle mortality in Sri Lanka (Jones and Fernando 1968)(Jinadasa 1984). In particular, it has been reported that Kandakuliya, a remote village in the Gulf of Mannar on the northwestern coast of Sri Lanka, has a high incidence of turtle (olive ridley) bycatch (Kapurusinghe and Cooray 2002)(Shanker and Choudhury 2006), but no nesting (Rajakaruna et al. 2009). From the northwestern to the southern coast of Sri Lanka, an annual catch of more than 5,000 turtles has been reported (Kapurusinghe and Cooray 2002), both from incidental takes and targeted catch of turtles, despite their protected status (Frazier 1980)(Hewavisenthi 1990). It is thought that these turtles are predominantly entangled in nets from the seasonal flying fish fishery, which uses 5/8-inch mesh nets. These nets are used both along the coast and offshore, along the western coast of Puttalam District, but are not used in Puttalam Lagoon or in blue swimming crab fishing grounds (pers. comm., S. Creech, February 27, 2017; per conversation with Sri Lanka sea turtle expert Dr. Lailith Ekanayake). The Gulf of Mannar (and Palk Bay) is part of the olive ridley turtle's migration route to nesting sites off the eastern coast of India (pers. comm., S. Creech, February 27, 2017; per conversation with Sri Lanka sea turtle expert Dr. Lailith Ekanayake).

Sharks

Factor 2.1 - Abundance

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

High Concern
Some shark species that are caught in the blue swimming crab fishery are listed on the IUCN Red List as "Near Threatened," "Vulnerable," or "Critically Endangered" (IUCN 2022), as shown in the table below. For these reasons, their abundance is ranked a high concern.

Justification:

Species name	IUCN status	Reference	Caught in the Gulf of Mannar	Caught in Palk Bay
Bignose shark (*Carcharhinus altimus*)	Near Threatened	{Rigby et al. 2020}	X	X
Grey bamboo shark (*Chiloscyllium griseum*)	Vulnerable	(VanderWright et al. 2020)	X	X

| Great hammerhead shark (*Sphyrna mokarran*) | Critically Endangered | (Rigby et al. 2019) | X | |
| Blacktip reef shark (*Carcharhinus melanopterus*) | Vulnerable | (Simfendorfer et al. 2020) | | X |

Factor 2.2 - Fishing Mortality

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern
The impact of the blue swimming crab fishery on shark species is unknown, but they are caught in such small numbers that the fishery is unlikely to be a substantial contributor to fishing mortality; therefore, this factor is scored a moderate concern.

Spider conch

Factor 2.1 - Abundance

Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

High Concern
Spider conch, which is found in the blue swimming crab catch, comprises two species: *Lambis lambis* and *Lambis chiragra*. Both are listed as "Schedule VII" species and are therefore protected under the Fauna and Flora Protection (Amendment) Act (FFPO) No. 22. of 2009 in Sri Lanka (GDSRSL 2009){Pelagikos Pvt ltd. 2022}. Thus, abundance of spider conch has been scored a high concern.

Factor 2.2 - Fishing Mortality

Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern
The impact of the blue swimming crab fishery on the spider conch stock is unclear; therefore, fishing mortality is scored a moderate concern.

Spiral melongena

Factor 2.1 - Abundance

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern
There is no stock assessment for spiral melongena (*Pugilina cochlidium*) in Sri Lankan waters. But, according to the SFW productivity-susceptibility analysis (PSA score = 3.12), spiral melongena is deemed moderately inherently vulnerable. Because there is no stock information for this species and it is considered moderately inherently vulnerable, we have scored abundance a moderate concern.

Justification:

Productivity Attribute	Relevant information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Average age at maturity	>5 years (Fisher 2015)	2
Average maximum age	up to 14 years (Fisher 2015)	2
Von Bertalanffy (Brody) Growth Coefficient (K)	0.16–2.00 in *Busycotypus canaliculatus* (Sealifebase 2022)	2
Fecundity	Neogastropods have several hundred eggs per egg case (Hua et al. 2001)	2
Reproductive strategy	Neogastropods are demersal egg layers (Hua et al. 2001)	2
Density dependence	No depensatory or compensatory dynamics demonstrated or likely	2
Total Productivity		**2**

Susceptibility Attribute	Relevant information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Areal overlap	70%–90% of species concentration is unfished by any fishery {Pelagikos Pvt ltd. 2022c}.	2
Vertical overlap	High overlap with bottom-set gillnets {Pelagikos Pvt ltd. 2022c}.	3
Seasonal availability	Overlaps with the blue swimming crab fisheries 3–6 months of the year {Pelagikos Pvt ltd. 2022c}.	2
Selectivity of the fishery	Mesh size is larger than size at maturity, so species is incidentally encountered and not likely to escape the gear, but conditions of high risk do not apply {Pelagikos Pvt ltd. 2022c}.	2
Post-capture mortality	100% of species are retained {Pelagikos Pvt ltd. 2022c}.	3
Total Susceptibility		**2.4**

Factor 2.2 - Fishing Mortality

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

The impact of the blue swimming crab fishery on the spiral melongena stock is unclear; therefore, fishing mortality is scored a moderate concern.

33

Factor 2.3 - Discard Rate/Landings

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

< 100%

Overall, the discard rate from the Gulf of Mannar was 11.5% (pelagikos Pvt ltd. 2022c) and from Palk Bay was 17% (pelagikos Pvt ltd. 2022d). Because discards are <100%, we assume a multiplying factor of 1.

Criterion 3: Management Effectiveness

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

- *5 (Very Low Concern) — Meets the standards of 'highly effective' for all five factors considered.*
- *4 (Low Concern) — Meets the standards of 'highly effective' for 'management strategy and implementation' and at least 'moderately effective' for all other factors.*
- *3 (Moderate Concern) — Meets the standards for at least 'moderately effective' for all five factors.*
- *2 (High Concern) — At a minimum, meets standards for 'moderately effective' for Management Strategy and Implementation and Bycatch Strategy, but at least one other factor is rated 'ineffective.'*
- *1 (Very High Concern) — Management Strategy and Implementation and/or Bycatch Management are 'ineffective.'*
- *0 (Critical) — Management Strategy and Implementation is 'critical'.*

The Criterion 3 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Management Strategy and Implementation is Critical.

Guiding principle

- The fishery is managed to sustain the long-term productivity of all impacted species.

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

Criterion 3 Summary

FISHERY	MANAGEMENT STRATEGY	BYCATCH STRATEGY	DATA COLLECTION AND ANALYSIS	ENFORCEMENT	INCLUSION	SCORE
Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka	Highly effective	Moderately Effective	Moderately Effective	Highly effective	Highly effective	**Green (4.000)**
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka	Highly effective	Moderately Effective	Moderately Effective	Highly effective	Highly effective	**Green (4.000)**

Criterion 3 Assessment

<u>SCORING GUIDELINES</u>

Factor 3.1 - Management Strategy and Implementation
Considerations: What type of management measures are in place? Are there appropriate management goals, and is there evidence that management goals are being met? Do manages follow scientific advice? To achieve a highly effective rating, there must be appropriately defined management goals, precautionary policies that are based on scientific advice, and evidence that the measures in place have been successful at maintaining/rebuilding species.

Factor 3.2 - Bycatch Strategy
Considerations: What type of management strategy/measures are in place to reduce the impacts of the fishery on bycatch species and when applicable, to minimize ghost fishing? How successful are these management measures? To achieve a Highly Effective rating, the fishery must have no or low bycatch, or if there are bycatch or ghost fishing concerns, there must be effective measures in place to minimize impacts.

Factor 3.3 - Scientific Research and Monitoring
Considerations: How much and what types of data are collected to evaluate the fishery's impact on the species? Is there adequate monitoring of bycatch? To achieve a Highly Effective rating, regular, robust population assessments must be conducted for target or retained species, and an adequate bycatch data collection program must be in place to ensure bycatch management goals are met.

Factor 3.4 - Enforcement of Management Regulations
Considerations: Do fishermen comply with regulations, and how is this monitored? To achieve a Highly Effective rating, there must be regular enforcement of regulations and verification of compliance.

Factor 3.5 - Stakeholder Inclusion
Considerations: Are stakeholders involved/included in the decision-making process? Stakeholders are individuals/groups/organizations that have an interest in the fishery or that may be affected by the management of the fishery (e.g., fishermen, conservation groups, etc.). A Highly Effective rating is given if the management process is transparent, if high participation by all stakeholders is encouraged, and if there a mechanism to effectively address user conflicts.

Factor 3.1 - Management Strategy And Implementation

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Highly effective

Sri Lanka has a comprehensive set of acts and regulations for all fisheries. The acts and regulations provide for the demarcation of FMAs (several have already been declared), and the membership of the committees is stipulated and includes fisher's representatives (PDSRSL 2013). All vessels and engines are numbered and registered, and all fishers and fishing gears are licensed annually. A Fishing Operating License (FOL) entitles a fisher to harvest a number of different species, including blue swimming crab, using the licensed gear (Creech 2013). FOLs are issued based on the mesh size of the gear, rather than on the fishery in which the gear is supposed to be used (Creech 2013). The overall fishery policy in Sri Lanka is committed to sustainable fishery management as a goal (DFAR 2016).

