Sustainable Fisheries Strategy
2017–2027

Crab Fishery Level 2 Ecological Risk Assessment

Productivity & Susceptibility Analysis (PSA)

Queensland Government

Crab Fishery
Level 2 Ecological Risk Assessment

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This publication has been compiled by Fisheries Queensland, Department of Agriculture and Fisheries.

Executive Summary

In May 2019, a whole-of-fishery Level 1 ERA was released for the *Mud and Blue Swimmer (C1) Crab Fishery* (Walton & Jacobsen, 2019). The Level 1 ERA provided a broad risk profile for the Crab Fishery, identifying key drivers of risk and the ecological components most likely to experience an undesirable event. As part of this process, the Level 1 ERA considered both the current fishing environment and what can occur under the current management regime. In doing so, the outputs of the Level 1 ERA helped differentiate between low and high risk elements and establish a framework that can be built on in subsequent ERAs.

In the Level 2 ERA, the focus of the assessment shifts to individual species with risk evaluations based on a *Productivity & Susceptibility Analysis* (PSA). The PSA evaluates risk through an assessment of seven biological attributes (*age at maturity*, *maximum age*, *fecundity*, *maximum size*, *size at maturity*, *reproductive strategy*, and *trophic level*) and up to seven fisheries-specific attributes (*availability*, *encounterability*, *selectivity, post-capture mortality, management strategy, sustainability assessments* and *recreational desirability / other fisheries*). As the PSA can over-estimate risk for some species (Zhou *et al.*, 2016), the Level 2 ERA also included a Residual Risk Analysis (RRA). The RRA gives further consideration to risk mitigation measures that were not explicitly included in the PSA and/or any additional information that may influence the risk status of a species (Australian Fisheries Management Authority, 2017). The primary purpose of the RRA it to minimise the number of 'false positives' or instances where the risk level has been overestimated.

Based on the results of the Level 1 ERA, two ecological components were considered for inclusion in the Level 2 ERA: *Target & Byproduct species* and *Marine turtles* (Walton & Jacobsen, 2019). A review of the catch data and species distributions produced a preliminary list of seven target & byproduct species and six marine turtles. A subsequent species rationalisation process reduced this list to eight: mud crabs (*Scylla serrata*), blue swimmer crabs (*Portunus armatus*) and six marine turtles (green turtle, *Chelonia mydas*; loggerhead turtle, *Caretta caretta*; hawksbill turtle, *Eretmochelys imbricata*; flatback turtle, *Natator depressus*; olive ridley turtle, *Lepidochelys olivacea*; and leatherback turtle, *Dermochelys coriacea*). As the speartooth shark (*Glyphis glyphis*) was the key driver of risk in the shark ecological component (Walton & Jacobsen, 2019), it was also included in the Level 2 ERA.

When the outputs of the PSA and RRA were considered, green turtles, loggerhead turtles and speartooth sharks were all classified as high risk from crab fishing activities. The risk profiles of these species were heavily influenced by the biological attributes (productivity); particularly those relating to their longevity and reproductive outputs. Other factors that increased the risk for these species included an increased encounterability potential and an elevated risk of post-interaction mortalities. The remaining species were all assessed as being at a medium or low risk including the two target species: mud crabs (medium) and blue swimmer crabs (low).

While the results indicate that that crab fishing presents a low to medium risk to the majority of species assessed, the Level 2 ERA did identify a number of areas where risk could be further reduced or mitigated in this fishery. Similarly, the assessment identified a number of factors that could not easily be accounted for in the PSA including black marketing of valuable crab product and the impact of ghost pots on regional marine turtle populations. These confounding factors have the potential to increase the risk for one or more of the species and contributed to a number of the species receiving more conservative risk scores.

Based on the above considerations, the Level 2 ERA provided the following recommendations to assist in the management and mitigation of risk in the Crab Fishery. Of significance, a number of these measures are already being discussed and considered as part of the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017; 2019a).

