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Spanner Crab Fishery
Level 1 Ecological Risk Assessment

Queensland Government

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Executive Summary

The Queensland Ecological Risk Assessment Guideline (the Guideline) was released in March 2018 as part of the Queensland Sustainable Fisheries Strategy 2017–2027 (Department of Agriculture and Fisheries, 2017; 2018a). This Guideline provides an overview of strategy being employed to develop Ecological Risk Assessments (ERAs) for Queensland's fisheries. The Guideline describes a four-stage framework consisting of a Scoping Study; a Level 1, whole-of-fishery qualitative assessment; a Level 2, species-specific semi-quantitative or low-data quantitative assessment and; a Level 3 quantitative assessment (if applicable).

The aim of the Level 1 ERA is to produce a broad risk profile for each fishery based on a qualitative ERA method described by Astles *et al.* (2006). The method considers a range of factors including the current fishing environment (*e.g.* current catch, effort and licensing trends), limitations of the current management arrangements (*e.g.* the potential for additional effort to be transferred into areas already experiencing higher levels of fishing mortality, changing target species) and life-history constraints of the species being assessed. In the Spanner Crab Fishery, the Level 1 ERA assessed fishing related risks in 15 ecological components including target species, bycatch, marine turtles, sea snakes, crocodiles, dugongs, cetaceans, protected teleosts, batoids, sharks, syngnathids, seabirds, terrestrial mammals, marine habitats, and ecosystem processes. As licence holders can only retain spanner crabs, the Level 1 ERA did not need to consider the risk posed to byproduct species.

To construct the risk profiles, seven fishing activities (harvesting, discarding, contact without capture, loss of fishing gear, travel to/from fishing grounds, disturbance due to presence in the area, boat maintenance and emissions) were assigned an indicative score (*e.g.* low, intermediate, high) representing the risk posed to each ecological component. Each ecological component was then assigned a preliminary risk rating based on the highest risk score within their profile. Preliminary risk ratings are precautionary and provided an initial evaluation of low-risk elements within each fishery. As this approach has the potential to overestimate the level of risk a secondary evaluation was conducted on ecological components with higher risk ratings. This evaluation examined the key drivers of risk within each profile, their relevance to the current fishing environment and the extent that a fishery contributes to this risk. The purpose of this secondary assessment was to examine the likelihood of the risk coming to fruition over the short to medium term and minimise the number of 'false positives'.

The Level 1 ERA indicated that all 15 ecological components were at a negligible, low or low/intermediate risk of experiencing an undesirable event due to fishing activities in the Spanner Crab Fishery. These results reflect the single-species nature of the fishery and the use of a gear type that is highly selective for spanner crabs. These factors combined with the area of operation and participation rates (Department of Agriculture and Fisheries, 2023) mean that the fishery poses a low to negligible risk to all but one of the ecological components. This includes all ecological components containing Threatened, Endangered or Protected (TEP) species and/or species with ongoing conservation concerns.

At low/intermediate, the target species ecological component was assigned the highest risk rating of the assessment. In the Level 1 ERA, the Spanner Crab Fishery Harvest Strategy 2020–2025 was given significant weighting and contributed to this ecological component receiving a lower risk rating. The harvest strategy includes a range of measures that minimise the long-term risk of stock overexploitation and safeguards the fishery from increasing effort across the commercial, recreational

and charter fishing sectors (Department of Agriculture and Fisheries, 2020a). Alternatively, the key drivers of risk for this fishery include high discard mortalities (particularly for injured crabs), and difficulties quantifying total rates of fishing mortality (retained catch plus discard mortalities). As the fishery already operates under detailed harvest strategy, these deficiencies/risks were not considered sufficient to assign the ecological component with a higher risk rating.

Based on the above findings, the Spanner Crab Fishery is viewed as a low priority for progression to a Level 2 (species-specific) ERA. There are however areas within this fishery where risk can be further understood, managed or mitigated. To assist in this process, the following recommendations were made as part of the Level 1 ERA findings:

- Identify mechanisms to aid in the validation/verification of data submitted through the Threatened Endangered and Protected Animal Logbook (TEP01) and to monitor interactions with non-target species.
- Explore avenues to improve the level of information on discards and options to monitor long-term changes in non-reported mortalities *e.g.* post-capture mortalities, depredation etc.
- Where possible, improve the level of information on gear loss in the Spanner Crab Fishery including the origin of the equipment *i.e.* commercial and/or recreational fishing sectors.

Summary of the outputs from the Spanner Crab Fishery Level 1 Ecological Risk Assessment.

Ecological Component	Level 1 Risk Rating	Progression
Target Species	Low/Intermediate	Harvest Strategy / Monitoring & Research Plan
Bycatch (non-SOCC)	Low	Not progressed further
Species of Conservation Concern (SOCC)		
Marine turtles	Low	Not progressed further
Sea snakes	Negligible	Not progressed further
Crocodiles	Negligible	Not progressed further
Dugongs	Negligible	Not progressed further
Cetaceans	Low	Not progressed further
Protected Teleosts	Negligible	Not progressed further
Batoids	Low	Not progressed further
Sharks	Low	Not progressed further
Syngnathids	Negligible	Not progressed further
Seabirds	Negligible	Not progressed further
Terrestrial mammal	Negligible	Not progressed further
Marine Habitats	Low	Not progressed further
Ecosystem Processes	Low	Not progressed further

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Definitions & Abbreviations

Active Licence	–	The definition of an active licence is the same as that used by DAF's data reporting system. An active licence is a licence that has reported any catch and effort in the Spanner Crab Fishery through the logbook reporting under a C2 or C3 fishery symbol within a given year.
AIVR	–	Automated Interactive Voice Response (AIVR) system.
Bycatch	–	The portion of the catch that is discarded / returned to sea. For the purpose of this ERA, the definition of bycatch does not include unwanted target species (*e.g.* due to poor product condition, regulations etc).
Byproduct	–	The portion of catch retained for commercial sale that was not intentionally targeted. Note – as the Spanner Crab Fishery is a single species fishery, operators in the Spanner Crab Fishery (C2 & C3 fishery symbol) are not permitted retain any byproduct.
C1 Fishery	–	Crab fishing operations that target mud and blue swimmer crabs under the C1 Fishery Symbol.
DAF	–	Queensland Department of Agriculture and Fisheries.
Ecological Component	–	Broader assessment categories that include Target Species, Bycatch, Species of Conservation Concern, Marine Habitats and Ecosystem Processes.
Ecological Subcomponent	–	Species, species groupings, marine habitats and categories included within each of the respective Ecological Component.
ERA	–	Ecological Risk Assessments.
Fishery Symbol	–	The endorsement that permits a fisher to access a fishery and defines what gear can be used *i.e.* N = Net, L = line, T = trawl, C = crab or pot fishing. The number of fishing symbols represents the maximum number of operators that could (theoretically) access the fishery at a single point in time.
Fishing Licence	–	Effectively a fishing platform. A Fishing Licence can have multiple symbols attached including a crab (C), net (N) and line (L) fishing symbol.
ITQ	–	Individual Transferable Quotas.
Managed Area A	–	Managed Area A covers fishing activities central and south-east Queensland conducted under the C2 fishery symbol.

Managed Area B	–	Managed Area B covers fishing activities in all waters north of Managed Area A and east of longitude 142º31'49" including the Gulf of Carpentaria under the C3 fishery symbol.
MEY	–	Maximum Economic Yield.
MSE	–	Management Strategy Evaluation.
Offshore waters	–	Defined as per the Fisheries (General) Regulations 2019 as: *Tidal waters that are at least 2m deep at low water, but do not include waters— (a) in a river or creek upstream of a line across its banks at low water; or (b) in an inlet.*
QBFP	–	Queensland Boating and Fisheries Patrol.
SAFS	–	Status of Australian Fish Stocks.
Spanner Crab Fishery	–	Commercial fishing operations conducted under the C2 and/or C3 Fishery Symbols.
SOCC	–	Species of Conservation Concern. Term used in the Level 1 and Level 2 ERA to define a broader collective of species that have ongoing conservation concerns including marine turtles, sea snakes, crocodiles, dugongs, cetaceans, protected teleosts, batoids, sharks, seabirds, syngnathids and terrestrial mammals. These species may or may not be subject to mandatory reporting requirements.
SOCI logbook	–	Historical logbook used to monitor interactions with Species of Conservation Interest (SOCI); a subset of no-take species that were subject to additional reporting requirements if caught in a commercial fishery operating in Queensland. This logbook has now been replaced by the Threatened, Endangered, and Protected Animals logbook.
StrandNET	–	Reporting system used by the Department of Environment and Science (DES) to complete the Marine Wildlife Stranding and Mortality Database. StrandNET summarises all records of sick, inured or dead marine wildlife reported through DES and annual reports can be accessed at: https://environment.des.qld.gov.au/wildlife/animals/caring-for-wildlife/marine-strandings/data-reports/annual-reports#document_availability.
TACC	–	Total Allowable Commercial Catch.
Target species	–	The primary species or species groups that have been selectively fished for and retained for commercial, recreational or traditional purposes.

1 Overview

The Spanner Crab Fishery primarily operates in offshore waters along the Queensland east coast. The framework of the fishery is relatively streamlined with operators only permitted to retain spanner crabs (*Ranina ranina*) using dillies (Department of Agriculture and Fisheries, 2023). While the fishery is one-dimensional (*i.e.* one species, one apparatus), the broader management regime incorporates a more complex array of input and output controls. Central to this is the use of a fishery-specific harvest strategy and a regional management system that subdivides the fishery into two key areas: Managed Area A (C2 fishery symbol) and Managed Area B (C3 fishery symbol) (Fig. 1; Department of Agriculture and Fisheries, 2020a; Department of Agriculture and Fisheries, 2023).

Managed Area A covers central and south-east Queensland and it is responsible for the majority of catch and effort reported from this fishery. This area has a more complex system of management controls which including the use of a Total Allowable Commercial Catch (TACC) limit administered through Individual Transferable Quotas (ITQs). While Managed Area B covers a larger area (all waters north of Managed Area A and east of longitude 142º31'49" including the Gulf of Carpentaria), the region attracts comparatively small amounts of effort. Within this area, harvest rates are managed through commercial trip limits instead of a TACC limit or ITQs (Department of Agriculture and Fisheries, 2023). Across the fishery, the long-term management of stocks is guided by the Spanner Crab Fishery Harvest Strategy 2020–2025 (Department of Agriculture and Fisheries, 2020a; b).

Fishing related risks in the Spanner Crab Fishery were previously assessed as part of a broader Scale, Intensity, Consequence, Analysis (Hill & Garland, 2009). This study also included mud and blue swimmer crabs (C1 fishery symbol) which have now been the subject of a more detailed Ecological Risk Assessment (Business Queensland, 2016; Walton & Jacobsen, 2019; 2020). To date, an analogous study has yet to be completed for the Spanner Crab Fishery (C2 & C3 fishery symbols; Department of Agriculture and Fisheries, 2022).

In March 2018, Queensland released the Ecological Risk Assessment Guidelines (the Guidelines) (Department of Agriculture and Fisheries, 2018a) as part of the broader Queensland Sustainable Fisheries Strategy 2017–2027 (Department of Agriculture and Fisheries, 2017). This Guideline provides an overview of the ERA strategy being employed by Queensland and includes a four-stage framework consisting of 1) a scoping study, 2) a Level 1, whole-of-fishery qualitative assessment, 3) a Level 2, species-specific semi-quantitative or low-data quantitative assessment, and 4) a Level 3 quantitative assessment (if applicable).