For each of the five districts in Palk Bay (Jaffna, Kilinochchi, and Mannar districts) and the Gulf of Mannar (Puttalam and Mannar districts) fisheries, there is a detailed Fishery Management Plan (FMP) (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f). The harvest control strategies used to manage the efficiency of the fishery include specifying the type of fishing gear, the number of net pieces, fishing hours, and days. These are as follows: 1) Fishers are required to use only polyfilament, bottom-set crab nets with a mesh of greater than 4.5" (114.3 mm) to harvest blue swimming crab for export; 2) No person who intends to supply blue swimming crab for export shall use any other gears such as traps, trawls, or fixed nets, other than the bottom-set crab net prescribed in #1 above; 3) Fishers shall not set more than 35 net-pieces per fisher, per day to harvest blue swimming crab for export; 4) Fishers shall not harvest BSC for more than 6 days/nights per week; and 5) Fishers shall not set bottom-set nets for more than one night (DFAR 2017)(DFAR 2018).

Fishing pressure on blue swimming crab is limited by the nationwide ban on the use of monofilament nets by reducing fishing efficiency, or escapability, during the 3–4 months throughout the year when the ocean is calm and there is a decrease in turbidity/increase in visibility (Creech 2013). The prohibition of monofilament nets also aids in the creation of an "off-season," when nylon crab nets are more visible and more easily avoided, and fishers tend to target other commercial species. But, the regulation prohibiting the use of monofilament nets in the blue swimming crab fishery is not fully enforced (Creech 2013).

Stock assessments (SAs) are conducted annually before January 30, with the assistance of blue swimming crab fishing communities and manufacturers/exporters of blue swimming crab products. Representatives of the regulatory authorities (DFAR or NARA) participate in the annual stock assessment and the results are made available (published) to the regulatory authorities, fishing communities, and manufacturers/exporters of products on or before February 28, or within 3 months of completing the stock assessment (in the Palk Bay fishery) (Creech 2013). Stock assessments use the Length-Based Spawning Potential Ratio (LB SPR) approach (Hordyk et al. 2015), with the following reference points (RPs): 1) Upper Target Reference Point (Upper TRP) =

Spawning Potential >40%; 2) Lower Target Reference Point (Lower TRP) = Spawning Potential ≥30%; and 3) Limit Reference Point (LRP) = Spawning Potential <20%. Stock assessments in the Gulf of Mannar fishery show that the LB SPR was above the LRP and the Lower TRP in most years for 7 years from 2014 to 2021, and in Palk Bay, the LB SPR was above the Upper TRP in most years during this time period (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f), indicating that both fisheries are being sustainably managed (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f). Four harvest control rules have been put into place and may be implemented in response to stock assessment results. In addition, there is an appropriate bycatch management strategy in place (scaly whipray and blue-spotted stingray are targeted by blue swimming crab fishers for part of the year in Sri Lanka), as well as monitoring and surveillance, and dispute resolution (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f).

Since 2013, Sri Lankan fishers in the north have campaigned and lobbied for the government to take action to end illegal, unreported, and unregulated (IUU) fishing by Tamil Nadu trawlers in Sri Lankan waters, including filing legal action in the court of appeal and supreme court (pers. comm., S. Creech October 1, 2018). An amendment to the Fisheries (Regulation of Foreign Fishing Boats) Act 1979 was published in November 2017 and became law in January of 2018 {Parliament of the Democratic Socialist Republic of Sri Lanka 2017}. Since then, the government has taken steps to arrest and prosecute Tamil Nadu boat owners under the amended act. As a result, the incidence of IUU fishing by Tamil Nadu trawlers in Sri Lankan waters had decreased by as much as 90%, compared to the situation prevailing at the start of the FIP in 2013, according to local fisher's leaders {pers. comm., S. Creech, October 1, 2018}.

In addition to the harvest control rules and tools above, there is a "Voluntary Code of Conduct" (CoC). The CoC was developed to ensure the sustainable use of resources by applying good management measures in maintaining the status of blue swimming crab stocks at healthy limits, and to minimize the impact on the marine environment and the associated species (see Justification) (DFAR 2017). In April 2022, the Blue Swimming Crab Fishery Management Regulation was signed by the Minister of Fisheries and Aquatic Resources, and is likely to soon replace the CoC, once it is approved by Parliament (see Justification) (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f)(GDSRSL 2022).

Because measures have been in place long enough to evaluate their success, and the stock in both fisheries is healthy, we have deemed this factor highly effective.

Justification:
Some of the input controls agreed by stakeholders that cannot be easily incorporated into the legislation are included in a "Voluntary Code of Conduct" (see below), to be agreed upon by the Fisheries Committees and other groups and associations representing fishers and other stakeholders. This pledges voluntary compliance by fishers to do the right thing with no sanctions, except social and moral obligations (DFAR 2013). As of May and July 2018, 97% of blue swimming crab fishers have endorsed the voluntary CoC for blue swimming crab fishing in the Palk Bay fishery, and 94% have endorsed the voluntary CoC in the Gulf of Mannar fishery (Gunasekera 2018a)(Gunasekera 2018b).

The voluntary CoC includes that: **Rule 1.** Blue swimming crab fishers will operate in compliance

with the Fisheries and Aquatic Resources Act No. 2 of 1996 (amendments and regulations); **Rule 2.** Blue swimming crab shall only be harvested using four-ply or six-ply bottom-set crab nets with a minimum mesh size of 4.5″ (114.3 mm); **Rule 3.** The maximum height of a bottom-set crab net shall be 15 eyes and the maximum length of shall be 1,500 eyes per piece; **Rule 4.** An individual fisher can use/set a maximum number of 35 net-pieces/panels in a single day; **Rule 5.** The set time (soakage time) of a bottom-set crab net for catching of blue swimming crab shall be not more than 12 hours: 6 p.m. to 6 a.m.; **Rule 6.** An individual fisher will not deliberately place or set bottom-crab nets on coral reefs, rocky reefs, or seagrass beds; **Rule 7.** Blue swimming crab fishing will be limited to six nights per week, commencing Sunday evening and ending on Saturday morning; **Rule 8.** Any person who intends to supply blue swimming crab for export shall not use any other gears such as traps, trawls, fixed nets, other than the bottom-set crab net prescribed above; **Rule 9.** Blue swimming crab fishers will dispose of all used, damaged, discarded crab nets on land, in an environmentally safe manner to avoid "ghost fishing"; and **Rule 10.** Any person who engages in fishing for blue swimming crab in compliance with this code and/or purchases, sells, or processes blue swimming crab harvested using bottom-set crab nets shall assist the DFAR in the collection of catch, effort data, and production data as and when requested by staff and officers of the respective District Fisheries Extension Offices and or the Fishery Management Division in Colombo (DFAR 2017).

A new regulation for blue swimming crab fisheries was written in 2016 and was submitted to the Director General, DFAR in June 2017 (pers. comm., S. Creech, June 8, 2017). In April 2022, the Minister of Fisheries and Aquatic Resources signed the regulation, known as the Blue Swimming Crab Fishery Management Regulation, under Section 61 of the Fisheries and Aquatic Resource Act (FARA) No. 2 of 1996, at the request of the Director General (DG) DFAR (GDSRSL 2022)(pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f). Once published, tabled, and approved by Parliament, the regulation will become law under the FARA (GDSRSL 2022)(pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f), and will replace the Voluntary Code of Conduct for Responsible (BSC) Fishing and Purchasing (GDSRSL 2022)(pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f). The regulation stipulates the following:

1. No person shall engage in blue swimming crab fishing in Sri Lanka waters using bottom set gillnets without a valid operating license issued by the DG DFAR.
2. No person shall harvest blue swimming crab using bottom-set nets with a mesh size of less than 114.3 millimetres (4.5″) or a yarn of more than six-ply.
3. No person shall use any net other than nylon polyfilament net to fish blue swimming crab.
4. No person shall process or export live or dead blue swimming crab weighing less than 100 grams in weight.
5. The DG shall determine the number of licenses issued annually, and operation specifications of crab fishing in accordance with the recommendations of the National Aquatic Resources Research and Development Agency.
6. The Minister shall declare closed and open seasons for crab fishing in areas under section 34 of the Fisheries and Aquatic Resources Act, No. 2 of 1996, based on the recommendations of the National Aquatic Resources Research and Development Agency.
7. No person shall use any other type of fishing vessel for blue swimming crab fishing except an outboard engine fiberglass-reinforced plastic boat, or mechanized or nonmechanized traditional boats.

8. No person shall dredge or damage the sea bottom when fishing for blue swimming crab.
9. A licensee for blue swimming crab fishing operations shall provide production data and other data, as required by the DG.