- Develop management strategies that better regulate catch and effort levels for mud and blue swimmer crabs at a whole-of-fishery, regional and species level.
- Obtain better information on the cumulative (commercial and recreational) fishing pressures including on regional variations in fishing intensities, rates of fishing mortality, discards and unreported catch (*e.g.* cryptic mortalities, illegal fishing).
- Implement strategies to minimise the capture of regulated crab species and help prevent the entrapment of non-target species in active (monitored) pots *e.g.* use of BRDs, escape vents.
- Explore strategies and mechanisms to minimise the incidental capture of marine turtles in ancillary equipment *e.g.* float line entanglements and mortalities.
- Quantify interaction rates and release fates for marine turtles (east coast and Gulf of Carpentaria) across the commercial and recreational fishing sectors.
- Examine fine-scale effort patterns and the extent of the overlap with marine turtle habitats identified as a) critical to the survival of a species and b) biologically important areas, prioritising green and loggerhead turtles.
- Increase the level of information on the prevalence of ghost pots in key areas, their origin and strategies to reduce pot-loss rates across the commercial and recreational fishing sectors.
- Identify avenues to provide a greater synthesis of data on marine turtle interactions collected through the *Species of Conservation Interest* (SOCI) logbooks and ancillary programs *e.g.* StrandNET.
- Improve the level of information on speartooth shark interactions in both the commercial and recreational mud crab fishery in the Gulf of Carpentaria *e.g.* total interaction rates, catch dynamics, release fates and fine-scale effort movements in high value habitat areas.
- Identify mechanisms that will assist in the minimisation of speartooth shark interactions and mortalities in the Gulf of Carpentaria including avenues to improve the effectiveness of spatial/temporal closures and suitability/applicability of bycatch reduction devices.

Summary of the outputs from the Level 2 Ecological Risk Assessment for the Crab Fishery.

Common name	Species	Productivity	Susceptibility	Risk Rating
Mud crab	*Scylla serrata*	1.14	2.43	Medium
Blue swimmer crab	*Portunus armatus*	1.00	2.43	Low
Green turtle	*Chelonia mydas*	2.29	2.25	High
Loggerhead turtle	*Caretta caretta*	2.29	2.25	High
Hawksbill turtle	*Eretmochelys imbricata*	2.29	2.00	Medium
Flatback turtle	*Natator depressus*	2.43	1.50	Precautionary Medium
Olive ridley turtle	*Lepidochelys olivacea*	2.14	1.50	Low
Leatherback turtle	*Dermochelys coriacea*	2.43	1.50	Precautionary Medium
Speartooth shark	*Glyphis glyphis*	3.0	2.00	High

Table of Contents

Definitions & Abbreviations

AFMA	–	Australian Fisheries Management Authority.
BRD	–	Bycatch Reduction Device.
CAAB	–	*Codes for Australian Aquatic Biota.*
CITES	–	*Convention on International Trade in Endangered Species of Wild Fauna and Flora.*
CMS	–	*Convention on the Conservation of Migratory Species of Wild Animals.*
CSIRO	–	*Commonwealth Scientific and Industrial Research Organisation.*
Ecological Component	–	Broader assessment categories that include *Target & Byproduct* (harvested) species, *Bycatch*, *Species of Conservation Concern*, *Marine Habitats* and *Ecosystem Processes.*
Ecological Subcomponent	–	Species, species groupings, marine habitats and categories included within each Ecological Component.
ECTF	–	*East Coast Trawl Fishery*. Blue swimmer crabs are classified as a ‘permitted fish’ in this fishery.
EPBC Act	–	*Environment Protection and Biodiversity Conservation Act 1999.*
ERA	–	Ecological Risk Assessment.
ERAEF	–	*Ecological Risk Assessment for the Effects of Fishing*. A risk assessment strategy established by Hobday *et al*. (2011) and employed by the AFMA.
False ‘positive’	–	The situation where a species at low risk is incorrectly assigned a higher risk rating due to the method being used, data limitations *etc.* In the context of an ERA, ‘false positives’ are preferred over ‘false negatives’.
False ‘negative’	–	The situation where a species at high risk is assigned a lower risk rating. When compared, false negative results are considered to be of more concern as the impacts/consequences can be more significant.
FMP	–	*Fishery Monitoring Program*. This program replaces the *Long Term Monitoring Program*.
FOP	–	*Fisheries Observer Program*. This program ceased in 2009.
PSA	–	*Productivity & Susceptibility Analysis.* One of the two ERA methodologies that can be used as part of the Level 2 assessments.
RRA	–	Residual Risk Analysis.