The following provides a broader, qualitative (Level 1) assessment of the risk posed by the Spanner Crab Fishery on a number of key ecological components. The Level 1 assessment follows-on from the completion of a scoping study that provides information on the current fishing environment, licencing trends and broader catch and effort analyses (Department of Agriculture and Fisheries, 2023).

2 Focus / Intent

The risk profiles for Queensland's commercial fisheries vary and are highly dependent on the apparatus used. For example, the risk posed by hand collection fishing activities will be lower when compared to a net or trawl fishery. Similarly, single-species fisheries (*e.g.* the Spanner Crab Fishery) will present a lower risk when compared to multi-species or multi-apparatus fisheries (*e.g.* the East Coast Inshore Fishery). However, every fishery will have elements that present as a higher risk for one

or more of the ecological components *i.e.* species groupings, marine habitats, and ecosystem process that interact with the fishery. These elements will still be present in smaller fisheries, including those where there is greater capacity to target individual species.

In recognition of the above, the primary objectives of the Level 1 assessments were to identify the key sources of risk within a particular fishery, and the ecosystem components that are most likely to be affected by this risk. Used in this context, Level 1 ERAs produce assessments that are fishery specific. The inherent trade off with this approach is that risk ratings cannot be compared between fisheries as the scale, extent and impact of the risks are unlikely to be equal. They will, however, provide insight into the areas or fishing activities within the Spanner Crab Fishery that may contribute to an undesirable event for one or more of the ecological components.

By restricting the focus of the assessment, Level 1 ERAs can be used to examine the types of risk each ecological component will be exposed to within that fishery. In doing so, the outputs of the Level 1 assessment will determine what ecological components should progress to a finer scale, Level 2 ERA (Department of Agriculture and Fisheries, 2018a). These Level 2 assessments focus on the species, species groupings, marine habitats or ecosystem processes (if applicable) contained within each of the respective ecological subcomponents.

3 Methods

The Level 1 assessment is used to assess risk at the whole-of-fishery level, with the primary objective being to establish a broad risk profile for each fishery. Level 1 assessments examine the risk posed to a wide range of ecological components and include detailed assessments for target (harvested) species, bycatch, species of conservation concern (SOCC), marine habitats, and ecosystem processes. As licence holders can only harvest spanner crabs, the fishery does not retain any alternate species as byproduct. Accordingly, the Level 1 ERA did not need to examine the risk posed to this fisheries component.

For the purposes of this ERA, the term ‘Species of Conservation Concern’ (SOCC) was used as the scope of the assessment as it will be broader than the list of species monitored through the Threatened, Endangered, and Protected Animal Logbook.[1] The SOCC includes species that are listed or classified as Threatened, Endangered or Protected and non-listed species that have ongoing conservation concern. In the Level 1 ERA, the SOCC ecological component was divided into marine turtles, sea snakes, crocodiles, dugongs, cetaceans, batoids, sharks, syngnathids, seabirds, protected teleosts and terrestrial mammals. While a number of these subgroups will have negligible or limited interactions with the Spanner Crab Fishery, their inclusion in the assessment provides the fishery with a more complete risk profile.

Of the ecological components assessed, ecosystem processes represent the biggest challenge for a management response as the viability of these processes will be influenced by factors outside of the control of fisheries management *e.g.* climate change, pollution, extractive use of the marine resources, and urban, port and agricultural development. From an ERA perspective, this makes it difficult to quantify the level of impact a fishery has on these processes. This problem is compounded by the fact that it is often difficult to identify measurable indicators of marine ecosystem processes (Evans *et al.*, 2016; Pears *et al.*, 2012). For example, what parameters need to be measured to determine if an

[1] *The Threatened, Endangered and Protected Animal Logbook replaced the Species of Conservation Interest (SOCI) Logbook which has historically been used to monitor interaction rates with these species.*

ecosystem process is in decline, stable, or improving, and how much of this change can be attributed to the presence or absence of fishing activities?

In order to refine the Level 1 ERA for ecosystem processes, a preliminary assessment was undertaken. This preliminary assessment examined the potential for a fishery to impact 16 categories outlined in the Great Barrier Reef Outlook Report 2019 (Great Barrier Reef Marine Park Authority, 2019). The specific processes examined in response to fisheries related impacts were sedimentation, nutrient cycling / microbial processes, particle feeding, primary production, herbivory, predation, bioturbation, detritivory, scavenging, symbiosis, recruitment, reef building, competition, connectivity, outbreaks of disease, and species introductions. Not all processes are applicable to every fishery, but all processes were considered before being eliminated. A full definition of each ecosystem process has been provided in Appendix 1.

The Level 1 ERA was modelled off of an assessment method established by Astles *et al.* (2006) and incorporates five distinct steps: Risk Context, Risk Identification, Risk Characterisation, Likelihood and Issues Arising. A brief overview of each step is provided below:

1. **Risk Context**—defines the broad parameters of the assessment including the risk that is to be analysed (*i.e.* the management objectives trying to be achieved or the nature of the undesirable events), the spatial extent of the analysis, the management regimes and the timeframes of the assessment.

2. **Risk Identification**—identifies the aspects of each fishery, or the sources of risk, with the potential to contribute to the occurrence of an undesirable event.

3. **Risk Characterisation**—provides an estimate (Low, Intermediate or High) of the likelihood that one or more of the identified sources of risk will make a substantial contribution to the occurrence of an undesirable event. Used as part of a Level 1 ERA, this stage will assign each fishing activity with an indicative risk rating representing the risk posed to each ecological component. These scores will then be used to assign each ecological component with a preliminary risk rating based on the highest risk score within the profile. Preliminary risk scores provide the first opportunity to identify low-risk elements within each fishery.

4. **Likelihood**—a secondary evaluation of the key factors underpinning the preliminary risk assessments, their relevance to the current fishing environment, and the potential for the fishery to contribute to this risk in the short to medium term. This step was included in recognition of the fact that preliminary scores (see Risk Characterisation) may overestimate the level of risk for some ecological components.

5. **Issues Arising**—examines the assigned risk levels and the issues or characteristics that contributed to the overall classifications.

The above framework differs slightly from Astles *et al.* (2006) in that it includes an additional step titled Likelihood. The inclusion of this additional step recognises the precautionary nature of qualitative assessments and the potential for risk to be overestimated in whole-of-fishery ERAs. This step assesses the likelihood of the risk occurring under the current management arrangements and takes into consideration the key factors of influence and their relevance to the current fishing environment. In doing so, the Likelihood step helps to differentiate between actual and potential risks. This aligns with

the objectives of the ERA Guideline (Department of Agriculture and Fisheries, 2018a) and helps limit the extent of false positives (*e.g.* the misclassification of low-risk elements as high risk).

While viewed as a higher-level assessment, the Level 1 ERA provides important information on the key drivers of risk, the ecological components at risk, and areas within the fisheries management system that contribute to the level of risk. Level 1 assessments will be undertaken for all ecological components including marine habitats and ecosystem processes which have the least amount of available data. These results will be used to inform the Level 2 assessments and to refine the scope of subsequent ERAs. If required, a Level 2 assessment will focus specifically on the ecological subcomponents including key species and species groupings.

Additional information on the four-staged qualitative assessment is provided in Astles *et al.* (2006) and Pears *et al.* (2012). A broad overview of the ERA strategy used in Queensland has been provided in the Guidelines (Department of Agriculture and Fisheries, 2018a).

4 Level 1 Qualitative Assessments

4.1 Risk Context

As the Level 1 assessments are based at the whole-of-fishery level, the risk context has been purposely framed at a higher level. It also takes into consideration the main purpose of the *Fisheries Act 1994* which is to: "*…provide for the use, conservation and enhancement of the community's fisheries resources and fish habitats in a way that seeks to: apply and balance the principles of ecologically sustainable development; and promote ecologically sustainable development."*

In line with this objective, the risk context for the Level 1 assessment has been defined as:

> *The potential for significant changes in the structural elements of the fishery or the likelihood that fishing activities in the Spanner Crab Fishery will contribute to a change to the fishery resources, fish habitats, environment, biodiversity or heritage values that is inconsistent with the objectives of the Fisheries Act 1994.*

The inclusion of the term "potential" in the definition recognises the need to take into consideration both current and historic trends, and the likelihood that a fishery will deviate from these trends in the short to medium term. The reference to "structural elements of a fishery" largely relates to the current fishing environment and the potential for it to change over the longer term *e.g.* the potential for effort to increase under the current management arrangements, effort displacements, or the ability for effort to shift between regions.

In order to frame the scope of the assessment, a 20-year period was assigned to all Level 1 assessments. That is, the likelihood that the one or more of the ecological components will experience an undesirable and unacceptable change over the next 20 years due to fishing activities in the Spanner Crab Fishery. The Level 1 assessment assumes that management arrangements for a fishery will remain the same over this 20-year period. The use of a 20-year timeframe aligns with other Level 1 ERAs constructed under the Guidelines and is considered precautionary (Department of Agriculture and Fisheries, 2022).

At a whole-of-fishery level, the risk of the Spanner Crab Fishery contributing to or causing an undesirable event has declined over the last 30 years. This has been achieved through a range of

management reform initiatives that have reduced both real and potential effort in this fishery. The most notable management reform occurred in 1999 when a TACC limit was introduced in the Spanner Crab Fishery. This limit is administered through ITQs and has been reviewed and refined since 2009 (Brown *et al.*, 2001; Department of Agriculture and Fisheries, 2020a; 2023).

While the primary role of the TACC is to limit annual harvest rates, a shift to output controls had a significant impact on effort levels and participation rates. For example, participation rates and effort (days fished) in the 10 years following the introduction on quota decreased by around 55 per cent and 65 per cent respectively. Participation rates and annual effort have continued to decline in the pursuing years due to variations in stock abundance and the continued consolidation of quota. For example, the 2018–2020 period recorded an average of 45 active fishing licences and 2,500 days fished. This compares to historical highs of >200 active licences and >10,000 days fished (Department of Agriculture and Fisheries, 2023). While not universal, it is reasonable to assume that declining participation rates and effort levels reduce the overall level of risk in this fishery (Department of Agriculture and Fisheries, 2023). This inference is based on the premise that the fishery would be harvesting smaller quantities of spanner crabs, have fewer discards and lower rates of fishing mortality. Similarly, with fewer dillies and lifts, expectations are that the fishery would have fewer interactions with non-target species.

The ability of the fishery to manage key risks has been enhanced with the introduction of the Spanner Crab Fishery Harvest Strategy 2020–2025 (Department of Agriculture and Fisheries, 2020a). The harvest strategy, amongst other things, outlines the TACC setting process, decision rules / harvest triggers for all three sectors, monitoring objectives (sustainability, economic and social) and directions on how to manage ecological risks (Department of Agriculture and Fisheries, 2020a). From a risk management perspective, the establishment and introduction of a spanner-crab specific harvest strategy is viewed as a significant step forward for this fishery.

4.2 Risk Identification

Fishing activities are frequently subdivided into categories that identify the sources of risk or potential hazards (Astles *et al.*, 2009; Hobday *et al.*, 2011; Pears *et al.*, 2012). What constitutes a hazard can vary between ERAs and is often dependent on the specificity and scale of the assessment. For larger scale assessments, some of the more commonly used fishing activities include *harvesting, discarding, contact without capture, loss of fishing gear, travel to/from fishing grounds, disturbance due to presence in the area,* and *boat maintenance and emissions* (Table 1). The fishing activities outlined in **Error! Reference source not found.** will provide the foundation for the risk profiles and will be used t o assign preliminary risk ratings to each ecological component (see section 4.4 Risk Characterisation).