Factor 3.2 - Bycatch Strategy

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderately Effective

The Sri Lanka blue swimming crab fishery recently implemented an FMP for all five districts in the Park Bay and Gulf of Mannar fisheries. In this FMP, an explicit bycatch management strategy is laid out (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f). The following measures will be implemented by the regulatory authority and representatives of the crab fishing communities in the respective districts, to minimize the impact of the bottom-set blue swimming crab net fishery on other species, particularly species of national and international concern.

These are: 1) Use of low net height: the maximum net height of bottom-set blue swimming crab nets shall be ≤25 eyes for all nylon nets used in the sea and in estuarine regions, and ≤20 eyes for all nylon nets used in the sea; 2) Use of weak (breakable) nets: the maximum thread used for bottom-set crab nets shall be six-ply; 3) Avoiding critical marine habitats: fishers shall not set crab nets on coral reefs, rocky reefs, or seagrass beds (frequented by dugong and turtles); 4) Safe disposal of old nets: fishers shall dispose of all used, damaged, discarded crab nets on land, in an environmentally safe manner; 5) Measures taken to reduce the fishery's impact on scaly whipray: fishers targeting both blue swimming crab and scaly whipray shall use bottom-set nets with a mesh of ≥5.5" (139.7 mm), to avoid catching immature individuals of the species; and 6) Supporting scientific research and implementing the findings: the regulatory authority and representatives of the blue swimming crab fishing communities will promote, encourage, and support further research about the impact of the blue swimming crab fishery on other species, including pale-edged stingray, turtles, and dugong. If any negative impacts are demonstrated, measures to mitigate these impacts will be formulated and implemented under the next annual DFMP (DFAR 2017)(DFAR 2018).

In addition to these mitigation measures, awareness programs have been conducted among fishers in the Gulf of Mannar and Palk Bay regions, between 2018 and 2022, on bycatch species that need to be protected (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f). Signboards depicting other capture species were created in 2021, as part of this awareness program. A poster depicting other capture species has also been created and will be distributed at landing centers, to encourage fishers to release protected and endangered species caught when fishing for blue swimming crab. A signboard for the conservation of sea turtles has also been created and will be erected in 2022. Furthermore, in 2022, trials on the use of blunt-ended net gaffes and stainless steel short-handled net cutting devices have been initiated among 25 fishers in the Gulf of Mannar. These devices help fishers safely release live turtles if they are caught in blue swimming crab gillnets. If the trials are successful, these devices will be distributed to fishers, where the risk of turtles interacting with blue

swimming crab bottom-set gillnets is high.

Because some species of concern are targeted, as well as caught as bycatch, and management appears to be only partly effective, this factor is scored moderately effective.

Justification:
Other legislation that applies to ETP species and species of concern, such as dugong and sea turtles, is the Fauna and Flora Protection Ordinance. This protective legislation exists on paper; however, implementation is quite weak, resulting in illegal take and illegal commercial use of bycatch (pers. comm., A. Langakoon, September 27, 2018).

Factor 3.3 - Scientific Data Collection and Analysis

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderately Effective
At the commencement of the FIP in 2013, there were no published scientific studies on the population biology of Sri Lanka blue swimming crab. To address this issue, the FIP commissioned NARA to undertake the first scientific study of the population biology (results published in 2016). Since then, the FIP has also had help from the Bay of Bengal Large Marine Ecosystem (BOBLME) Project, which conducted a survey of fishing effort for blue swimming crab, and had numerous undergraduate students from Uva Wellassa University, Ocean University, and the University of Colombo conduct their bachelor's theses on all aspects of the crab fishery; seven stock assessments have been conducted in each of the fisheries (Palk Bay and Gulf of Mannar) using the LB SPR approach. In 2020, Prince et al. published a summary of stock assessments conducted in the Gulf of Mannar and Palk Bay blue swimming crab fisheries (Prince et al. 2020). Other reports and symposium proceedings have been published on the population biology, morphometric analysis, reproductive biology, management, and bottom-set crab net selectivity of the blue swimming crab (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f).

The FIP is working with local institutions to ensure ongoing research into the impacts of the fishery; stock assessments are conducted annually and are peer-reviewed, but do not include fishery-independent data, and they include a data-limited approach. Bycatch is regularly monitored, but there are no data on lost gear/effects of ghost fishing, and no stock assessments of bycatch species have been conducted. For these reasons, this factor is rated moderately effective.

Factor 3.4 - Enforcement of and Compliance with Management Regulations

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Highly effective

Most of the blue swimming crab fishers comply with the regulations that currently govern the exploitation and management of the fishery and the Fisheries and Resource Act (FARA) (Creech 2013)(pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f). Monitoring, control, and surveillance mechanisms for vessel and gear licenses (by DFAR) and the prohibition of illegal fishing gears (e.g., monofilament nets and trawlers) are implemented systematically across the entire fishery and are satisfactory (Creech 2013)(pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f), given the physical and human resources available to DFAR at the district and village level. In 2016, DFAR filed 285 cases of fishing infractions in the districts that compose the Palk Bay and Gulf of Mannar crab fisheries (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f). As laid out in the blue swimming crab FMPs, any person who engages in blue swimming crab fishing in compliance with the FMP and/or purchases, sells, or processes blue swimming crab harvested using bottom-set crab nets shall assist the DFAR in the collection of catch, effort data, and production data when requested by DFAR and/or the Fishery Management Division in Colombo. Monitoring of the implementation of the FMP is undertaken every 3 months by the Fishery Inspector in collaboration with blue swimming crab fishing communities in each FID (every 6 months in the Palk Bay fishery) (DFAR 2017)(DFAR 2018). Compliance with the provisions set out in the FMP and/or the voluntary CoC for blue swimming crab is monitored annually by the Assistant Director, DFO (DFAR 2017)(DFAR 2018).

In 2021, DFAR conducted follow-up compliance surveys of the crab fishery against the CoC. Overall compliance was high in both fisheries. In Palk Bay, compliance levels were as follows: Jaffna 98%, Kilinochchi 98%, and Mannar North 95% (pelagikos Pvt ltd. 2022f). In the Gulf of Mannar, compliance levels were: Puttalam 89% and Mannar South 95% (pelagikos Pvt ltd. 2022e). The regulatory authority takes immediate action against any fisher or seafood company found to be in contravention of the provisions set out in the FMP and, before 2022, the voluntary CoC for blue swimming crab fishing (DFAR 2017). From 2022, commercial blue swimming crab fishers and seafood companies purchasing blue swimming crab in Palk Bay and the Gulf of Mannar will be required to comply with, and the DFAR will be compelled to enforce, the Blue Swimming Crab Fishery Management Regulation, which is currently waiting to be passed by the Parliament
(pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f).

IUU fishing has been a cause of concern for the overarching effectiveness of fisheries management in Sri Lanka, but the Sri Lankan Parliament passed a bill in July 2017 banning the destructive fishing practice of bottom-trawling in the island waters, and imposing heavy fines on the violators {ColomoPage 2017}. Since then, incursions by Indian trawlers have been reduced by 50% as a result of illegal fishers/boats being taken into custody (Parliment newspaper article: "Fish Exports Will Reach 44% by End of Year: Amaraweera"), and the new amendment, which fishers lobbied for in the supreme court, will further increase the deterrent (pers. comm., S. Creech, December 20, 2017).

Enforcement and/or monitoring have been in place for several years to ensure that goals are successfully met, compliance has been consistently high, and enforcement is now formalized by law; thus, a score of highly effective is given.

Justification:
Monofilament net use is prohibited under the Fisheries & Aquatic Resources Act in Sri Lanka, but these nets are still thought to be used, mostly in Puttalam estuarine complex and in the Jaffna District. Previously, as much as 75% of the catch was landed using monofilament nets (Creech 2013). Monofilament net use is thought to be a remnant of the 30-year civil conflict, where fishing was only allowed between 6 a.m. and 6 p.m. each day and fishers needed to be more efficient. These nets are used because they are cheaper than nylon, harder to see in turbid water, are more efficient, and catch fewer nontargeted species (Creech 2013).

Factor 3.5 - Stakeholder Inclusion

**Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka**

Highly effective

Stakeholders form the very basis of the Sri Lanka blue swimming crab FIP, which was initiated when SEASL received a request from representatives of Sri Lankan seafood companies, government authorities, researchers, and civil society organizations associated with the north blue swimming crab fishery. The aim of the FIP is to gather all those associated with the fishery to create and implement a local plan that will improve the economic, social, and ecological sustainability of the fishery.

In particular, the scoping document was based on comments and suggestions by fishing communities. The fishery preliminary assessment included interviews with fishers in all four districts (Creech 2013). The primary stakeholders in the fishery, including fisher societies, regulatory authorities, and crab manufacturers, have all made written commitments to improve the biological and ecological status of blue swimming crab fisheries and sustainably manage them (pelagikos Pvt ltd. 2022e)(pelagikos Pvt ltd. 2022f). Producers, processors, and regulators all participate in annual meetings. The Harvest Control Strategy and Harvest Control Rules and Tools were translated into the local languages (Sinhala and Tamil) and stakeholders were asked for their comments, feedback, and opinions. Key management decisions including the CoC for responsible fishing, the CoC for responsible purchasing, and the recent blue swimming crab management regulation, and any actions to improve the fishery have been and will be taken following consultations with representatives of blue swimming crab fishing communities, officers and staff of DFAR, senior scientists at NARA, and representatives of the seafood export industry (pelagikos Pvt ltd. 2022e) (pelagikos Pvt ltd. 2022f).