SAFE	–	*Sustainability Assessment for Fishing Effects*. One of the two ERA methodologies that can be used as part of the Level 2 assessments. This method can be separated into a base SAFE (bSAFE) and enhanced SAFE (eSAFE). The data requirements for eSAFE is higher than for a bSAFE, which aligns more closely to a PSA.
SAFS	–	The National *Status of Australian Fish Stocks*. Refer to www.fish.gov.au for more information.
Species of Conservation Concern (SOCC)	–	Broader risk assessment category used in the Level 1 assessments that incorporates 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.
Species of Conservation Interest (SOCI)	–	A limited number of species subject to mandatory reporting requirements as part of the Queensland logbook reporting system. Any reference to 'SOCI' refers specifically to the SOCI logbook or data compiled from the SOCI logbook.

1 Introduction

Ecological Risk Assessments (ERA) are important tools for sustainable natural resource management and they are being used increasingly in commercial fisheries to monitor long-term risk trends for target and non-target species. In Queensland, ERAs have previously been developed on an as needs basis and these assessments have often employed alternate methodologies. This process is now being formalised as part of the *Queensland Sustainable Fisheries Strategy 2017–2027* (the Strategy) with risk assessments for priority species and fisheries scheduled for completion by the end of 2020 (Department of Agriculture and Fisheries, 2018b). More broadly, ERAs will inform a range of fisheries reforms being undertaken as part of the Strategy including the development of harvest strategies (Department of Agriculture and Fisheries, 2018b; a) and the identification of priority areas for research and monitoring (Department of Agriculture and Fisheries, 2018c).

In May 2019, a whole-of-fishery or Level 1 ERA was released for the Crab Fishery (Walton & Jacobsen, 2019). The Level 1 ERA provided a broad risk profile for the Crab Fishery, identifying key drivers of risk and the ecological components most likely to experience an undesirable event. As part of this process, the Level 1 ERA considered what was occurring in the fishery and what can occur under the current management regime (Walton & Jacobsen, 2019). In doing so, the outputs of the Level 1 ERA helped differentiate between low and high risk elements and established a framework that can be built on in subsequent ERAs.

For the Level 2 ERA, the focus of the analysis shifts to a species-specific level and the scope of the assessment is refined to the current fishing environment. Applying more detailed assessment tools, Level 2 ERAs establish risk profiles for individual species using one of two methods: the semi-quantitative *Productivity & Susceptibility Analysis* (PSA) or the quantitative *Sustainability Assessment for the Effects of Fishing* (SAFE) (Hobday *et al.*, 2007; Zhou & Griffiths, 2008; Department of Agriculture and Fisheries, 2018b). While both methods have been developed for use in data limited fisheries, the use of the PSA or SAFE will be dependent on the species being assessed, the level of information on gear effectiveness, and the distribution of the species in relation to fishing effort (Hobday *et al.*, 2011).

The completion of a Level 2 assessment provides additional depth to the risk profile of the Crab Fishery. With the focus shifting to individual species, the assessment helps differentiate between real and potential risks (Department of Agriculture and Fisheries, 2018b) and identifies avenues where risk could be further reduced or mitigated. The outputs of the assessment will inform the Crab Fishery harvest strategy, bycatch mitigation strategies and strengthens linkages between the ERA process and the remaining areas of reform (Department of Agriculture and Fisheries, 2017).