In addition to the cumulative fishing pressures, this section will include a secondary examination of the cumulative risks that exist outside of the control of fisheries management. These factors often have a wide range of contributors, are generally more complex and are, at times, unavoidable. Consequently, it can be difficult to assign an accurate rating to these factors or to quantify how much of a contribution (if any) a fishery will make to this risk. The primary purpose of including these factors in the Level 1 assessment is to provide the ERA with further context on the relationship between fisheries-specific risks and external risk factors. These include broader risk factors that the Spanner Crab Fishery will contribute to (*e.g.* boat strike) and factors that have the potential to negatively impact on the fishery (*e.g.* climate change, the potential for urban development to affect recruitment rates).

***Table 1**. Summary of the key fishing activities and their relation to risk. Table based on an extract from Pears et al. (2012) .*

Sources of Risk
Harvesting: capture and retaining of marine resources for sale.
Discarding: returning unwanted catch to the sea. This component of the catch is landed on the deck of the boat or brought to the side of the vessel before its release and the reference is applied to all sectors *e.g.* commercial, recreational and charter.
Contact without capture: contact of any part of the fishing gear with ecological subcomponents (species, habitats etc.) whilst deployed but which do not result in the ecological components being captured and landed on deck.
Loss of fishing gear: partial or complete loss from the boat of gear including dillies, float / trot lines, or floats.
Travel to / from fishing grounds: steaming of boat from port to fishing grounds and return.
Disturbance due to presence in the area: other influences of boat on organisms whilst fishing activities take place (*e.g.* underwater sound disturbances).
Boat maintenance and emissions: tasks that involve fuel, oil or other engine and boat-associated products that could be accidentally spilled or leaked into the sea or air.
Cumulative fishing pressure: Indirect external factors, including other fisheries or fishing sectors; and non-fisheries factors that apply across fishery sectors.

The inclusion of cumulative impacts in the Level 1 ERA provides further context on factors that may contribute to an undesirable event. However, it can be difficult to account for these impacts in the final risk ratings of a fisheries-based ERA. This is because it can be difficult to quantify the extent of this risk and/or their contribution to the overall risk rating. Given this, ratings assigned to cumulative risks will not be used in the determination of preliminary risk scores (see section 4.4 Risk Characterisation). The main reason for this is that the preliminary risk scores relate specifically to commercial fishing activities. If one or more of the ecological components are progressed to a Level 2 assessment, cumulative impacts will be given additional considerations.

The following provides an overview of the key fishing activities / sources of risk in the Spanner Crab Fishery, and for each of the respective ecological components. When and where appropriate, the contributor of risk (*i.e.* the fishing activity) is also identified in the text.

4.2.1 Whole of Fishery

At a whole-of-fishery level, *harvesting* and *discarding* will be the key sources of risk in the Spanner Crab Fishery with *contact without capture* and *loss of fishing gear* identified as secondary risk factors (Table 1). These risks will be largely confined to the target species and be most relevant in *Managed Area A* (C2 fishery symbol). *Managed Area A* accounts for around 99 per cent of the total catch/effort and it will be the major factor of influence with respect to the final risk ratings – refer to *Spanner Crab Fishery Scoping Study* (Department of Agriculture and Fisheries, 2023).

The remaining fishing activities will make low to negligible contribution to overall level of risk. For most of the identified fishing activities, they will have an indirect impact on target and non-target species *e.g. travel to/from fishing grounds*, *disturbance due to presence in the area* and *boat maintenance and emissions*.

4.2.2 Ecological Subcomponents

Target Species

The single species, single apparatus nature of the fishery helps limit the interaction potential for non-target species. As spanner crab fishers cannot retain any other species (Department of Agriculture and Fisheries, 2023), an assessment of the risk posed to byproduct species was not required.

Of the fishing activities identified, *harvesting* and *discarding* will be the key sources of risk for spanner crabs (Table 1). In the Spanner Crab Fishery, the *harvesting* risk is managed through a detailed, fisheries-specific harvest strategy. The Spanner Crab Fishery Harvest Strategy 2020–2025 establishes clear objectives for the fishery and formalises performance indicators, triggers for management action and management responses (if applicable) based on the status of east coast stock (Department of Agriculture and Fisheries, 2020a). The TACC is administered through ITQs and is complimented by provisions that protect undersized crabs, egg-bearing (berried) females and limits fishing during the spawning season (Department of Agriculture and Fisheries, 2023).

Management initiatives implemented as part of the harvest strategy limits the over-exploitation risk in Queensland managed waters. This in itself helps to minimise one of key historical risks for this fishery. In 2018, declines in a Fishery Independent Survey (FIS) and commercial catch per unit effort (CPUE) indicated fishing activities were having a detrimental impact on the east coast spanner crab stock. This was reflected in the 2018 National Status of Australian Fish Stocks (SAFS) where the stock was classified as depleting (Campbell *et al.*, 2016; Department of Agriculture and Fisheries, 2020d; McGilvray & Johnson, 2018).

At the time of the SAFS assessment (2018), the Spanner Crab Fishery operated under a set of decision rules that were designed to manage harvest rates. These decision rules had been in place since 2008 and were less effective in terms of adjusting the TACC to address changes in the abundance indicators (*pers. comm.* S. Williams). In response to these findings and the FIS/CPUE analyses, a new management approach[2] was applied to the fishery. This approach enabled the fishery to respond more reactively to changes in abundance and included a lowering the TACC limit (from 1,621 t to 847) to reduce fishing mortality to below 2018 harvest levels (Department of Agriculture and Fisheries, 2020a). Importantly, the TACC reduction was effective in terms of addressing the above over-fishing event and establishing a fishing environment more conducive to stock rebuilding. This was evident in the most-recent SAFS assessment which classified the east coast spanner crab stocks as sustainable (Roelofs *et al.*, 2020).

While noting the above success, the approach applied to address historical overfishing was reactionary; therefore limited in terms of managing catch and effort against key sustainability reference points. This issue/risk has since been addressed with the introduction of the Spanner Crab Fishery Harvest Strategy 2020–2025 (Department of Agriculture and Fisheries, 2020a). Under this (new)

[2] *Management of the Spanner Crab Fishery has undergone further reforms including the introduction of the Spanner Crab Fishery Harvest Strategy 2020–2025*.

system, the fishery has a more comprehensive and effective framework to manage long-term harvesting-related risks.

As noted, harvest rates in the Spanner Crab Fishery are monitored against two key indicators, a FIS and CPUE (both standardised). These two indices provide insight into long-term catch and effort trends and underpin advice provided to management (Department of Agriculture and Fisheries, 2020a; d). While spanner crabs have not been the subject of a stock assessment, the fishery is tracking towards an indicator-based target reference point and decision rules for setting the TACC are based on a comprehensive Management Strategy Evaluation (MSE) (*pers. comm*. S. Williams; Filar *et al.*, 2021). These decision rules ensure that the fishery is in a good position to meet one of the core Queensland Sustainable Fisheries Strategy 2017–2027 objectives of rebuilding the stock to 60 per cent of the unfished biomass (Department of Agriculture and Fisheries, 2020a).

When compared to harvesting, discarding-related risks may be more difficult to address. Research has shown that discarded spanner crabs have comparatively poor post-release survival rates. This is of particularly relevance to regulated crabs (*i.e.* undersized crabs, egg-bearing females) that sustain an injury during the fishing event (Brown *et al.*, 2001; Brown *et al.*, 1999; Kennelly *et al.*, 1990; Wiley *et al.*, 2020). For example, post-release mortality estimates for injured spanner crabs can range from 20 per cent for minor damage (*e.g.* loss of a dactyl) to greater than 60 per cent for individuals that have lost an entire cheliped (Brown *et al.*, 1999; Wiley *et al.*, 2020). This risk is partly mitigated in the fishery through provisions that restrict the size of the dillies permitted for use, the drop of the net, the number of net layers and the size of the mesh (Department of Agriculture and Fisheries, 2023). These restrictions are aimed at reducing the capture of undersized crabs and minimising injuries incurred during the catch sorting / de-entanglement process (Brown *et al.*, 1999; Sumpton *et al.*, 1995). While noting these restrictions, post-release mortalities resulting from injuries sustained during the event remains a key source of cryptic mortality.

In addition to injuries, predation will be another source of cryptic mortalities. As the fishery uses open, flat mesh dillies, enmeshed crabs can and will be preyed on before the string has been recovered (*contact without capture).* However, recent research suggests that predation of this nature has a minor impact on spanner crab catch rates (<4% of delpoyed dillies; Milburn, 2021). More broadly, the predation risk will extend to unwanted (*e.g.* size-driven market demand) and regulated crabs that are brought to the surface and discarded (Juanes & Smith, 1995; Kirkwood & Brown, 1998). Limited research on spanner crab behaviours suggest that while the majority of released spanner crabs bury within a minute of returning to the substrate, this process can take up to 20 minutes (Kirkwood & Brown, 1998). During this period, discarded crabs will be susceptible to predation and/or injuries (*pers. comm.* S.M. Williams; Brown *et al.*, 1999; Kirkwood & Brown, 1998). These risks have been recognised in the Spanner Crab Fishery Harvest Strategy 2020–2025 as mortalities from depredation or discarding will have implications for the TACC (Department of Agriculture and Fisheries, 2020a). The maintenance of research on mortality rates of non-harvested individuals will be important moving forward.

When compared to *harvesting*, *discarding* and *contact without capture* (*i.e.* depredation), the remaining fishing activities pose a lower risk to this ecological component. While *loss of fishing gear* may be a risk factor, it is considered less of an issue when compared to the mud and blue swimmer crab fishery (Walton & Jacobsen, 2019). In mud and blue swimmer crab fishery (C1 fishery), ghost pots have been identified as a key contributor of risk for a range of target and non-target species. Of significance, ecological risk assessments involving the C1 fishery identify recreational fishing as a key

contributor to the ghost-pot risk (Walton & Jacobsen, 2019; 2020). This in part is due to the accessibility of regional mud and blue swimmer crab stocks and the availability/prevalence of inexpensive, light-weight pots that are easily replaced if lost.

In the Spanner Crab Fishery where commercial dilly configurations are more prevalent (*i.e.* dillies typically attached in strings), gear translocation is considered a more likely scenario *e.g.* during poor weather conditions, when the apparatus interacts with marine megafauna or a non-affiliated vessel. When this occurs, multiple dillies are likely to be moved/translocated at the same time; making them easier to find and retrieve (compared to a single pot). This risk will also be mitigated through the use shorter soak periods with operators retrieving dilly-strings after approximately 60 minutes (*pers. comm.* S. Williams). While gear loss due to third-party interference is a possibility, recreational crab fishing predominantly takes place in tidal waters and there is less of an overlap with commercial spanner crab fishing grounds.

The remaining fishing activities (Table 1) will have a lower impact on the east coast spanner crab stock. Of those activities identified, *contact without capture* events will be prevalent in this fishery. While a *contact without capture event* includes predation, this category also incorporates unsuccessful fishing interactions *e.g.* when a spanner crab interacts with the dilly but does not get caught or entangled in the mesh. In most instances, this type of interaction will have a negligible to low risk for the individual. The notable assumption being that the crab was able to transverse the dilly without incurring an injury significant enough to impede their long-term survivability.