Any disputes arising in connection with the provisions set out in the blue swimming crab FMP and/or the voluntary CoC will be resolved by either: 1) The Fisheries Inspector, with representatives of blue swimming crab fishing communities and/or seafood exporters at the FID level; 2) The Assistant Director, with representatives of blue swimming crab fishing communities and/or seafood exporters at the DFO level; or 3) The Director General, with representatives of blue swimming crab communities and/or seafood exporters at the DFAR (DFAR 2017)(DFAR 2018).

The management process is transparent, high participation by all stakeholders is encouraged, and there is a mechanism in place to effectively address user conflicts, so this factor is rated highly effective.

Criterion 4: Impacts on the Habitat and Ecosystem

This Criterion assesses the impact of the fishery on seafloor habitats, and increases that base score if there are measures in place to mitigate any impacts. The fishery's overall impact on the ecosystem and food web and the use of ecosystem-based fisheries management (EBFM) principles is also evaluated. Ecosystem Based Fisheries Management aims to consider the interconnections among species and all natural and human stressors on the environment. The final score is the geometric mean of the impact of fishing gear on habitat score (factor 4.1 + factor 4.2) and the Ecosystem Based Fishery Management score. The Criterion 4 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Guiding principles

- Avoid negative impacts on the structure, function or associated biota of marine habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.
- Follow the principles of ecosystem-based fisheries management.

Rating cannot be Critical for Criterion 4.

Criterion 4 Summary

FISHERY	FISHING GEAR ON THE SUBSTRATE	MITIGATION OF GEAR IMPACTS	ECOSYSTEM-BASED FISHERIES MGMT	FORAGE SPECIES?	SCORE
Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka	Score: 3	Score: 0	Moderate Concern		**Yellow (3.000)**
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka	Score: 3	Score: 0	Moderate Concern		**Yellow (3.000)**

Criterion 4 Assessment

SCORING GUIDELINES

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

Goal: The fishery does not adversely impact the physical structure of the ocean habitat, seafloor or associated biological communities.

- *5 - Fishing gear does not contact the bottom*
- *4 - Vertical line gear*
- *3 - Gears that contacts the bottom, but is not dragged along the bottom (e.g. gillnet, bottom*

longline, trap) and is not fished on sensitive habitats. Or bottom seine on resilient mud/sand habitats. Or midwater trawl that is known to contact bottom occasionally. Or purse seine known to commonly contact the bottom.

- *2 - Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Or gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Or bottom seine except on mud/sand. Or there is known trampling of coral reef habitat.*
- *1 - Hydraulic clam dredge. Or dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)*
- *0 - Dredge or trawl fished on biogenic habitat, (e.g., deep-sea corals, eelgrass and maerl)*
  Note: When multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, the score will be based on the most sensitive, plausible habitat type.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts
Goal: Damage to the seafloor is mitigated through protection of sensitive or vulnerable seafloor habitats, and limits on the spatial footprint of fishing on fishing effort.

- *+1 —>50% of the habitat is protected from fishing with the gear type. Or fishing intensity is very low/limited and for trawled fisheries, expansion of fishery's footprint is prohibited. Or gear is specifically modified to reduce damage to seafloor and modifications have been shown to be effective at reducing damage. Or there is an effective combination of 'moderate' mitigation measures.*
- *+0.5 —At least 20% of all representative habitats are protected from fishing with the gear type and for trawl fisheries, expansion of the fishery's footprint is prohibited. Or gear modification measures or other measures are in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing that are expected to be effective.*
- *0 —No effective measures are in place to limit gear impacts on habitats or not applicable because gear used is benign and received a score of 5 in factor 4.1*

Factor 4.3 - Ecosystem-Based Fisheries Management
Goal: All stocks are maintained at levels that allow them to fulfill their ecological role and to maintain a functioning ecosystem and food web. Fishing activities should not seriously reduce ecosystem services provided by any retained species or result in harmful changes such as trophic cascades, phase shifts or reduction of genetic diversity. Even non-native species should be considered with respect to ecosystem impacts. If a fishery is managed in order to eradicate a non-native, the potential impacts of that strategy on native species in the ecosystem should be considered and rated below.

- *5 — Policies that have been shown to be effective are in place to protect species' ecological roles and ecosystem functioning (e.g. catch limits that ensure species' abundance is maintained at sufficient levels to provide food to predators) and effective spatial management is used to protect spawning and foraging areas, and prevent localized depletion. Or it has been scientifically demonstrated that fishing practices do not have negative ecological effects.*
- *4 — Policies are in place to protect species' ecological roles and ecosystem functioning but have not proven to be effective and at least some spatial management is used.*
- *3 — Policies are not in place to protect species' ecological roles and ecosystem functioning but detrimental food web impacts are not likely or policies in place may not be sufficient to protect species' ecological roles and ecosystem functioning.*

- *2 — Policies are not in place to protect species' ecological roles and ecosystem functioning and the likelihood of detrimental food impacts are likely (e.g. trophic cascades, alternate stable states, etc.), but conclusive scientific evidence is not available for this fishery.*
- *1 — Scientifically demonstrated trophic cascades, alternate stable states or other detrimental food web impact are resulting from this fishery.*

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Score: 3

Palk Bay, specifically, has a number of marine habitats of high importance, including coral reefs, rocky (limestone) reefs, seagrass beds, fringing mangroves, mudflats, and open marine environment (Creech 2013). Using the community-based mapping data, and overlapping it with sensitive marine habitats (using the Shapely library in Python and Q-GIS 3.4), in 2021, the blue swimming crab fishery in Palk Bay recorded an observed potential overlap of 7,509 hectares (ha) or 9% with seagrass beds (3,653 ha from the Jaffna District, 641 ha from the Kilinochchi District, and 3,215 ha from the Mannar District), 65 ha or 0.9% of coral reefs, 1.2 ha or 0.01% of mangroves, and 0 ha of limestone reefs (Figure 10) (pelagikos Pvt ltd. 2022g), totaling 8% of potential overlap of fishing grounds with sensitive habitats.

Community-based data for blue swimming crab fishing grounds in the Gulf of Mannar recorded an observed potential overlap of 144 ha or 2% with seagrass beds (57 ha from the Mannar District and 87 ha from the Puttalam District), 190 ha or 7% of coral reefs, 33 ha or 2% of mangroves, and 181 ha or 4% of limestone reefs (Figure 11) (pelagikos Pvt. ltd. 2022h), totaling 3% of potential overlap of fishing grounds with sensitive habitats.

According to the Seafood Watch criteria, bottom-set nets that come into contact with substrates other than boulders/coral reef (e.g., mud, sand, and other nonsensitive/resilient substrates) are scored a 3 out of 5.

Justification:

In Puttalam District, bottom-set crab nets used in the fishery are mainly set within the Puttalam Estuary (inner/middle Puttalam Lagoon, Dutch Bay, and Portugal Bay); the majority of coral/rocky reefs in the district are located outside the estuary. Bottom-set nets are also not set close to the shore, in very shallow water (<2 m), where mangroves are ubiquitous.
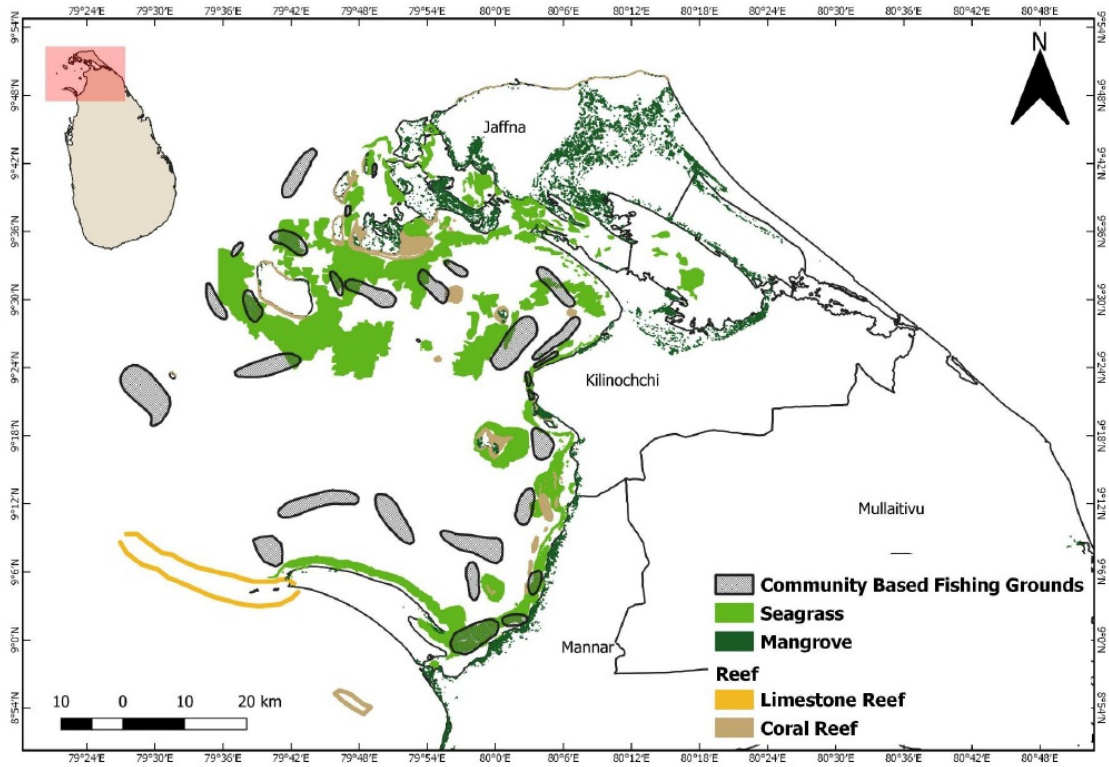
Figure 10: Potential overlap of blue swimming crab fishing grounds and marine habitats in Palk Bay. Taken from (pelagikos Pvt ltd. 2022g).
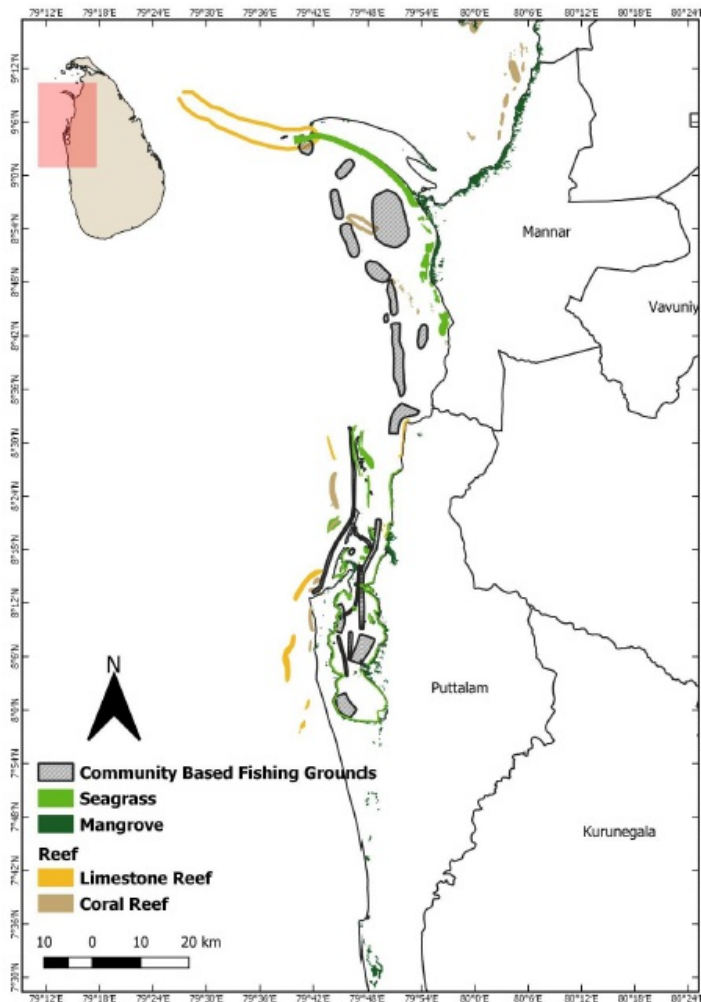
Figure 11: Potential overlap of blue swimming crab fishing grounds and marine habitats in the Gulf of Mannar. Taken from {pelagikos Pvt ltd. 2022h}.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

**Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka**

Score: 0

It has been observed that the bottom-set crab nets used for the blue swimming crab are not associated with any damage of critical marine habitat in the fished areas of Sri Lanka (Creech 2013). The percentage of overlap between the crab fishery and sensitive habitats was low overall. For example, the Palk Bay fishery overlapped with 7,509 ha of seagrass beds, which represents 9% of seagrass found in the Palk Bay (81,036 ha) (pelagikos Pvt ltd. 2022g). The Gulf of Mannar fishery overlapped with 144 ha of seagrass beds, which represents 2% of seagrass found in the Gulf of

Mannar (8,866 ha) (pelagikos Pvt. ltd. 2022h). Aside from these potentially fished sensitive habitats, blue swimming crab is mostly fished over mud/sand.

There are seven marine protected areas (MPA) around the region where blue swimming crab is fished: one National Park (Adam's Bridge) spans Palk Bay and the Gulf of Mannar; Palk Bay has one other national park, one nature reserve, and two sanctuaries; and the Gulf of Mannar has two sanctuaries (pelagikos Pvt ltd. 2022g) (pelagikos Pvt. ltd. 2022h). Fishing and agriculture usually cannot be carried out inside a national park, whereas sanctuaries have some restrictions on fishing (though they are not clearly mentioned in the legislation), and nature reserves have no restrictions on fishing (Bandara 2018b). Traditional fishing and farming activities can continue to be carried out in marine protected areas (including national parks, nature reserves, and sanctuaries), with permission, if these activities took place before the declaration of the MPA (pers. comm., S. Creech, May 10, 2016). Nevertheless, the overlap between blue swimming crab fishing grounds and MPAs in Palk Bay and the Gulf of Mannar is low: in Palk Bay, the overlap is 4,231 ha, or 8%, and in the Gulf of Mannar, it is 1,221 ha or 2% (pelagikos Pvt ltd. 2022g)(pelagikos Pvt. ltd. 2022h).

Because there are no gear modifications in place to protect the marine habitat from blue swimming crab fishing activity and there is some fishing in the marine protected areas, Seafood Watch considers there to be no effective mitigation.

Justification:
It is important to note that blue swimming crab fishers switch gears and fisheries throughout the year, depending on the availability and wholesale value of different fisheries (Creech 2013). There are always alternatives to blue swimming crab when the catch is low; for example, when crabs move offshore due to unusual weather (e.g., too rough, too wet, too hot) (Creech 2013). In addition, when other species are more abundant than blue swimming crab (e.g., carangids, scombrids, prawns, cuttlefish), crab fishers target those species instead, giving the blue swimming crab stocks and their habitat a "break" (pers. comm., S. Creech, May 10 2016).

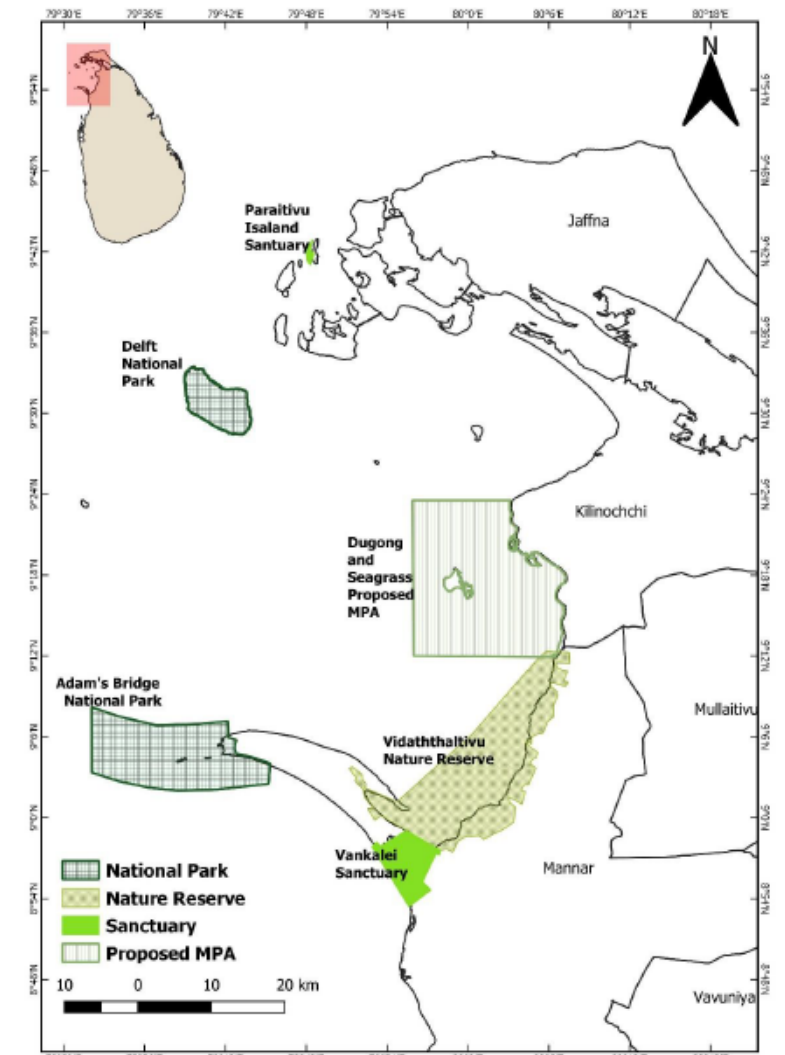| Marine Protected Area	Marine area (ha)	Region
Adam's Bridge National Park	18,990	Palk Bay/Gulf of Mannar
Delft National Park	124	Palk Bay
Vidaththalthivu Nature Reserve	22,412	Palk Bay
Vankalei Sanctuary	3,014	Palk Bay
Paraitivu Sanctuary	97	Palk Bay
Bar Reef Marine Sanctuary	30,670	Gulf of Mannar
Vankalei Sanctuary	3,014	Gulf of Mannar