2 Methods

2.1 The Fishery

The PSA and SAFE are more commonly used to assess risk in commercial fisheries and a large proportion of the Level 2 ERA will concentrate on commercial fishing activities conducted under the Crab Fishery symbol. The defined area for the Crab Fishery includes both the Gulf of Carpentaria and the Queensland east coast (Department of Agriculture and Fisheries, 2019b). This differs from most other commercial fishing symbols where the designated fishing area restricts effort to either the Gulf of Carpentaria or the Queensland east coast. These arrangements are currently being reviewed and alternates including the use of regional management and species-specific quotas are being considered as part of the Strategy (Department of Agriculture and Fisheries, 2019a). As these reforms are still in development, the Level 2 ERA for the Crab Fishery included both the Queensland east coast and the Gulf of Carpentaria.

While C1 operators retain a range of species, the fishery primarily targets mud and blue swimmer crabs using pots and trotlines (Department of Agriculture and Fisheries, 2019b). Operators targeting mud crabs spread their effort over a significant portion of Queensland's coast, including in regional areas such as the eastern coast of the Gulf of Carpentaria and north of Cooktown. Blue swimmer crab effort is more sparsely distributed with operators mainly fishing in waters off of south east Queensland (Department of Agriculture and Fisheries, 2019b). This is reflected in the catch and effort data for the fishery which is dominated by the more marketable mud crabs (Department of Agriculture and Fisheries, 2019b; Walton & Jacobsen, 2019).

While noting the importance of the commercial fishery, both mud and blue swimmer crabs attract a significant level of fishing attention from the recreational fishing sector. Recreational fishers harvest an estimated 346t of mud crabs and 36t of blue swimmer crabs each year (Johnston *et al.*, 2018; Northrop *et al.*, 2019) and the sector makes a notable contribution to the annual rate of fishing mortality. As both commercial and recreational fishers use similar apparatus, this sector also interacts with a similar range of non-target species. Given these factors, the Level 2 ERA considered the impact of this sector on target and non-target species. As the recreational fishery does not have a designated area (excluding spatial closures), the Level 2 ERA incorporated recreational data from across the State (Webley *et al.*, 2015).

Additional information on the C1 fishing boundaries, management regime and catch, effort and licence trends can be found in the Crab Fishery Scoping Study and Level 1 ERA (available: https://www.daf.qld.gov.au/business-priorities/fisheries/monitoring-compliance/data/sustainability-reporting/ecological-risk-assessment).

2.2 Information Sources / Baseline References

Where possible, baseline information on the life history constraints and habitat preferences for each species were obtained from peer-reviewed articles. In the absence of peer-reviewed data, additional information was sourced from grey literature and publicly accessible databases such as *FishBase* (www.fishbase.org), *SeaLifeBase* (www.sealifebase.ca), *Fishes of Australia* (www.fishesofaustralia.net.au), *Seamap Australia* (www.seamapaustralia.org) and the *IUCN Red List of Threatened Species* (www.iucnredlist.org). Additional information including on the distribution of key seabirds, fish and endangered species was obtained through the *Atlas of Living Australia* (www.ala.org.au), *Species Profile and Threats Database* (Department of Environment and Energy, *www.environment.gov.au/cgi-bin/sprat/public/sprat.pl*) and resources associated with the management and regulation of marine national parks *e.g.* the *Great Barrier Reef Marine Park*, *Moreton Bay Marine Park* and *Great Sandy Marine Park.* Where possible regional distribution maps were sourced for direct comparison with effort distribution data (Whiteway, 2009).

Fisheries data used in the Level 2 ERA were obtained through the fisheries logbook program (including *Species of Conservation Interest* or SOCI logbook), a previous *Fisheries Observer Program* (FOP), the *Fishery Monitoring Program* (FMP)[1] and the *Statewide Recreational Fishing Survey*

[1] *The Fishery Monitoring Program was previously known as the Long-Term Monitoring Program (LTMP).*

(Webley *et al.*, 2015). This information was supplemented with data from ancillary sources including from the *Marine Wildlife Stranding and Mortality Database* also referred to as '*StrandNET*' (Department of Environment and Science, www.environment.des.qld.gov.au/wildlife/caring-for-wildlife/marine_strandings.html).