Bycatch (non-SOCC)

Bycatch in the Spanner Crab Fishery is minimised through the use of an open, flat mesh trap that is highly selective for spanner crabs. This contrasts with the closed system used in the mud and blue swimmer crab fisheries where there is greater potential to trap non-target species including invertebrates, teleosts, marine reptiles and small elasmobranchs (Hill & Garland, 2009; Walton & Jacobsen, 2019; 2020). Of the species that interact with the fishery, regulated (non-retainable) spanner crabs are the most likely form of bycatch. The risk posed to this component of the catch was examined as part of the target species ecological component.

As with most traps, there is a risk that non-target species will become enmeshed in the dilly including other crab species. The extent and frequency of these interactions are not expected to have any long-term implications for regional populations and/or the conservation status of the species involved. This inference is supported by a previous assessment examining the risk posed to target and non-target species across the three Queensland crab fisheries (Hill & Garland, 2009).

Species of Conservation Concern (SOCC)

The Spanner Crab Fishery interacts with a small range of SOCC. As none of the SOCC can be retained for sale in the Spanner Crab Fishery, *discarding* and *contact without capture* are the most notable fishing activities for this subgroup. The potential for ghost dillies and their associated float lines to become a trap / entanglement hazard will also make *loss of fishing gear* an issue for some species. The risk of an interaction resulting in serious injury or death is considered low and will be dependent on how the animal interacts with the fishery (*e.g.* with the apparatus or the boat), what part of the apparatus the animal interacted with (*e.g.* float lines, dilly mesh), the length of the interaction and the presence or absence of gear remnants *e.g.* broken ropes or floats wrapped around an appendage.

Marine turtles

Data submitted through the historic *Species of Conservation Interest (SOCI)* logbook[3] does not contain any interactions between the Spanner Crab Fishery and the marine turtle complex. There are however three reports of a marine turtle interacting with a commercial dilly in the *Marine Wildlife Stranding and Mortality Database* (Department of Environment and Science, 2017; Greenland & Limpus, 2003; Greenland *et al.*, 2002). Two of these interactions were in 2001 and before the introduction of a logbook specifically targeted at threatened, endangered and protected (TEP) species. The third interaction was in 2003 and resulted in the death of the animal. Release fates for the two previous marine turtle reports are unknown.

While there is some potential for this SOCC subgroup to interact with the Spanner Crab Fishery, they are more likely to be encountered in the mud and blue swimmer crab fisheries. The collective mud and blue swimmer crab fishery (*i.e.* commercial, recreational & charter) will also pose a greater risk in terms of ghost pots (*loss of fishing gear*) and the number of cryptic mortalities (Walton & Jacobsen, 2019; 2020). In the Spanner Crab Fishery, these factors will present as a lower risk for this subgroup.

In the unlikely event that a marine turtle becomes trapped in the apparatus, it will more likely be with the ancillary equipment like float lines. Depending on the extent of the entanglement, an interaction with a float line has the potential to restrict movement, increase stress and limit access to the surface. Data compiled through the TEP logbooks[4] and StrandNET suggest that these types of interactions occur infrequently in the Spanner Crab Fishery. The hypothesis though has yet to be fully tested as there is limited capacity within the current management system to validate data submitted through logbooks or monitor interaction rates in real or near-real time.

The omnivorous diet of some species, may attract them to the bait bag or enmeshed crabs (Department of Employment Economic Development and Innovation, 2011; Dobbs, 2001). In these instances, a *contact without capture* event is considered more likely as the design of the dilly (mesh pulled tight over a flat, two-dimensional frame) reduces the likelihood of a marine turtle becoming trapped in the apparatus. Conversely, it increases the probability of a *contact without capture* event which are less likely to result in significant injury or impact on the long-term survivability of the individual.

Dugongs

Dugong interactions in the Spanner Crab Fishery are highly unlikely. There are no reports of a dugong interacting with a spanner crab dilly, in data collected as part of the Long-Term Monitoring Program or the Marine Wildlife Stranding and Mortality Database (Department of Agriculture and Fisheries, 2023; Department of Environment and Science, 2017; McGilvray *et al.*, 2006). Of the fishing activities identified (Table 1), disturbance associated with *travel to/from fishing grounds* is most applicable to this subgroup. The impacts of this fishing activity will be low to negligible when compared to other commercial fisheries, recreational fishing and other general boating activities.

Cetaceans

While limited in number (n = 6), there have been reports of whales interacting with commercial dilly ropes (Department of Agriculture and Fisheries, 2021b). The majority of these interactions will involve passing whales that have become inadvertently entangled in the float lines. Given the size of the

[3] *This logbook has now been replaced with the Threatened, Endangered, and Protected Animals Logbook.*

[4] *Including the previous SOCI logbook.*

animals involved, the immediate consequences of these types of interactions will be small to negligible. The risk of injury will increase if a whale moves out of the immediate area with fishing gear still attached and/or it cannot extricate itself from a longer section of gear. The trailing of remnant gear will be a risk factor for any whale that interacts with the commercial fishing apparatus. Whales that cannot extract themselves from the fishing gear completely may have their mobility impeded or incur long-term injuries including loss of appendage function due to a restricted blood flow.

While it is difficult to quantify without real or near-real time monitoring, cetaceans are expected to have low and infrequent interactions with the Spanner Crab Fishery. As these interactions primarily consist of *contact without capture* events, they are less likely to result in a mortality. Given the area of operation, the fishery has greater potential to interact with migrating humpback whales (*Megaptera movaeangliae*). While dolphins may also interact with this fishery, these interactions are more likely to be with the dilly and a high percentage will be instigated by the animal (*contact without capture*). Risk levels associated with *contact without capture events* are viewed as low to negligible.

Based on the above considerations, it is unlikely that the Spanner Crab Fishery will have a long-term or detrimental impact on regional cetacean populations or the conservation status of key species.

Batoids

The risk of the batoid subgroup experiencing an undesirable event as a result of fishing activities in the Spanner Crab Fishery is expected to be low. As the fishery overlaps with water depths and habitats preferred by a number of species (Last *et al.*, 2016), there is an increased probability that batoids will interact with this fishery. These interactions will be largely confined to *contact without capture* events and involve benthic batoids that have been attracted to the bait or enmeshed crabs. *Contact without capture* events are unlikely to result in significant damage to the animal and will be more of a risk for the target species ecological component (*e.g.* depredation). Outside of *contact without capture* the remaining fishing activities (Table 1) will have a low to negligible impact on this subgroup.

Sharks

The risk profile for sharks will be similar to that reported for batoids. The direct capture of a shark in a dilly is unlikely as is their entanglement in ancillary equipment like float lines. As the diet of sharks varies more than batoids (Cortés, 1999; Jacobsen & Bennett, 2013), this group is more likely to prey opportunistically on bait bags and enmeshed crabs. The consequences of this type of interaction will be more economical and have more significance to the fisher. The remaining fishing activities (Table 1) will have a low to negligible impact on this subgroup.

Protected teleosts

Four teleost species are listed as protected and cannot be harvested or retained in Queensland waters: the humphead Maori wrasse (*Cheilinus undulatus*), Queensland groper (*Epinephelus lanceolatus*), barramundi cod (*Cromileptes altivelis*), and potato rockcod (*Epinephelus tukula*). While the fishing area overlaps with the natural range of these species, the group generally prefers habitats with more structural elements (Australian Museum, 2013; 2016a; b; c). Fishing activities in the Spanner Crab Fishery will have a low to negligible impact on this SOCC subgroup.

Sea snakes

Sea snakes are at negligible risk of experiencing an undesirable event due to activities in the Spanner Crab Fishery. While sea snakes may be attracted to the bait bags, a high majority if not all of the interactions will be passive, instigated by the animal and have a very low probability of ending in their capture or injury (*contact without capture*).

Syngnathids

Interactions between this subgroup and the Spanner Crab Fishery will be rare and are unlikely to have a long-term of significant impact on regional populations.

Crocodiles

Crocodiles will be at negligible risk of experiencing an undesirable event as the Spanner Crab Fishery operates in offshore waters in areas outside of their preferred habitats.

Seabirds

Seabirds are at negligible risk of experiencing an undesirable event due to activities in the Spanner Crab Fishery. While the fishing area does overlap with the natural range of some species, there is limited opportunity for them to interact with gear. The fishing activity most likely to impact this group will be *disturbance due to presence in the area*, particularly during the dilly setting and retrieval process. This activity is unlikely to result in any direct impact on regional seabird populations.

Terrestrial mammals

Terrestrial mammals will be of negligible risk of experiencing an undesirable event as spanner crab fishing activities take place offshore environments.

Marine Habitats

The majority of effort in the Spanner Crab Fishery takes place in south-east Queensland in offshore waters with sandy-bottomed substrates (Brown *et al.*, 1999; Skinner & Hill, 1986). The benthos in these areas are typically void of structure, and are generally only impacted on by hydrological forces (Dean & Dalrymple, 1991). Given the fishing method employed, the direct impacts of the Spanner Crab Fishery on marine habitats are expected to be smaller but may be more pronounced during the dilly setting and retrieval process. Likely impacts during this period include disturbance to the benthos, increased turbidity and sediment resuspension (*disturbance due to presence in the area*, *contact without capture*). All of these impacts are expected to be localised and temporary in nature.

Loss of fishing gear arguably presents more of a long-term risk for marine habitats. If lost, dillies will introduce non-degradable pollutants into the marine environment such as nylon mesh and ropes, plastic floats, and metal frames, and have the potential to become an environmental hazard. Further, ghost float ropes may exist on the surface, in the water column, or attached to the benthos, and are likely to be a hazard for marine megafauna, which are highly susceptible to entanglement (Gregory, 2009). It is noted though that *loss of fishing gear* will be a comparatively low risk for this fishery given the prevalence of the commercial fishing sector and the absence of a large recreational fishing sector.

Ecosystem Processes

The preliminary review of spanner crab activities suggest that the fishery poses a comparatively low risk to assessed ecosystem processes (Appendix A). Of those processes reviewed as part of the

Level 1 ERA only predation, scavenging and recruitment received a preliminary risk rating higher than low. Most of which were associated with discarding (Appendix A).

Spanner crabs are known to have poor discard mortality; particularly if they are injured during the fishing event (Brown *et al.*, 2001; Brown *et al.*, 1999). There is also a risk that discarded crabs will be more susceptible to predation, scavenging and (if injured) outbreaks of disease (Appendix 2) and it may reduce the effectiveness of the minimum legal-size limits. Similarly, there is a risk that natural predators of spanner crabs such as sharks and marine turtles will take advantage of fishing activities and predate upon trapped crabs (*contact without capture*) (Brown, 2008). All of these factors have the potential to impact, impede or disrupt regional recruitment rates. The extent of this disruption is expected to be low but will be difficult to quantify in the marine environment.

4.3 Cumulative Impacts

A significant portion of fisheries-based ERAs are dedicated to understanding the potential impacts and risks posed by commercial fishing activities. There will, however, be a range of factors that contribute to an ecological component experiencing an undesirable event, including the presence and size of other fishing sectors, broader environmental trends, and operations that are not managed within the fisheries framework.

For the purpose of this assessment, the Cumulative Impacts section has been subdivided into *Fisheries Related Impacts* and *External Risks.* The inclusion of *Fisheries Related Impacts* as a cumulative fishing pressure reflects the fact that most of Queensland's fisheries are made up of multiple sectors (commercial, recreational, charter, subsistence). These sectors, for the most part, are managed alongside the commercial fishery and are subject to management regimes managed by DAF. The inclusion of *Fisheries Related Impacts* in the Risk Characterisation process reflects DAF's ability to mitigate potential risks through the broader management structure.