Figure 12: Marine protected areas in Palk Bay. (pelagikos Pvt ltd. 2022g)
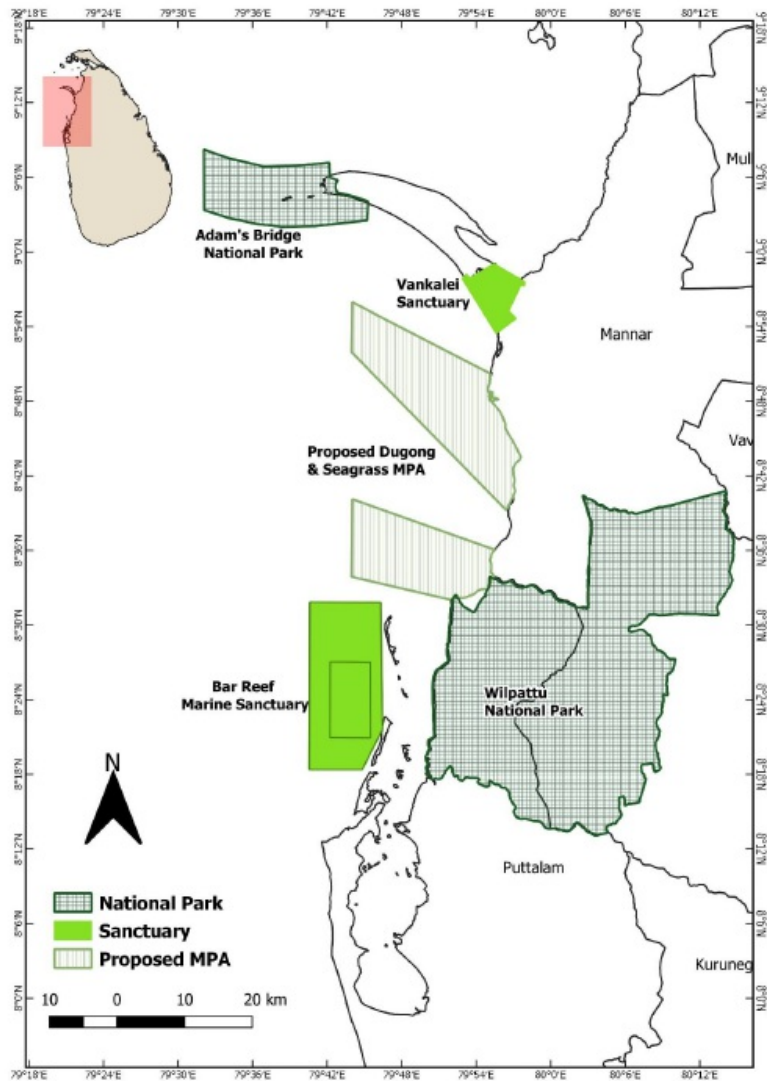
Figure 13: Marine protected areas in the Gulf of Mannar. (pelagikos Pvt. ltd. 2022h)

Factor 4.3 - Ecosystem-based Fisheries Management

Gulf of Mannar | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka
Palk Strait and Palk Bay | Indian Ocean, Eastern | Gillnets and entangling nets | Sri Lanka

Moderate Concern

Blue swimming crab is often considered an opportunistic, bottom-feeding carnivore and scavenger. It primarily consumes various sessile and slow-moving prey such as worms, mollusks, and crustaceans (Batoy et al. 1987), as well as smaller fish, but not much is known about the role of blue swimming crab as prey in Sri Lankan waters. In Australia, blue swimming crab is prey to turtles, sharks, rays, large fish, birds, and other blue swimming crab (GWA DOF 2011). Intense

fishing pressure on blue swimming crab could alter the trophic structure and species composition by reducing predation on crab prey, and/or by reducing food for higher-level predators.

There is a proposed EAFM (Ecosystem Approach to Fisheries Management) plan written for Sri Lankan blue swimming crab (BOBLME 2015), and a "report on inputs" to the proposed plan (Jayakody 2015), which aims to offer a "practical and effective means to manage fisheries, representing a move away from traditional fisheries management that focuses on target species, towards systems and decision-making processes that balance environmental, human, and social well-being within improved governance frameworks" (BOBLME 2015)(pelagikos Pvt ltd. 2022g) (pelagikos Pvt. ltd. 2022h). Because the goal is to run the blue swimming crab fisheries using EBFM, and progress is being made toward this goal, we have scored this factor a moderate concern.

Acknowledgements

References

12.

Bandara, J. 2018b. Analysis of the Interaction Between Blue Swimming Crab Fishing Grounds and Marine Habitats in Gulf of Mannar, Sri Lanka. June 30. 26 pp.

Batoy, C., J. Sarmago, B. Pilapil. 1987. Breeding Season, Sexual Maturity and Fecundity of the Blue Crab, Portunus pelagicus (L.) in Selected Coastal Waters in Leyte and Vicinity, Philippines. Annals of Tropical Research 9,157-177.

BOBLME (Bay of Bengal Large Marine Ecosystem Project). 2015. Ecosystem Approach to Fisheries Management (Essential EAFM) Training and TOT in Sri Lanka. BOBLME-2015 Governance-11.

complete.

Creech, S. 2013. Final Report: Sri Lanka Blue Swimming Crab Fishery Assessment. Submitted to Seafood Exporters"" Association of Sri Lanka. Revised on May 28, 2014. 81 pp.

Creech, S., J. Bandara, D. de Silva. 2016. Project Proposal: An Assessment of the Ecological Impact (Habitats & Ecosystem) of the Blue Swimming Crab (Portunus pelagicus) Fishery in the Palk Bay (Bay of Bengal), Sri Lanka. Sri Lankan Blue Swimming Crab Fishery Improvement Project. 11pp.

Deraniyagala, P.E.P. 1953. A Coloured Atlas of Some Vertebrates from Ceylon. Vol. 2 Tetrapod Reptiles, 101pp. Colombo Museum, Colombo, Sri Lanka.

DFAR (Department of Fisheries and Aquatic Resources). 2013. Fisheries Development and Management Plan of Puttalam Lagoon. Prepared for the Regional Fisheries Livelihoods Programme for South and Southeast Asia. May. 35 pp.

DFAR (Department of Fisheries and Aquatic Resources). 2017. Blue Swimming Crab District Fishery Management Plans (Palk Bay and Gulf of Mannar).

DFAR (Department of Fisheries and Aquatic Resources). 2018. Palk Bay Blue Swimming Crab Fishery Management Plan. June 30. 45pp.

Dulvy, N.K., J. Carlson, P. Charvet, M. J. Ajemian, K. Bassos-Hull, M. P. Blanco-Parra, E. Chartrain, D. Derrick, M. Dia, M. Diop, P. Doherty, J. Dossa, G. De Bruyne, K. Herman, G. H. L. Leurs, P. A. Mejía-Falla, A. F. Navia, N. Pacoureau, J. C. Pérez Jiménez, J. D. Pires, I. Seidu, A-L. Soares, A. Tamo, W. J. VanderWright and A. B. Williams. 2021. *Aetobatus narinari* (amended version of 2021 assessment). The IUCN Red List of Threatened Species 2021: e.T42564343A201613657. https://dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T42564343A201613657.en

Dulvy, N.K., K. V. Akhilesh, K. K. Bineesh, D. Derrick, D. A. Ebert, D. Fernando, A. B. Haque, R. W. Jabado, M. Khan and A. Maung. 2021b. *Rhinobatos annandalei*. The IUCN Red List of Threatened Species 2021: e.T161478A124492224. https://dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T161478A124492224.en

FAO (Fisheries and Aquaculture Organization). 2016a. Species Fact Sheet: Portunus pelagicus. Available at: http://www.fao.org/fishery/species/2629/en.

Fisher, R.A. 2015. Age, Growth, Size at Sexual Maturity and Reproductive Biology of Channeled Whelk, Busycotypuscanaliculatus, in the U.S. Mid-Atlantic. Final Report for the Virginia Fishery Resource Grant Program Project 2009-12.

Food and Agricultural Organization. 2022. Fisheries and Aquaculture: *Portunus pelagicus* (Linnaeus, 1758).