2.3 Species Rationalisation Processes

The scope of the Level 2 (species-specific) ERA was determined by the outcomes of the whole-of-fishery (Level 1) assessment. For the Crab Fishery, the Level 1 ERA recommended that the *Target & Byproduct* species ecological component and *Marine turtles* subcomponent be progressed to a finer scale assessment (Table 1). Fishing related risks for a further three ecological components were progressed through *Queensland Monitoring & Research Plan* (Table 1).

Table 1. *Summary of the outputs from the Level 1 (whole-of-fishery) Ecological Risk Assessment for the Crab Fishery. *Does not include Species of Conservation Concern or Target & Byproduct species returned to the water for any reason.*

Ecological Component	Level 1 Risk Rating	Progression
Target & Byproduct	Intermediate/High	Level 2 ERA (this report)
Bycatch*	Intermediate	*Progressed through the Monitoring & Research Plan.*
Species of Conservation Concern (SOCC)		
Marine turtles	High	Level 2 ERA (this report)
Dugongs	Low	Not progressed further.
Cetaceans	Low	Not progressed further.
Sea snakes	Low	Not progressed further.
Crocodiles	Low	Not progressed further.
Protected teleosts	Low	Not progressed further.
Batoids (non-sawfish)	Low	Not progressed further.
Batoids (sawfish)	Intermediate	*Progressed through the Monitoring & Research Plan.*
Sharks	Low/Intermediate	Speartooth shark progressed to Level 2 ERA
Syngnathids	Negligible	Not progressed further.
Seabirds	Negligible/Low	Not progressed further.
Terrestrial mammals	Low	Not progressed further.
Marine Habitats	Intermediate/High	*Progressed through the Monitoring & Research Plan.*
Ecosystem Processes	Low	Not progressed further.

While the Level 1 ERA assessed the shark ecological subcomponent as a low to intermediate risk (Table 1), the speartooth shark (*Glyphis glyphis*) was singled out as a potentially higher risk species (Walton & Jacobsen, 2019). The speartooth shark is an estuarine species and has a restricted home range encompassing key sections of northern Australia (Department of the Environment, 2019a). The distribution of this species overlaps with the Crab Fishery and evidence suggests that juvenile speartooth sharks are caught in crab pots used in the Gulf of Carpentaria, particularly the Wenlock River (Last & Stevens, 2009; Lyon *et al.*, 2017; Department of Agriculture and Fisheries, 2019b).

As the speartooth shark has conservative life history traits and small population sizes, the species is highly susceptible to overfishing, and risks will be present at even low levels of fishing mortality. For these reasons, the speartooth shark was considered for inclusion in the Crab Fishery Level 2 ERA.

2.3.1 Target Species

A preliminary list of target & byproduct species was compiled using catch data submitted through the logbook monitoring program from 2015–2018 (inclusive). Catch reported against each species or species complex was summed across years and ranked from highest to lowest. Cumulative catch comparisons were then used to identify the species / species complexes that made up 95% of the total catch. Any categories with low species resolution (*e.g.* unspecified crabs) were removed from the analysis and the *Codes for Australian Aquatic Biota* (CAAB; http://www.marine.csiro.au/data/caab/) used to expand multi-species catch categories. A secondary review was then undertaken to remove duplicates, species with low or negligible catches, and species that have limited potential to interact with the fishery.

A full overview of the species rationalisation process for target & byproduct species has been provided in Appendix A and Appendix B.

2.3.2 Species of Conservation Concern

Queensland's list of *Species of Conservation Interest* formed the basis of Level 2 assessments involving threatened, endangered and protected (TEP) species. *Species of Conservation Interest* or SOCI refers specifically to a limited number of non-target species that are subject to mandatory commercial reporting requirements.