The establishment of a secondary cumulative risks category, *External Risks*, recognises that there are factors outside the control of DAF that have the potential to contribute to an undesirable event occurring for one or more of the ecological components. These risks represent an accumulation of issues or activities that span across stakeholders, fisheries, and often State and Federal management bodies. Of those that are identified, fishing activities are considered to be a contributing factor but are unlikely to be the primary source of risk and/or cannot simply be resolved through a fisheries context *e.g.* climate change.

In Queensland, *External Risks* are addressed through a wide variety of forums and by various departments. Given the wide-ranging nature of these risks, they will not be addressed directly within Queensland's ERA framework. They have, however, been included in the Level 1 assessment as they have the potential to pose a risk to the fishery or are a factor that the fishery contributes to. When and where appropriate, the Queensland Government will contribute to these discussions, including (among others) through participation in broader management reform initiatives, national plans of action, and recovery strategies. In these instances, DAF will continue to participate and represent the fishing interests of the State.

4.3.1 Fisheries Related Impacts

Other Fisheries

When compared to other species, spanner crab stocks will experience fewer cumulative fishing pressures. As spanner crabs can only be harvested by fishers with a C2 or a C3 fishery symbol, they cannot be retained in any other commercial fishery operating in Queensland waters (Department of Agriculture and Fisheries, 2020a; 2023; Roelofs *et al.*, 2020). The stock however will incur additional mortalities in the adjacent New South Wales (NSW) Ocean Trap and Line fishery (Department of Agriculture and Fisheries (NSW), 2020). Harvests in this fishery average out at around 10 per cent of that reported from Queensland (Department of Agriculture and Fisheries, 2020d; Roelofs *et al.*, 2020).

While spanner crabs can be retained by recreational and charter fishers, harvest rates from these sectors are comparatively small (Department of Agriculture and Fisheries, 2020c; 2021a; Roelofs *et al.*, 2020). In these sectors, fishing-related risks are principally managed through spawning closures, minimum legal-size limits and a prohibition on the take of egg-bearing (berried) females. Recreational and charter fishers are also subject to additional restrictions including a recreational limit of 4 dillies per person, a charter limit of 10 dillies per string and crab in-possession limits (Department of Agriculture and Fisheries, 2020a). These constraints combined with low effort levels indicate that these sectors will make a small contribution to the overall level of risk.

Aboriginal peoples and Torres Strait Islander peoples do not have catch or gear limits and are permitted to harvest female and undersized crabs using recreational gear or traditional methods, provided it is not for commercial purposes (*Native Title Act 1993; Fisheries Act 1994*). However, annual harvest of spanner crab by Aboriginal peoples and Torres Strait Islander peoples is estimated to be negligible and the sector will not be a significant contributor of risk.

4.3.2 External Risks

Marine Debris & Pollutants

Discarded and lost fishing gear from both commercial and recreational fishing is abundant in the marine environment and nylon mesh is extremely persistent. Plastic marine debris is a significant problem for the health of marine environments, through the degradation of habitats, ingestion by organisms and entangling marine life. In addition to fishing activities, plastic debris originates from tourism, both land and sea based, land based runoff and shipping (Bergmann *et al.*, 2015). Discarded fishing line, and other plastic debris, will degrade into microplastics, which are easily ingested by many species, including species harvested for human consumption. These microplastics are highly mobile and able to interact with species from all trophic levels (Bergmann *et al.*, 2015).

Discharge of garbage from a marine vessel is illegal in all Australian waters. However, boating causes the discharge of a number of pollutants. The major pollution sources associated with recreational and small to medium fishing vessels is fuel and oil. Antifouling paints, exhaust fumes including greenhouse gases and Polycyclic Aromatic Hydrocarbons (PAHs), and heavy metals are also released into the marine environment through boating activities (Burgin & Hardiman, 2011). Many of these pollutants are bioaccumulative, *i.e.* they build up in the environment due to their persistence. Discarding and loss of fishing related debris also occur in this fishery. This includes both deliberate and incidental release. Aside from lost fishing gear, the most significant sources of fishing related marine debris are bait bags and cigarettes, and food packaging (Byrnes *et al.*, 2016).

The Spanner Crab Fishery is likely to represent a comparatively small source of marine pollution. However, these risks are very difficult to quantify and almost impossible to assign to a particular sector or activity, due to the multifaceted sources of this risk.

Boat Strike

The effects of vessel use are generally similar regardless of whether they are used for commercial or recreational fishing, or some other form of recreational use. Therefore, despite the direct impacts being relatively low for the Spanner Crab Fishery, these impacts, when analysed in context of all vessel activity, may be a higher risk than initially perceived.

For most air breathing species, the general probability of boats strike is low, but becomes more likely depending on habitat use and vessel traffic. For turtles, interactions are more likely in internesting habitats and whilst travelling through shallow coastal foraging areas to/from the fishery (United Nations Environment Program, 2014). Dugongs are also vulnerable in shallow coastal foraging areas. Boat strikes are considered a major risk to turtles, particularly in areas like Moreton Bay. In the Queensland stranding database, stranded turtles with mortalities attributed to vessel strikes greatly outnumber fishing related mortalities (Department of Environment and Science, 2017). The greatest risk for humpback whales occurs in offshore areas around major ports and the offshore area between the Whitsundays and Shoalwater Bay (Department of the Environment and Energy, 2017).

The risk associated with boat strike mortalities is significant as it will be much larger than fisheries (commercial and recreational) and involve a wide range of recreational and commercial services. It is for this reason that boat strike mortalities will present a higher risk than commercial fishing in some areas. For example, the Marine Wildlife Stranding and Mortality Database attributed between 60 and 116 turtle mortalities per year to boat strike or fractures (2000 – 2011 data; Meager & Limpus, 2012).

Climate Change

Anthropogenic climate change is expected to have significant and lasting effects on the marine environment. These will likely impact fisheries operations, with some effects already perceptible in recent years. In Queensland, the severity of storms, tropical cyclones and extreme rainfall events are predicted to increase by the end of the century (Steffen *et al.*, 2017). In the past, these events have led to population reductions in affected areas and reduced fish catchability for extended periods after these events (Holbrook & Johnson, 2014). Further to this, increased warming of the atmosphere also leads to increased sea surface temperatures. Temperatures have been steadily increasing around Australia, and globally. This increase in temperature has been responsible for several largescale mass die-offs of coral, mangroves and seagrass (Arias-Ortiz *et al.*, 2018; Duke *et al.*, 2017; Hoegh-Guldberg *et al.*, 2007), which are critical spawning and nursery grounds for many species.

Changes in temperature and oceanic chemistry have been seen to affect physiology, growth and reproduction of fisheries species as well as the primary production that many of these species depend on (Sumaila *et al.*, 2011). Environmental variables such as oceanographic anomalies and chlorophyl concentrations were found to have significant correlations with spanner crab catchability along the east coast of Queensland. These relationships varied between management regions, which was attributed to differences in latitude or cross-shelf depth (Filar *et al.*, 2021). Increased ocean acidity is another climate change induced risk. Increased carbon dioxide in the atmosphere decreases the pH of seawater (*i.e.* increased acidity), leading to ocean acidification and dissolution of calcium based reef-building corals, molluscs and crustaceans (Hoegh-Guldberg *et al.*, 2007). Within this context, sustainably managed fisheries will be in a better position to respond to the effects of climate change. Fisheries already under significant stress due to, for example, overfishing, pollutants, and habitat degradation, may not have the resilience to deal with such a largescale threat (Sumaila *et al.*, 2011).

While DAF is currently unable to manage for the effects of climate change, due to the largely unquantifiable nature of largescale climatic effects on this Fishery, these issues are important to consider when identifying risks and future management decisions for the fishery. The Queensland Government will continue to address these issues through a range of forums and try to align these changes with the objectives of the Queensland Sustainable Fisheries Strategy 2017–2027.

4.4 Risk Characterisation

The primary purpose of the *Risk Characterisation* stage is to assign a qualitative value to each fishing activity that represents the potential (Low, Intermediate or High) for it to contribute to an undesirable event (Table 2). In doing so, the *Risk Characterisation* stage aims to identify the key sources of risk from each fishery in order to inform finer-scale assessments. If, for example, an ecological subcomponent is identified as high risk in the Level 2 *Productivity-Susceptibility Analysis* (PSA) or a *base Sustainability Assessment for Fishing Effects* (bSAFE), the results of the Level 1 assessment will identify the activities within the fishery that are contributing to this risk.

Scores assigned to each ecological component (excluding *ecosystem processes*) and SOCC subcomponent are based on the issues raised during the *Risk Identification* process. They take into consideration the current fishing trends (*e.g.* current catch, effort and licensing), limitations of the current management regime (*e.g.* the potential for additional effort to be transferred into areas already experiencing higher levels of fishing mortality, substantial increases in fishing mortality for key species, changing target species) and the consequences of the interaction. While the majority of SOCC are classified as bycatch they have been assessed as separate entities in recognition of their complex life histories. Risk scores assigned to ecosystem processes are based on the preliminary assessment (Appendix 1) and represent the maximum score assigned to that particular fishing activity.

Outputs of the Risk Categorisation stage, excluding *cumulative impacts*, were used to assign each ecological component with a preliminary risk rating based on the highest risk score in the profile (Table 2). For example, if an ecological component received a high risk for one or more of the fishing activities, it would be reflected in the preliminary risk ratings (Table 2; Appendix 2). These preliminary risk ratings are conservative and provide the first opportunity to remove low-risk elements from the assessment. Scores assigned to *Cumulative Impacts* were not considered as the preliminary risk scores are only applicable to the commercial fishery. *Cumulative impacts* scores provide insight into the potential for ancillary risks to impact each of the respective ecological components.

The scores assigned to each ecological component (excluding *ecosystem processes*) and SOCC subcomponent are based on the issues raised during the *Risk Identification* process (refer section 4.2). While the majority of SOCC are classified as bycatch they have been assessed as separate entities in recognition of their complex life histories. Risk scores assigned to the ecosystem processes ecological component are based on the preliminary assessment (Appendix 2) and represents the maximum score that was assigned to that particular fishing activity. To this extent, the scores assigned to this ecological component represent the highest potential risk and will not be applicable to all of the ecosystem processes outlined in Appendix 1. Accordingly, the Level 1 assessment for ecosystem processes should be considered as both precautionary and preliminary in nature.

Preliminary assessments indicate that activities in the Spanner Crab Fishery presented a negligible or low risk to most ecosystem components. The notable exception being the target species ecological component which was assigned a preliminary ‘high’ risk rating (Appendix 2; Table 2). The rating

assigned to this ecological component was heavily influenced by *discarding* (Table 2) and overestimates the level of concern surrounding spanner crab stock sustainability (Department of Agriculture and Fisheries, 2020d; Roelofs *et al.*, 2020). The suitability and applicability of this rating was given further consideration in section 4.5 of this report.

A full account of the preliminary risk ratings, key considerations and risk factors has been provided in Appendix 2. However, the following provides a general overview of the key findings of the *Risk Characterisation* stage.

- The majority of the identifiable risks in the Spanner Crab Fishery relate to interactions with the target species *i.e.* spanner crabs.
- The establishment and implementation of a spanner-crab specific harvest strategy was significant in terms of managing the long-term risk of over-exploitation (*harvesting*).
- Discarding was identified as a key risk factor for the target species ecological component due to a) spanner crabs having relatively poor post-release survival rates and b) the potential for this risk to be compounded by injuries.
- Few SOCC groups were at risk from spanner crab fishing activities and cetaceans the only SOCC subgroup to be at higher risk due to entanglement.