Food and Agriculture Organization 2022. FishStatJ v4.02.07. Accessed from: https://www.fao.org/fishery/en/statistics/software/fishstatj/en

Frazier, J. 1980. Exploitation of marine turtles in Indian Ocean. Human Ecology. 8, 329-370.

Froese, R. and D. Pauly. Editors. 2022. FishBase. World Wide Web electronic publication. www.fishbase.org, version (06/2022).

Gazette of the Democratic Socialist Republic of Sri Lanka. 1993. Fauna and flora protection ordinance (Chapter 469): As amended by Acts No. 44 of 1964, 1 of 1970 and 49 of 1993. Section 30, page 17. Colombo, Sri Lanka.

Gazette of the Democratic Socialist Republic of Sri Lanka. 2009. Fauna and Flora Protection (Amendment) Act, No. 22 of 2009. Colombo, Sri Lanka.

Germano, B. P., J.L.F. Melgo, J.C. Evangelio. 2006. Population, Reproduction and Fishery Biology of the Blue Crab Portunus pelagicus (Linnaeus 1758) in Eastern Visayas. Terminal Report, Volume 3. AFMA – Invertebrate Project of Leyte State University (LSU) and the Department of Agriculture – Bureau of Agriculture Research (DA-BAR). 116 pp.

Gunasekera, E. 2018a. Code of Conduct for Blue Swimming Crab Fishing Compliance Survey Field Report II: Gulf of Mannar Fishery Mannar (South) District and Puttalam District. May 4. 10pp.

Gunasekera, E. 2018b. Code of Conduct for Blue Swimming Crab Fishing Compliance Survey Field Report II: Palk Bay Fishery Jaffna/Kilinochchi/Mannar (North) Districts. June 30. 10pp.

GWA DOF (Government of Western Australia, Department of Fisheries). 2011. Fisheries Fact Sheet: Blue Swimmer Crab. Available at: http://www.fish.wa.gov.au/Documents/recreational_fishing/fact_sheets/fact_sheet_blue_swimmer.pdf.

Hewavisenthi, S. 1990. Exploitation of Marine Turtles in Sri Lanka: Historic background and the Present Status. Marine Turtle Newsletter 48, 14-19.

Hines, E., G. Verutes, L. Ponnampalam. 2018. Marine Megafauna Bycatch in Swimming Crab Nets in Northwestern Sri Lanka A Final Report for Monterey Bay Aquarium Seafood Watch. 57 pp.

Hordyk, A, K. Ono, S. Valencia, N. Loneragan, and J. Prince. 2015. A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. ICES Journal of Marine Science. 72(1): 217-231.

Hua, N.P., T.X.T. Nguyen, D.M. Mai, D.H. Phan and T.Y. Kieu. 2001. Spawning characteristics of *Babylonia areolata* (Neogastropoda : Buccinidae). Phuket Marine Biological Center Special Publication 25(1): 167-165.

Ilangakoon A., D. Sutaria, E. Heins, R. Aghavan. 2008. Community interviews on the status of the dugong (Dugong dugon) in the Gulf of Mannar (India and Sri Lanka). Marine Mammal Science 24:3, 704–710.

IUCN. 2022. The IUCN Red List of threatened species.

Jacobsen, I. P., M. B. Bennett. 2010. Age and growth of Neotrygon picta, Neotrygon annotata and Neotrygon kuhlii from North-East Australia, with Notes on their Reproductive Biology. Journal of Fish Biology 77:10, 2405-2422.

Jayakody, S. 2015. Report on Inputs to Proposed EAFM Plan for Blue Swimmer Crab, Sri Lanka. For the Department of Fisheries of Sri Lanka. 7pp.

Jinadasa, J. 1984. The Effect of Fishing on Turtle Populations. Loris. 16, 311-314.

Jones, S., A.B. Fernando. 1968. The Present Status of the Turtle Fishery in the Gulf of Mannar and Palk Bay. Proceedings of the Symposium of Living Resources of the Seas Around India. Cochin. 712-715pp.

Josileen J., N. G. Menon. 2007. Fishery and Growth Parameters of the Blue Swimmer Crab Portunus pelagicus (Linnaeus, 1758) Along the Mandapam Coast, India. Journal Marine Biological Association of India 49:2, 159-165.

Kangas, M. I. 2000. Synopsis of the biology and exploitation of the blue swimmer crab, Portunus pelagicus Linnaeus, in Western Australia. Fisheries Research Report 121: 1-22.

Kapurusinghe, T., M.M. Saman. 2001. Marine turtle bycatch in Sri Lanka. Three-year study from September 1996 to September 1999. Proceedings of the Twenty First Annual Symposium on Marine Turtle Biology and Conservation, Philadelphia, USA.

Kapurusinghe, T., R. Cooray. 2002. Marine turtle bycatch in Sri Lanka: Survey report. Turtle Conservation Project (TCP) Publications, Sri Lanka.

Lai, J. C. Y, P. K. L Ng, and P. J. F Davie. 2010. A revision of the Portunus pelagicus (Linnaeus, 1758) species complex (Crustacea: Brachyura: Portunidae), with the recognition of four species. The Raffles Bulletin of Zoology 58:2, 199-237.

National Marine Fisheries Service. 2022. US foreign trade data. Accessed from: https://www.fisheries.noaa.gov/foss/f?p=215:2:15819791811655::NO:::

PDSRSL (Parliament of the Democratic Socialist Republic of Sri Lanka). 2013. Fisheries and Aquatic Resources (Amendment) Act, No. 35 of 2013. November 22. Available at: http://faolex.fao.org/docs/pdf/srl132448.pdf.

pelagikos 2022. Impact on the species under assessment: Gulf of Mannar Fishery 2014 -2021. A report for the Sri Lankan blue swimming crab fishery improvement project.

pelagikos Pvt ltd. 2022b. Impact on the species under assessment: Palk Bay Fishery 2015-2021. A report for the Sri Lankan blue swimming crab fishery improvement project.

pelagikos Pvt ltd. 2022c. Impacts on Other Capture Species Report 2022: Gulf of Mannar fishery. A report for the Sri Lankan blue swimming crab fisheries improvement project.

pelagikos Pvt ltd. 2022d. Impacts on Other Capture Species Report 2022: Palk Bay Fishery. A report for the Sri Lankan blue swimming crab fisheries improvement project.

pelagikos Pvt ltd. 2022e. Criterion 3 - Management effectiveness: Gulf of Mannan fishery 2014-2021. A report for the Sri Lankan blue swimming crab fishery improvement project. pp 42, Sri Lanka.

pelagikos Pvt ltd. 2022f. Criterion 3 - Manageement effectiveness: Palk Bay fishery 2014-2021. A report for the Sri Lankan blue swimming crab fishery improvement project. pp 38, Sri Lanka.

pelagikos Pvt ltd. 2022g. Ecological impacts on marine habitats: The Palk Bay blue swimming crab fishery. A sub project of the Sri Lankan blue swimming crab fishery improvement project. pp 18, Sri Lanka.

pelagikos Pvt. ltd. 2022h. Ecological impacts on marine habitats: The Gulf of Mannar blue swimming crab fishery. A sub project of the Sri Lankan blue swimming crab fishery improvement project. pp 17, Sri Lanka.

Pierce, S. J., M. B. Bennett. 2009. Validated Annual Band-Pair Periodicity and Growth Parameters of Blue-Spotted Maskray Neotrygon kuhlii from South-East Queensland, Australia. Journal of Fish Biology 75, 2490–2508.

Prince, J., S. Creech, H. Madduppa, A. Hordyk 2020. Length based assessment of spawning potential ratio in data-poor fisheries for blue swimming crab (*Portunus spp.*) in Sri Lanka and Indonesia: Implications for sustainable management. *Regional Studies in Marine Science*. 36. https://doi.org/10.1016/j.rsma.2020.101309

Rasmussen, A., K. Sanders, A. Lobo and T. Courtney. 2018. *Hydrophis schistosus* (amended version of

2010 assessment). The IUCN Red List of Threatened Species 2018: e.T176719A136258180. http://dx.doi.org/10.2305/IUCN.UK.2010-4.RLTS.T176719A136258180.en

Rigby, C.L., R. Barreto, J. Carlson, D. Fernando, S. Fordham, M. P. Francis, K. Herman, R. W. Jabado, K. M. Liu, A. Marshall, N. Pacoureau, E. Romanov, R. B. Sherley and H. Winker. 2019. *Sphyrna mokarran*. The IUCN Red List of Threatened Species 2019: e.T39386A2920499. http://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39386A2920499.en

Sea Fare Group. 2011. Quantification and Market Analysis of the Top 30 Seafood Species/Categories Consumed in the U.S. Prepared by Sea Fare Group for Monterey Aquarium Seafood Watch®, March 15, 2011.

Sealifebase 2022. Growth parameters for Busycotypus canaliculatus. Acessed from: https://www.sealifebase.ca/PopDyn/PopGrowthList.php?ID=5515&GenusName=Busycotypus&SpeciesName=canaliculatus&fc=2009

SEASL and NFICC (Seafood Exporters' Association of Sri Lanka and National Fisheries Institute Crab Council). 2013. Seafood Exporters' Association of Sri Lanka Sri Lankan Blue Swimming Crab Fisheries Improvement Project Scoping Document. October 11. 11pp.