For the purposes of this ERA, the SOCI list was expanded though a review of Commonwealth and State legislation (*e.g.* the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), *Fisheries Declaration 2019*, the *Nature Conservation Act 1992*) and international conventions with the potential to influence fishing activities in Queensland *e.g.* the *Convention on the Conservation of Migratory Species of Wild Animals* (CMS) an the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES). This list was then refined through a review of the species' distributions and an initial assessment of their potential to interact with fisheries in Queensland. This review ensured that the baseline of TEP species included in the Level 2 ERA was regionally specific.

For the purpose of this ERA, the above collective of TEP species were referred to as the *Species of Conservation Concern* or SOCC. This classification aligns with the Level 1 ERA (Walton & Jacobsen, 2019) and reflects the fact that the subgroup may include species that can be retained for sale in Queensland or species afforded additional protections under State and Commonwealth legislation. As the SOCC list will include species with limited potential to interact with the Crab Fishery, a final review was undertaken to ensure that the baseline of TEP species were relevant to the fishery. A full account of the species rationalisation process for the SOCC has been provided in Appendix A and Appendix B.

2.4 Ecological Risk Assessment Methodology

Level 2 ERA methodology aligns closely with the *Ecological Risk Assessment for the Effects of Fishing* (ERAEF) and includes two assessment options: the PSA and SAFE (Zhou & Griffiths, 2008; Hobday *et al.*, 2011; Australian Fisheries Management Authority, 2017). Data inputs for the two methods are similar and both were designed to assess fishing-related risks for data-poor species (Zhou *et al.*, 2016). Similarly, both methods include precautionary elements that help limit the potential for false negatives *i.e.* 'high risk' species being incorrectly assigned a lower risk rating. However, research has shown that the PSA tends to be more conservative and has a higher potential to produce 'false positives' *i.e.* low risk species that are assigned a higher risk rating due to the conservative nature of the method, data deficiencies *etc.* (Hobday *et al.*, 2007; Hobday *et al.*, 2011; Zhou *et al.*, 2016).

Data inputs for the PSA and SAFE are similar; although the two methods examine risk differently. In the PSA, the level of risk (low, medium or high) is defined through a finer scale assessment of the life-history constraints of the species (*Productivity*), the potential for the species to interact with the fishery and the associated consequences (*Susceptibility*). In contrast, the SAFE method quantifies risk by comparing the rate of fishing mortality against key reference points including the level of fishing mortality associated with *Maximum Sustainable Fishing Mortality* (F_{msm}), the point where biomass is assumed to be half that required to support a maximum sustainable fishing mortality (F_{lim}) and fishing mortality rates that, in theory, will lead to population extinction in the long term (F_{crash}) (Zhou & Griffiths, 2008; Zhou *et al.*, 2011; Zhou *et al.*, 2016). As SAFE is a quantitative assessment, the method provides an absolute or numerical measure of risk or a continuum of values that can be compared directly to the above reference points. This contrasts with the PSA which provides an indicative measure (low, medium, high) of the potential risk (Hobday *et al.*, 2007).

While research has shown that SAFE produces fewer false-positives, it requires a sound understanding of the fishing intensity and the degree of overlap between a species' distribution and fishing effort (Zhou *et al.*, 2009; Hobday *et al.*, 2011). These requirements mean that SAFE may not be suitable for species with insufficient data; typically protected species (*e.g.* especially mammals, reptiles and seabirds) and marine invertebrates (Australian Fisheries Management Authority, 2017). The method also requires a sound understanding of the 'gear affected area' (Zhou & Griffiths, 2008) or the proportion of the fished area that a species resides in that is impacted on by the apparatus (Zhou *et al.*, 2014; Zhou *et al.*, 2019).

In the Crab Fishery, determining the gear affected area can be difficult as it will depend on a range of factors including the number of pots that are deployed, the way in which the pots are set (*i.e.* individually or on a trotline), the distance between pots and the frequency with which they are checked. As commercial fishers are only required to submit information on the number of pots used and the total number of lifts, there is limited information on crab pot configurations, fishing densities and the distribution of fishing effort. These deficiencies are significant as the gear affected area for ten pots set in close proximity will be vastly different to a string of ten pots dispersed along the coast line. These issues are compounded by the fact that the gear affected area will be influenced by other environmental factors including the distance over which a species may be attracted to the bait or the type of bait used (*pers. comm.* Z. Zhou; Zhou *et al.*, 2014).