Table 2. *Summary of risk scores for the Spanner Crab Fishery including the impact of the main fishing activities on key ecological components.*

Ecological Component	Dilly Fishing – Main activities of the Fishery							Preliminary Risk Rating	Cumulative Fishing Impacts
	Harvesting	Discarding	Contact without capture	Loss of fishing gear	Travel to/from grounds	Disturbance due to presence in area	Boat maintenance & emissions		
Target Species	L/I	H	I	L	-	I/L	-	H	L
Bycatch species	-	L	L	L	-	-	-	L	-
SOCC									
Turtles	-	L	L	L	-	L	-	L	-
Sea snakes	-	-	-	-	-	L	-	L	-
Crocodiles	-	-	-	-	-	-	-	-	-
Dugongs	-	-	-	-	L	-	-	L	-
Cetaceans	-	L	I	I	-	-	-	I	-
Protected teleosts	-	-	-	-	-	-	-	-	-
Batoids	-	-	L	-	-	L	-	L	-
Sharks	-	-	L	-	-	L	-	L	-
Syngnathids	-	L	L	-	-	-	-	-	-
Seabirds	-	-	-	-	-	L	-	L	-
Ter. mammals	-	-	-	-	-	-	-	-	-
Marine Habitats	-	-	-	L	-	L	-	L	-
Ecosystem Processes	L	I	L	-	-	-	-	I	-

4.5 Likelihood

The *Risk Characterisation* stage takes into consideration what is occurring in the fishery and what can occur under the current management regime. This provides a more holistic account of the risks posed by the fishery and provides the Level 1 ERA with greater capacity to address the (potential) long-term consequences of a risk. The inherent trade off with this approach is that some of the ecological components may be assigned more conservative risk ratings. Otherwise known as false positives, these values overestimate the level of risk posed to an ecological component or subcomponent. In other words, preliminary risk ratings compiled in the *Risk Characterisation* stage may represent a potential risk—something that is discussed at length in the *Ecological Risk Assessment Guideline* (Department of Agriculture and Fisheries, 2018a).

False positives should not be discounted as they point towards areas where further monitoring and assessment may be required. However, triggering management changes or progressing an ecological component to a Level 2 (species-specific) ERA based on a conservative whole-of-fishery (Level 1) assessment may be unwarranted. This places added importance on examining the preliminary risk ratings and determine if they represent a real or potential high risk (Department of Agriculture and Fisheries, 2018a).

In order to address the potential overestimation of risk for some ecological components, a secondary qualitative review of the preliminary risk ratings was undertaken. This review examined factors underpinning each assessment, their relevance to the current fishing environment and areas where this risk may be overestimated. The purpose of the secondary review is not to dismiss the preliminary findings of the *Risk Characterisation* stage. Rather, this secondary assessment aims to assess the likelihood of the risk coming to fruition over the short to medium term. This will aid in the identification of priority risk areas and help to inform broader discussions surrounding the development of risk management strategies for key species. Given the extent of fisheries reforms outlined in the Queensland Sustainable Fisheries Strategy 2017–2027 (Department of Agriculture and Fisheries, 2017) and the available resources, this was considered to be an important and necessary step.

When mitigation measures and risk likelihood are given further consideration, the risk ratings of seven ecological components were reduced (Appendix 2). The most notable of these was the downgrading of the risk rating assigned to the target species ecological component from high to low/intermediate (Table 3; Appendix 2). The preliminary risk rating for this ecological component was heavily influenced by *discarding* and it was the only fishing activity in the study to receive a high-risk rating (Table 2). The reasons for this being that post-capture mortality rates for discarded spanner crabs tend to be higher due to injuries incurred during the fishing event, predation *etc*. (Brown *et al.*, 2001; Brown *et al.*, 1999; Kennelly *et al.*, 1990; Wiley *et al.*, 2020).

While *discarding* and post-interaction mortalities are an issue in the Spanner Crab Fishery, the preliminary risk rating was considered an over-estimate. This inference is supported by the most recent management advice and indicative sustainability evaluations which show that the stock is being sustainably fished (Department of Agriculture and Fisheries, 2020d; Roelofs *et al.*, 2020). Further, the Queensland component is now managed under a fisheries-specific harvest strategy that includes a range of decision rules and trigger limits (Department of Agriculture and Fisheries, 2020a). These provisions provide certainty surrounding the TACC setting process, safeguards against potential increases in the non-commercial catch and establishes a strong foundation for the long-term

management of the stock on the Queensland east coast. For these reasons, the risk score assigned to the target species ecological component was downgraded from high to low/intermediate.

The remaining changes involved ecological components that have limited to no interactions with the fishery and/or have interactions with minimal consequences. A summary of the key findings of the Level 1 ERA have been provided in Table 3. Additional information on the Level 1 risk ratings including key considerations of both the preliminary risks and mitigation measures has been provided in Appendix 2.

***Table 3**. Level 1 ratings for the ecological components and subcomponents interacting with the Spanner Crab Fishery taking into consideration the likelihood of the risk coming to fruition in the short to medium term.*

Ecological Component	Level 1 Risk Rating	Likelihood Considerations	Level 2 Required?
Target Species	*Low / Intermediate*	• Spanner crabs are not managed under a stock assessment and have experienced historical declines. However indices used to monitor catch in the fishery (*e.g.* standardised FIS, standardised CPUE, SAFS) indicate that the fishery is being sustainably fished. • Previous measures including a 2018 TACC reduction helped redress a previous overfishing event and improve the long-term sustainability of the east coast stock. • The long-term sustainability of the stocks is safeguarded through the use of decision rules and trigger limits contained within the Spanner Crab Fishery Harvest Strategy 2020–2025. These decision rules are based on a detailed MSE. • Spanner crabs are prone to post-release mortalities, particularly if they are injured during the fishing event. Discarded crabs and crabs trapped within the dilly will also be exposed to increased predation. • The absence of biomass indicators, the potential for post-release mortalities and cryptic mortalities all contributed to the subgroup receiving a marginally higher risk rating. • While the species can be retained by non-commercial fishers, cumulative fishing pressures exerted on this species are comparatively low.	No – Best addressed through the Harvest Strategy
Bycatch (non-SOCC)	Low	• Bycatch in the Spanner Crab Fishery will mainly consist of regulated spanner crabs *e.g.* undersized crabs and egg-bearing (berried) females.	No

Ecological Component	Level 1 Risk Rating	Likelihood Considerations	Level 2 Required?
		• While some bycatch may be caught in the Spanner Crab Fishery, levels are not expected to pose a significant long-term risk to these species. • Most interactions with non-target species will be *contact without capture* events. In most instances, this type of interaction will have minimal impact on the effected individual. • The open nature of the apparatus used (dillies) limits the number of non-target species that are captured and brought to the surface. • If a non-target species is brought to the surface (*e.g.* other crab species), post-capture mortality rates will (likely) be higher than what has been reported for spanner crabs.	
Marine turtles	Low	• High spatial overlap between key fishing grounds and habitats where marine turtles are found. There are however only limited reports of this subgroup interacting with the fishery. • The structure of the apparatus (*e.g.* open trap with taught mesh netting) reduces the risk of an entanglement or entrapment. • The subgroup is more likely to interact with ancillary equipment (*e.g.* float lines) or experience *contact without capture* events (*e.g.* boat strike, attraction to bait bags). • Minimal recreational interests / cumulative fishing risks *i.e.* reduced cumulative effort and fewer ghost pots/dillies. • Key risks like boat strike will be applicable to most commercial fisheries, the recreational fishing sector and other marine-based activities. • Further management of risk may not be required.	No
Dugongs	Negligible	• Area of operation minimises the interaction potential and overall level of risk and interactions with the apparatus including ancillary highly unlikely/improbable. • Indirect impacts (boat strike, *travel to/from fishing grounds,*) will be higher risk than direct impacts. These risks will apply to most commercial fisheries, the	No

Ecological Component	Level 1 Risk Rating	Likelihood Considerations	Level 2 Required?
		recreational fishing sector and other marine-based activities. • Further management of risk not viewed as necessary.	
Cetaceans	Low	• Given the area of operation there is some potential for the Spanner Crab Fishery to interact with this subgroup, particularly whales. • Cetaceans are the only SOCC subgroup with reported interactions with the Spanner Crab Fishery (*n* = 6 whales). These interactions are most likely to be with migrating humpback whales. • Direct mortalities as a result of a Spanner Crab Fishery interaction are unlikely. Longer-term impacts may include the dragging of gear remnants and the potential for long-term injury *e.g.* strangulation of fins/appendages. • The frequency of these interactions are not expected to impact the long-term conservation status of the affected species. • Further management of risk not viewed as necessary. However, the fishery would benefit from additional information on interaction rates; particularly the number of *contact without capture* events.	No
Protected Teleosts	Negligible	• Apparatus not suited to the targeting of teleosts. Interactions between operators and protected species are unlikely.	No
Batoids	Low	• Benthic batoids will likely be attracted to the bait bag or entangled spanner crabs. • The direct capture of a batoid in the dilly are unlikely and will not pose a significant risk to regional populations. • Interactions with batoids are more likely to be *contact without capture* events and are unlikely to result in significant long-term injuries. • Direct management of risk not viewed as necessary. However, obtaining additional information on batoid interactions may provide insight into the extent of consequences *e.g.* crab loss, injuries or disturbance.	No

Ecological Component	Level 1 Risk Rating	Likelihood Considerations	Level 2 Required?
Sharks	Low	• Interactions with the shark subgroup are considered likely within the immediately fished area. • The direct capture of a shark in the dilly will be rare with *contact without capture* events the most probable outcome. • Most interactions will be instigated by the shark and will lead to cryptic mortalities and economic losses (*e.g.* preying on bait bags or entangled spanner crabs). • Further management of risk not viewed as necessary. However additional information on shark depredation may be of use for the long-term management of spanner crab stocks.	No
Sea snakes	Negligible	• No reports of this subgroup interacting with the fishery and interactions (if applicable) are unlikely to impact regional populations.	No
Crocodiles	Negligible	• Very limited overlap between key fishing grounds and preferred habitats. • Interactions with this subgroup are highly unlikely and (if applicable) would not pose a significant risk to their long-term sustainability.	No
Syngnathids	Negligible	• Fishery unlikely to have significant interactions with subgroup. • Interactions (if applicable) will have a negligible impact on the long-term conservation status of these species. • Further management of these risks are not required.	No
Seabirds	Negligible	• No reported interactions with sea birds and there is a low probability of seabirds becoming entangled in the apparatus (including ancillary equipment). • *Disturbance due to presence in the area* is viewed as the key fishing activity most likely to impact this subgroup. These impacts will be indirect and mostly confined to the gear setting and retrieval process. • Further management of these risks are not required.	No
Terrestrial mammals	Negligible	• Negligible interactions or spatial overlap.	No

Ecological Component	Level 1 Risk Rating	Likelihood Considerations	Level 2 Required?
Marine Habitats	Low	• Regional impacts on the marine environment will include increased turbidity/sediment resuspension, disturbance to the immediate area and dislocation of benthic communities. • These impacts are more likely to occur during the gear setting and retrieval process. They will however be temporary and localised. • While gear loss is considered a risk in trap fisheries, this risk is considered smaller when compared to the collective mud & blue swimmer crab fishery. • Further management of risk not required.	No
Ecosystem Processes	Low	• The specificity of the fishery/apparatus limits the risk posed to key ecosystem processes. • The fishery has the potential to impact things like recruitment, scavenging and connectivity. These risks will be more pronounced if there is an overfishing event and be influenced by discarding / post-capture mortalities. These risks have been partly addressed through a fisheries-specific harvest strategy. • Further management of risk not viewed as a priority. However, this ecological component would benefit from additional information on how regional communities interact with the apparatus when fishing and during the net setting/retrieval process.	No – Monitoring & Research Plan

4.6 Issues Arising

When compared to other commercial fisheries, a comparatively small number of issues were identified in the Spanner Crab Fishery Level 1 ERA. This is due to the single-species nature of the fishery and the use of an apparatus that is highly-selective for spanner crabs (Department of Agriculture and Fisheries, 2023). The establishment and introduction of a fishery-specific harvest strategy was also identified as a key development in terms of minimising risks/issues identified in some of the remaining Level 1 assessments.[5]

[5] *For most of the fisheries that were subject to a Level 1 ERA, the assessment was completed before 1 September 2021 and the introduction of their harvest strategy. Risk assessments developed under the Queensland Sustainable Fisheries Strategy 2017–2027 are available at: https://www.daf.qld.gov.au/business-*

Discards & Cryptic Mortalities

Some of the more significant data deficiencies in the Spanner Crab Fishery relate to discards, post-release mortalities and cryptic mortalities. This is reflected in the harvest strategy where the collection of additional information on discards and depredation have been identified as key information and research priorities (Department of Agriculture and Fisheries, 2020a).