Shanker, K., B.C. Choudhury. 2006. A Brief history of Marine Turtles of Indian Subcontinent. In: Marine Turtles in the Indian Subcontinent. Eds. K. Shanker & B.C. Choudhury. 173-187pp. Universities Press, India.

Sherman, C. S., A. Bin Ali, K. K. Bineesh, D. Derrick, F. Dharmadi, D. Fernando, A. B. Haque, A. Maung, L. Seyha, D. Tanay, J. A. T. Utzurrum, V. Q. Vo and R. R. Yuneni. 2021. *Brevitrygon imbricata*. The IUCN Red List of Threatened Species 2021: e.T161728A109916824. https://dx.doi.org/10.2305/IUCN.UK.2021-1.RLTS.T161728A109916824.en

Sherman, C.S., A. Bin Ali, K. K. Bineesh, D. Derrick, Dharmadi, Fahmi, D. Fernando, A. B. Haque, A. Maung, L. Seyha, D. Tanay, J. A. T. Utzurrum, V. Q. Vo, and R. R. Yuneni. 2021c. *Himantura uarnak*. The IUCN Red
List of Threatened Species 2021: e.T201098826A124528737. https://dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T201098826A124528737.en

Sherman, C.S., K. V. Akhilesh, A. Bin Ali, K. K. Bineesh, D. Derrick, Dharmadi, D. A. Ebert, Fahmi, D. Fernando, A. B. Haque, A. Maung, L. Seyha, D. Tanay, D. Tesfamichael, J. A. T. Utzurrum T. Valinassab, V. Q. Vo, and R. R. Yuneni. 2021b. *Gymnura poecilura*. The IUCN Red List of Threatened Species 2021: e.T60117A124440205. https://dx.doi.org/10.2305/IUCN.UK.2021-1.RLTS.T60117A124440205.en

Sherman, C.S., K. V. Akhilesh, M. Ali, A. Bin Ali, K. K. Bineesh, D. Derrick, Dharmadi, Fahmi, D. Fernando, A. B. Haque, R, W. Jabado, M. Khan, A. Maung, L. Seyha, D. Tanay, J. A. T. Utzurrum, V. Q. Vo, and R. R. Yuneni. 2020b. *Pateobatis bleekeri.* The IUCN Red List of Threatened Species 2020: e.T104208524A175220678. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T104208524A175220678.en

Sherman, C.S., M. Ali, A. Bin Ali, K. K. Bineesh, D. Derrick, Dharmadi, I. Elhassan, Fahmi, D. Fernando, A. B. Haque, R. W. Jabado, A. Maung, L. Seyha, J. Spaet, D. Tanay, J. A. T. Utzurrum, T. Valinassab, V. Q. Vo, and R, R. Yuneni. 2020. *Maculabatis gerrardi.* The IUCN Red List of Threatened Species 2020: e.T161566A175219648. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T161566A175219648.en [

Simpfendorfer, C., R. R. Yuneni, D. Tanay, L. Seyha, A. B. Haque, Fahmi, A. Bin Ali, K. K. Bineesh, D. A. Gautama, A. Maung, A. Sianipar, J. A. T. Utzurrum, and V. Q. Vo. 2020. *Carcharhinus melanopterus*. The IUCN Red List of Threatened Species 2020: e.T39375A58303674. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T39375A58303674.en

The Gazette of the Democratic Socialist Republic of Sri Lanka. 2022. Part I: Section (I) - General Government Notifications. Fisheries and Aquatic resources Act, No 2 of 1996. Blue Swimming Crab Fishery Management6 Regulations 2022. Colombo, Sri Lanka.

VanderWright, W.J., A. Bin Ali, K. K. Bineesh, D. Derrick, A. B. Haque, T. Krajangdara, A. Maung and L. Seyha. 2020. *Chiloscyllium griseum*. The IUCN Red List of Threatened Species 2020: e.T41792A124416752. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T41792A124416752.en

VanderWright, W.J., Bin Ali, A., Bineesh, K.K., Derrick, D., Fahmi & Rigby, C.L. 2021. *Narke dipterygia*. The IUCN Red List of Threatened Species 2021: e.T161607A124514068. https://dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T161607A124514068.en

Wetland Conservation Project. 1994. Wetland Site Report: Puttalam Lagoon, Dutch Bay and Portugal Bay. Central Environmental Authority, Colombo, Sri Lanka.

Appendix A: Criteria 3.3–3.5

Criterion 3.3 Scientific Research and Monitoring

Palk Bay and Gulf of Mannar, Bottom-set crab net

Moderately effective

Key relevant information:
At the commencement of the FIP in 2013, there were no published scientific studies on the population biology of Sri Lanka blue swimming crab. To address this issue, the FIP commissioned NARA to undertake the first scientific study of the species' population biology (results published in 2016). Since then, the FIP has also had help from the Bay of Bengal Large Marine Ecosystem (BOBLME) Project, which conducted a survey of fishing effort for blue swimming crab, and had numerous undergraduate students from Uva Wellassa University to conduct their bachelor's theses on the crab's reproductive biology and nontarget species (bycatch). There have been four stock assessments conducted in each of the fisheries with the help of Dr. Prince's LB SPR approach. An assessment has also been proposed to determine the impact of the prawn stake net fishery on immature and juvenile blue swimming crab in Puttalam Lagoon.

But, because the stock assessments do not appear to be peer-reviewed or contain fishery-independent data, and there is a lack of regular bycatch monitoring and data on lost gear/effects of ghost fishing, this factor is rated moderately effective.

Criterion 3.4 Enforcement of Management Regulations

Palk Bay and Gulf of Mannar, Bottom-set crab net

Ineffective

Key relevant information:
Most of the Sri Lanka blue swimming crab fishers comply with the regulations that currently govern the exploitation and management of the fishery (Creech 2013). Monitoring, control, and surveillance mechanisms for vessel and gear licenses (by DFAR) and the prohibition of illegal fishing gears (e.g., monofilament nets and trawlers) are implemented systematically across the entire fishery and are satisfactory (Creech 2013). But, the monitoring, control, and surveillance mechanisms are not comprehensive or consistently applied across the fishery (Creech 2013).

Because the regulation prohibiting the use of monofilament nets in the fishery is incompletely enforced (Creech 2013), the FIP is working with cooperatives to enforce this measure. But, IUU fishing by Tamil Nadu and Sri Lankan trawlers is an external obstacle that also needs to be addressed/enforced (pers. comm., S. Creech, June 5, 2016). In order to see if there is even an institutional capacity and the intention to implement blue swimming crab-specific regulation once written, DFAR has been asked to prepare a list of enforcement cases of the Fisheries Act (pers. comm., S. Creech, June 5, 2016).

Therefore, a score of ineffective is given for this factor. IUU fishing is a cause for concern for the overarching effectiveness of fisheries management in Sri Lanka.

Justification:

Monofilament net use is prohibited under the Fisheries & Aquatic Resources Act in Sri Lanka, but these nets are still thought to be used, mostly in Puttalam Lagoon and in the Jaffna District. Previously, as much as 75% of the catch was landed using monofilament nets (Creech 2013). Monofilament net use is thought to be a remnant of the 30-year civil conflict, where fishing was only allowed between 6 a.m. and 6 p.m. each day and fishers needed to be more efficient. These nets are used because they are cheaper than nylon, harder to see in turbid water, are more efficient, and catch fewer nontargeted species (Creech 2013).

Criterion 3.5 Stakeholder Inclusion

Palk Bay and Gulf of Mannar, Bottom-set crab net

Moderately effective

Key relevant information:

Stakeholders literally form the very basis of the Sri Lanka blue swimming crab FIP, which was initiated when SEASL received a request from representatives of Sri Lankan seafood companies, government authorities, researchers, and civil society organizations associated with the Palk Bay blue swimming crab fishery. The aim of the FIP is to gather all those associated with the fishery to create and implement a local plan that will improve the economic, social, and ecological sustainability of the fishery.

In particular, the scoping document was based on comments and suggestions by fishing communities. The initial fishery preliminary assessment included interviews with fishers in all four districts (Creech 2013). Fishing cooperatives have endorsed the FIP, with letters of commitment. Producers, processors, and regulators are all participants in the annual meetings. Eventually, the aim is to get each village society to endorse the FIP by the end of 2017 (pers. comm., S. Creech, June 5, 2016). The Harvest Control Strategy and Harvest Control Rules and Tools will be translated into the local languages (Sinhala and Tamil) and stakeholders will be asked for their comments, feedback, and opinions. If issues arise, the HCS and HCR&T will be amended. The FIP also aims to get cooperatives registered as FT producers to further build decision-making about the fishery (pers. comm., S. Creech, June 5, 2016).

The management process is transparent and high participation by all stakeholders is encouraged; however, there is no mechanism in place to effectively address user conflicts, so this factor is rated moderately effective.