In addition to the gear affected area, both mud and blue swimmer crabs are targeted by recreational fishers and this sector will contribute to the overall level of risk. The SAFE method was developed for use in commercial fisheries and the method has yet to evolve to a point where it can accurately account for recreational fishing pressures. In Queensland, the majority of information from this sector is obtained through the voluntary localised collection of data (*e.g.* the boat ramp survey program, the Fisheries Monitoring Program) and a more expansive voluntary recreational fisher survey (Webley *et al.*, 2015). However, these measures are limited and the data for some species has poor resolution due to lack of sampling power. Similarly, there is limited data on the total number of pots used in this sector, fishing frequency and intensity. This makes it difficult to construct and overall estimate the total effort and/or include recreational data in a SAFE.

Given the importance of the ‘gear affected area’ to SAFE and the methodology limitations with respect to a) assessing risk for key species groups and b) accounting for recreational fishing mortality, the PSA was adopted for the Crab Fishery Level 2 assessment. While the use of a PSA increases the potential for false positives, previous ERAs have successfully modified this method to account for recreational fishing (Patrick *et al.*, 2010; Furlong-Estrada *et al.*, 2017). To this extent, it was considered to be the best method to assess the collective risk in this fishery.

2.4.1 Productivity & Susceptibility Analysis (PSA)

The PSA was largely aligned with the ERAEF approach employed for Commonwealth fisheries (Hobday *et al.*, 2011; Australian Fisheries Management Authority, 2017). As a detailed overview of the methodology and the key assumptions are provided in Hobday *et al*. (2007), only an abridged version will be provided here.

The *Productivity* component of the PSA examines the life-history constraints of a species and the potential for an attribute to contribute to the overall level of risk. These attributes are based on the biology of the species and include the *size and age at sexual maturity*, *maximum size and age*, *fecundity*, *reproductive strateg*y and *trophic level* (Table 2). Productivity attributes used in the Level 2 assessment were consistent with the ERAEF (Hobday *et al.*, 2011) and were applied across all ecological components subject to a PSA. Criteria used to assign each attribute a score of low (1), medium (2) or high (3) risk are outlined in Table 2.

Table 2. *Scoring criteria and cut-off scores for the productivity component of the PSA undertaken as part of the Level 2 ERA. Attributes and the corresponding scores/criteria align with national (ERAEF) approach (Hobday et al., 2011).*

Attribute	**High Productivity (low risk, score = 1)**	**Medium Productivity (medium risk, score = 2)**	**Low Productivity (high risk, score = 3)**
Age at maturity*	<5 years	5–15 years	>15 years
Maximum age*	<10 years	10–25 years	>25 years
Fecundity**	>20,000 eggs per year	100–20,000 eggs per year	<100 eggs per year
Maximum size*	<100cm	100–300cm	>300cm
Size at maturity*	<40cm	40–200cm	>200cm
Reproductive strategy	Broadcast spawner	Demersal egg layer	Live bearer (& birds)
Trophic Level	<2.75	2.75–3.25	>3.25

** Where only ranges for species attributes were provided and/or ranges differed between sexes, the most precautionary measure was used. **Fecundity for broadcast spawners was assumed to be >20,000 eggs per year (Miller & Kendall, 2009).*

For the *Susceptibility* component of the PSA, ERAEF attributes were used as the baseline of the assessment and included *availability*, *encounterability*, *selectivity* and *post-capture mortality* (Hobday *et al.*, 2007; Hobday *et al.*, 2011). The following provides an overview of the susceptibility attributes used in the PSA with Table 3 detailing the criteria used to assign scores for this part of the analysis.