Discard information will be the easiest to obtain in an active fishing environment. However, post-capture mortalities will be more difficult to quantify as they often go unobserved. In the Spanner Crab Fishery, this issue could be partly resolved by documenting the release fate of discarded crabs *e.g.* alive, injured or dead. Research has shown that injured spanner crabs have comparatively poor post-release survival rates (Kirkwood & Brown, 1998). With additional information on the status of discarded crabs, a more informed estimate of the total rate of fishing mortality could be obtained. This would be of some value when evaluating the total rate of fishing mortality and any implications in terms of the TACC setting process. This information though would need to be supported with updated research on post-interaction survival rates, particularly in injured crabs.

Similarly, other sources of cryptic mortality including changes in depredation rates may need to be considered when assessing changes in the FIS. These mortalities can be attributed to fishing activities and would ideally be accounted for the total rate of fishing mortality. The challenge being how best to account for undetectable spanner crab mortalities across a longer timescale.

Catch Validation & Threatened, Endangered & Protected Species reports

Issues relating to catch validation/verification extend across Queensland's commercial fisheries and are being actively addressed as part of the Queensland Sustainable Fisheries Strategy 2017–2027 (Department of Agriculture and Fisheries, 2017). In the Spanner Crab Fishery, the main issues relate to quantifying total catch rates (retained plus discards) and interactions with Threatened, Endangered and Protected (TEP) animals.

The majority of the spanner crab catch and effort comes from the output controlled Managed Area A (C2 fishery symbol). As such, the vast majority of operators are already subject to additional reporting requirements. This includes the need to prior-report catch through the Automated Interactive Voice Response (AIVR) system (*e.g.* landing location, crab numbers, weight of crabs landed) and complete catch disposal records (Business Queensland, 2019; Department of Agriculture and Fisheries, 2018b; 2020a). These measures combined with logbook records provide a system of crosschecks that can be used to validate catch against key reference points including ITQs. These measures though only apply to retained catch and there is limited capacity within the current system to document catch and interaction rates (including discards) in real or near-real time.

Given the area of operation, participation rates, and the apparatus used, the Spanner Crab Fishery will interact with a smaller subset of the SOCC (Department of Agriculture and Fisheries, 2023). The interaction potential of the fishery will also be lower when compared to the East Coast Inshore Net Fishery and the mud & blue swimmer crab fisheries (Jacobsen *et al.*, 2021a; b; c; Jacobsen *et al.*,

priorities/fisheries/monitoring-research/data/ecological-risk-assessments. Harvest strategies can also be accessed at: https://www.daf.qld.gov.au/business-priorities/fisheries/sustainable/harvest-strategy

2019; Walton & Jacobsen, 2019; 2020). This was reflected in the scores assigned to these groups as part of the Level 1 ERA (Table 3).

At present, there is limited capacity to validate or verify information submitted through the logbook program or monitor interactions with TEP species. The inherent risk being that data provided through the logbook system underestimates the number of TEP species interactions. This inference is partly supported by data compiled through ancillary programmes like the Marine Wildlife Stranding and Mortality Database which include a small number of whale interactions that were not included in the logbooks (Department of Environment and Science, 2017; Meager, 2013; 2016; Meager *et al.*, 2012).

Gear loss

Gear loss will be a risk for most fisheries that deploy the apparatus for an extended period of time. Limited information exists on gear-loss rates in the Spanner Crab Fishery, but evidence suggests that this is an issue of more significance in the mud & blue swimmer crab fisheries (Sumpton *et al.*, 2003; Walton & Jacobsen, 2019; 2020). Traps/pots used in the mud & blue swimmer crab fisheries are closed systems that prevent animals from leaving and are capable of self-baiting once lost. While the risk of self-baiting still exists in this fishery, dillies are open traps, are highly selective for spanner crabs and have a lower probability of entangling/ensnaring non-target species (NSW Department of Primary Industries, 2006).

Further, the recreational fishing sector has been identified as key source of ghost pots in the mud and blue swimmer crab fisheries (Walton & Jacobsen, 2019; 2020). Recreational fishers targeting mud and blue swimmer crabs also use pots that form a closed system. However, recreational pots tend to be more light weight, are relatively inexpensive and are readily replaced if lost. When compared to mud and blue swimmer crabs, spanner crabs attract significantly less recreational fishing effort. This in turn reduces the likelihood of the fishery making a significant contribution to the number of ghost (lost) dillies and the overall level of risk.

While noting the above, future ERAs would benefit from additional information on the number of dillies that are lost during a given fishing season. The number of lost dillies is expected to be lower when compared to other crab fisheries; as too will the level of risk. There would however be some benefit in examining the level of risk loss of fishing gear poses in this fishery including the ancillary equipment *e.g.* entanglement in ropes / float lines. With that said, it may be viewed as a lower priority when compared to the quantification of pot loss in the mud and blue swimmer crab fisheries (Walton & Jacobsen, 2019; 2020).

5 Summary & Recommendations

When the outputs of the preliminary risk assessment and the secondary evaluation of likelihood (Table 3; Appendix 2) are taken into consideration, only the target species ecological component was assigned a risk rating above low. These results reflect the single-species nature of the fishery and the use of a gear type that is highly selective for spanner crabs.

Of notable importance, a number of the key risks are already being addressed, minimised and mitigated through a fisheries-specific harvest strategy (Department of Agriculture and Fisheries, 2020a). However, the Level 1 ERA did identify a number of areas where information levels could be improved and management refined. The following recommendations may assist with this process and improve the level of understanding surrounding the risk posed to key species or species complexes. In

some instances, a recommendation may be best addressed or progressed through the Fisheries Queensland Monitoring and Research Plan:

- Identify mechanisms to increase capacity to validate data submitted through the Threatened, Endangered, and Protected Animals logbook and monitor interactions with non-target species.
- Explore avenues to improve the level of information on discards and options to monitor long-term changes in non-reported mortalities *e.g.* post-capture mortalities, depredation etc.
- Where possible, improve the level of information on gear loss in the Spanner Crab Fishery including (if applicable) the origin of the equipment *i.e.* commercial and/or recreational fishing sectors.

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Appendix 1—Ecological Processes Preliminary Assessment

***Appendix 1A**—Ecological Processes Categories*

Categories taken into consideration as part of the Level 1 preliminary assessment for the *Ecological Processes* ecological component. Definitions adopted from the Great Barrier Reef Outlook Report (Great Barrier Reef Marine Park Authority, 2014; 2019) and Pears *et al.* (2012).

CATIGORY	DESCRIPTION
SEDIMENTATION	The inflow, dispersion, resuspension and consolidation of sediments
NUTRIENT CYCLING / MICROBIAL PROCESSES	The input, export and recycling of nutrients within the ecosystem, including microbial activity. Removal of animals through harvesting is a direct loss of nutrients to the ecosystem
PARTICLE FEEDING	Feeding process targeted at particles suspended in the water column, or deposited on submerged surfaces
PRIMARY PRODUCTION	The conversion of the sun's energy into carbon compounds that are then available to other organisms
HERBIVORY	The consumption of plants
PREDATION	The removal of mid and top order predators from the marine environment and the potential for animals to be subject to increase predation
BIOTURBATION	The biological reworking of sediments during burrow construction and feeding and bioirrigation (mixing of solutes) leading to the mixing of oxygen-bearing waters into sediments
DETRITIVORY	Feeding on detritus (decomposing organic matter)
SCAVENGING	Predators eating already dead animals
SYMBIOSIS	The interdependence of different organisms for the benefit of one or both participants
RECRUITMENT	The impact of the fishery on the ability of a species replenishment populations
REEF BUILDING	The process of creating habitats composed of coral and algae and includes the creation of all biogenic (*i.e.* of living origin) habitats
COMPETITION	Interactions between species that favour or inhibit mutual growth and functioning of populations
CONNECTIVITY	Migration, movement and dispersal of propagules between habitats at a range of scales; and functional connectivity which represents ontogenetic cycles of habitat use
OUTBREAKS OF DISEASE	The spread or introduction of disease to organisms or ecosystems
SPECIES INTRODUCTIONS	The introduction of exotic species and their spread once established

***Appendix 1B**—Ecosystem Processes Preliminary Assessment*

Due to the difficulty of assessing the impacts of a fishery on ecosystem processes, a precautionary approach was adopted for the Level 1 ERA. In line with this approach, an initial or preliminary assessment was undertaken for 16 ecosystem processes that may be influenced by fishing activities (Great Barrier Reef Marine Park Authority, 2014; 2019). As with risk scores for the whole-of-fishery assessment (Table 4) each category was assigned a risk rating of Low (L), Intermediate (I), High (H), or negligible (-). This risk score describes the potential for each fishing activity (*e.g. harvesting, discarding etc.*) to negatively impact on the ecosystem process category (*e.g.* sedimentation, nutrient cycling *etc.*).

For the Level 1 assessment (Table 4), each fishing activity was assigned a final risk score that corresponded with the maximum risk rating assigned in the preliminary assessment. If for example 'Predation' received a 'H' for harvesting but the remaining categories received a 'L' or 'I', then the final risk score for harvesting will be a H. To this extent, the final risk scores assigned to each fishing activity present the highest potential risk and therefore may not be applicable to all of the ecosystem processes categories. Used in this context, the Level 1 assessment for ecosystem processes should be considered as both precautionary and preliminary in nature.

***Table A1**. Summary of preliminary risk scores for the main fishing activities in the Spanner Crab Fishery on key ecosystem processes.*

	Dilly fishing – Main activities of the Fishery							
Category	**Harvesting**	**Discarding**	**Contact without capture**	**Loss of fishing gear**	**Travel to/from grounds**	**Disturbance due to presence in area**	**Boat maintenance & emissions**	**Cumulative Fishing Impacts**
Sedimentation	-	-	-	L	-	L	-	-
Nutrient cycling / Microbial processes	L	-	-	-	-	-	-	-
Particle feeding	-	-	-	-	-	-	-	-
Primary production	-	-	-	-	-	-	-	-
Herbivory	-	-	-	-	-	-	-	-
Predation	L	I	L/I	-	-	-	-	-
Bioturbation	L	-	-	-	-	-	-	-
Detritivory	-	-	-	-	-	-	-	-
Scavenging	L	I	-	-	-	-	-	-
Symbiosis	-	-	-	-	-	-	-	-
Recruitment	L	I	L	-	-	-	-	-
Reef building	-	-	-	-	-	-	-	-
Competition	L	-	-	-	-	-	-	-
Connectivity	-	-	-	-	-	-	-	-
Outbreaks of disease	-	L	-	-	-	-	-	-
Species introductions	-	-	-	-	-	-	-	-
Overall Rating	L	I	L/I	L	-	L	-	-

Appendix 2—Risk Ratings and Outputs

The primary objectives of the Level 1 ERAs were to identify a) the key sources of risk within a particular fishery, and b) the ecosystem components that are most likely to be affected by this risk. Preliminary risk ratings developed as part of the *Risk Characterisation* stage take into consideration the current fishing environment (*e.g.* catch, effort, and licensing trends) and risk factors associated with the current management regime (*e.g.* the potential for the transfer of additional effort to areas of high fishing mortality, increases in fishing mortality for key species, changing target species). Depending on the fishery, broader risk factors may also contribute to conservative risk ratings being assigned to ecological components. These preliminary ratings are precautionary/conservative in nature, provide a more holistic account of the risks posed by the fishery, and provide the Level 1 ERA with greater capacity to address the long-term consequences of a risk. Inherent trade-offs with this approach include the preliminary overestimation of the level of risk posed to an ecological component, or the representation of the potential risk, otherwise known as false positives.

The potential for large-scale, qualitative ERAs to produce false positives places added importance on examining the likelihood of the risk coming to fruition in the short to medium term. The following provides an overview of the preliminary risk ratings and an assessment of the likelihood of it occurring in the Spanner Crab Fishery. Depending on the species and the current fishing pressures, preliminary risk ratings may be amended to reflect the current fishing environment.

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
Target Species	• While the fishery operates under a harvest strategy, spanner crabs are not managed under a stock assessment there have been ones produced for the fishery. However, these re-affirm that management under the indicatory based harvest strategy framework are likely more informative.	High	*Likelihood* • Lower probability of the risk coming to fruition over the short to medium term. *Mitigation Measures & Considerations* • Preliminary risk rating was heavily influenced by *discarding*; the only fishing activity to score a high-risk rating. • While spanner crabs are not managed under a modelled stock assessment the	Low/Intermediate

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
	• Spanner crabs are prone to post-release mortalities, particularly if they are injured during the fishing event. • There is previous evidence that the east coast spanner crab stocks are susceptible to overfishing events (McGilvray & Johnson, 2018).		MSE tested indicator framework used to monitor catch in the fishery (*e.g.* standardised FIS, standardised CPUE, SAFS) indicate that the fishery is now being sustainably fished (Department of Agriculture and Fisheries, 2020d; Johnson, 2021; Roelofs *et al.*, 2020). • Decision rules applied to the TACC setting process through the harvest strategy are also based on a comprehensive MSE. • With the fishery is tracking towards an indicator-reference points and the TACC setting process supported by a MSE, there is less need to conduct a stock assessment for this species. • Previous measures including a 2018 TACC reduction helped redress a previous overfishing event and improve the long-term sustainability of the east coast stock. • The long-term sustainability of the stocks is also safeguarded through the use of decision rules and trigger limits contained	

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
			within the Spanner Crab Fishery Harvest Strategy 2020–2025 (Department of Agriculture and Fisheries, 2020a). • While the species can be retained by non-commercial fishers, cumulative fishing pressures exerted on this species are comparatively low.	
Bycatch (non-SOCC)	• Bycatch in the Spanner Crab Fishery will mainly consist of regulated spanner crabs *e.g.* undersized, egg-bearing (berried) females. • While some bycatch may be caught in the Spanner Crab Fishery, levels are not expected to pose a significant long-term risk to these species.	Low	*Likelihood* • Low *Mitigation measures & considerations* • Most interactions with non-target species will be *contact without capture* events. • In most of these instances, there will be a low to negligible risk to the effected individual. • While some non-target species (*e.g.* other crabs) may be brought to the surface, post-capture mortality rates for these species will be better than for spanner crabs.	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
			• The number of non-target species that are a) caught in an open-faced dilly and b) brought to the surface will be small.	
Species of Conservation Concern (SOCC)				
Marine turtles	• High spatial overlap between key fishing grounds and preferred habitats. • The subgroup is most likely to interact with ancillary equipment *e.g.* float-lines.	Low	<u>*Likelihood*</u> • Low <u>*Mitigation measures & considerations*</u> • No reported interactions with this subgroup and their direct capture within the dilly is highly unlikely. • The structure of the apparatus (*e.g.* open trap with taught mesh netting) reduces the risk of an entanglement or entrapment. • Contact without capture event like boat strike will be a higher risk when compared to their capture within the dilly. • Minimal recreational interest in spanner crabs also minimises the cumulative risk posed to this subgroup.	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
			• Marine turtle interactions are more likely to occur in the collective mud & blue swimmer crab fishery. This fishery has prominent commercial and non-commercial fishing sectors, uses closed trapping systems and has a more prevalent ghost-pot risk. • Key risks to this subgroup will be applicable to most commercial fisheries, the recreational fishing sector and other marine-based activities *e.g.* boat strike. • Further management of risk may not be required.	
Dugongs	• Indirect impacts (boat strike, *travel to/from fishing grounds,*) will be higher risk than direct impacts.	Low	<u>*Likelihood*</u> • Negligible <u>*Mitigation measures & considerations*</u> • Area of operation minimises the interaction potential and overall level of risk. • Interactions with the apparatus including ancillary equipment highly unlikely.	Negligible

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
			• Further management of risk not viewed as necessary.	
Cetaceans	• Only SOCC subgroup with reported interactions (*n* = 6 whales). • Interactions are more likely to occur with ancillary equipment including entanglement in float lines. • Direct risk of mortality is low but interactions with the fishery may result in long-term complications for the individual.	Intermediate	*Likelihood* • Low *Mitigation measures & considerations* • Given the area of operation there is increased potential for the Spanner Crab Fishery to interact with this subgroup, particularly whales. • Preliminary risk rating was considered an overestimate that was influenced to scores assigned to *contact without capture* and *loss of fishing gear*. • Direct mortalities because of Spanner Crab Fishery interactions are unlikely. Longer-term impacts may include the dragging of gear remnants and the potential for long-term injury *e.g.* strangulation of fins.	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
			• The frequency of these interactions are unlikely to impact the long-term conservation status of the affected species. • Further management of risk not viewed as necessary.	
Protected Teleosts	• Apparatus not suited to the targeting of teleosts. Interactions between operators and protected species are unlikely.	Negligible	<u>*Likelihood*</u> • Negligible <u>*Mitigation measures & considerations*</u> • Further management of risk not viewed as necessary.	Negligible
Batoids	• Indirect interactions are more likely to occur with this subgroup as batoids may be attracted to the bait bag or entangled spanner crabs.	Low	<u>*Likelihood*</u> • Low <u>*Mitigation measures & considerations*</u> • The direct capture of these species in a dilly would be rare with *contact without capture* events considered more likely. • The overwhelming majority of the interactions in the Spanner Crab Fishery	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
			will not result in significant injuries or mortalities. • Batoid interactions with the Spanner Crab Fishery will not result in any long-term implications for this subgroup and/or the conservation status of key species. • Further management of risk not viewed as necessary.	
Sharks	• Indirect interactions likely to occur with this subgroup within the immediately fished area.	Low	<u>*Likelihood*</u> • Low <u>*Mitigation measures & considerations*</u> • The direct capture of these species in a dilly will be rare with *contact without capture* events considered more likely. • The overwhelming majority of the interactions between the Spanner Crab Fishery and sharks will not result in significant injuries or mortalities. • In most instances, interactions with the fishery will be instigated by the animal *e.g.*	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
			preying on bait bags or entangled spanner crabs. • Further management of risk not viewed as necessary. However additional information on shark depredation may be of use for the long-term management of spanner crab stocks.	
Sea snakes	• No reported interactions and (if applicable) fishery are unlikely to impact significantly on regional populations. • High spatial overlap between key fishing grounds and preferred habitats. • Indirect impacts (*travel to/from fishing grounds,* and *disturbance due to presence in the area*) considered to be higher risk than direct impacts.	Low	*Likelihood* • Negligible *Mitigation measures & considerations* • Risk rating was influenced by indirect impacts *e.g. disturbance due to presence in the area*. • These risks will have a negligible impact on regional sea snake populations and the fishery does not pose a long-term risk to this subgroup. • Further management of risk not viewed as necessary.	Negligible

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
Crocodiles	• Limited spatial overlap between key fishing grounds and preferred habitats (possibly in FNQ). • Interactions with this subgroup are highly unlikely and infrequent.	Negligible	*Likelihood* • Negligible / Not applicable	Negligible
Syngnathids	• Limited interaction potential with this subgroup.	Low	*Likelihood* • Negligible *Mitigation measures & considerations* • Fishery unlikely to have significant interactions with subgroup. • Interactions with this subgroup (if applicable) will have a negligible impact on the long-term conservation status of these species. • Further management of these risks are not required.	Negligible
Seabirds	• No reported interactions and (if applicable) fishery are unlikely to impact significantly on regional populations.	Low	*Likelihood* • Negligible *Mitigation measures & considerations*	Negligible

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
	• *Disturbance due to presence in the area* viewed as the key fishing activity for this subgroup. These interactions will be indirect and be confined to the gear setting and retrieval process.		• Impacts on this subgroup will be indirect and are unlikely to result in an injury or mortality. • Low probability of seabirds becoming entangled in the apparatus including the ancillary equipment. • Further management of risk not viewed as necessary.	
Terrestrial mammals	• Negligible interactions or spatial overlap.	Negligible	N/A	Negligible
Marine Habitats	• Contact with marine habitat is highly localised and regional impacts may include increased turbidity/sediment resuspension, disturbance to the immediate area and dislocation of benthic communities. • Cumulative impacts will be a risk for areas that attract higher levels of effort.	Low	*Likelihood* • Low *Mitigation measures & considerations* • Disturbance to the marine habitat will largely confined to the gear setting and retrieval process. • The fishery operates in environments with sandy substrates with limited structures. These characteristics suggest that the impacts of setting and retrieving the gear will be temporary and localised.	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood and Mitigation Measures	Level 1 Risk Rating
			• Further management of risk not required.	
Ecosystem Processes	• The specificity of the fishery/apparatus limits the risk posed to key ecosystem processes. • The fishery has the potential to impact things like recruitment, scavenging and connectivity. • These risks will be more pronounced if there is an overfishing event and be influenced by discarding / post-capture mortalities.	Intermediate	*Likelihood* • Low *Mitigation measures & considerations* • Key risks have been addressed through a fisheries-specific harvest strategy and the preliminary risk rating likely represents a risk overestimate. • The estimate is connected to the potential for stocks to be overfished and the influence of discarding / post-capture mortalities. • Further management of risk not viewed as a priority. However, this ecological component would benefit from additional information on how fishing activities influence regional feeding patterns (*e.g.* depredation, discarding of injured crabs *etc*.).	Low