- **Availability**—Where possible, *availability* scores were based on the overlap between fishing effort and the portion of the species range that occurs within the broader geographical spread of the fishery. To account for inter-annual variability, percentage overlaps were calculated for three years (2016, 2017 and 2018) and the highest value used as the basis of the *availability* assessment. Regional distribution maps were sourced from the *Atlas of Living Australia*, the *Species Profile and Threats Database* (Department of Environment and Energy, www.environment.gov.au/cgi-bin/sprat/public/sprat.pl), the *Commonwealth Scientific and Industrial Research Organisation* (CSIRO) and, where possible, refined using bathymetry and topographical data (Whiteway, 2009). In instances where a species did not have a distribution map, *availability* scores were based on a broader geographic distribution assessment (global, southern hemisphere, Australian endemic) described in Hobday *et al.* (2007) (Table 3). A full summary of the overlap percentages used to assess *availability* has been provided in Appendix C.

- **Encounterability**—*Encounterability* considers the likelihood that a species will encounter the fishing gear when it is deployed within the known geographical range (Hobday *et al.*, 2007). The *encounterability* assessment is based on the behaviour of the species as an adult and takes into consideration information on the preferred habitats and bathymetric ranges. For the PSA, both parameters (*i.e.* adult habitat overlap and bathymetric range overlap) are assigned an individual risk score with the highest value used as the basis of the *encounterability* assessment. The notable exceptions to this are air breathing species which, under the ERAEF framework, are assigned the highest risk rating due to their need to access the surface and their potential to interact with the gear during the deployment and retrieval process (Hobday *et al.*, 2007).

- **Selectivity**—*Selectivity* is effectively a measure of the likelihood that a species will get caught in the apparatus. Factors that will influence *selectivity* include the fishing method, the apparatus used and the body size/morphology of the species in relation to the gear size (*e.g.* mesh size, trap opening). For the purpose of the Crab Fishery, *selectivity* scores were based on the likelihood that the animal will actively interact with the apparatus (*e.g.* access bait, product) and become partly or wholly entrapped within the pot.

- **Post-capture mortality**—*Post-capture mortality* is one of the more difficult attributes to assess; particularly for non-target species. For the majority of target & byproduct species that fall within the prescribed regulations, survival rates are considered to be zero as they will (most likely) be retained for sale. Survival rates for the remainder of the species will vary, may be subject to data limitations and may require further qualitative input or expert opinion.

In addition to the four baseline attributes, the Level 2 ERA included three additional susceptibility attributes for target & byproduct species: *management strategy*, *sustainability assessments* and *recreational desirability / other fisheries*. These attributes were included in the assessment to address risks associated with other fishing sectors (*e.g.* recreational and charter fisheries) and management limitations for key species (*e.g.* an absence of effective controls on catch or effort). While the additional attributes are not included in the ERAEF, variations of all three have been used in risk assessments involving species experiencing similar fishing pressures (Patrick *et al.*, 2010; Furlong-Estrada *et al.*, 2017). In the Level 2 ERA, they will be used to further reduce the influence of false positives or risk overestimations for key species.

Table 3. *Scoring criteria and cut-off scores for the susceptibility component of the PSA. Attributes and the corresponding scores/criteria are largely aligned with ERAEF approach (Hobday et al., 2011).*

Attribute	**Low Susceptibility (low risk, score = 1)**	**Medium Susceptibility (medium risk, score = 2)**	**High Susceptibility (high risk, score = 3)**
Availability			
Option 1 – Overlap of species range with fishing effort.	<10% overlap.	10–30% overlap.	>30% overlap.
Option 2 – Global distribution & stock proxy considerations.	Globally distributed.	Restricted to same hemisphere / ocean basin as fishery.	Restricted to same country as fishery.
Encounterability			
*Option 1. Habitat type**	Low overlap with fishery area.	Medium overlap with fishery area.	High overlap with fishery area.
*Option 2. Depth check**	Low overlap with fishery area.	Medium overlap with fishery area.	High overlap with fishery area.
Selectivity	Low susceptibility to gear selectivity.	Moderate susceptibility to gear selectivity.	High susceptibility to gear selectivity.
Post-capture mortality**	Evidence of post-capture release and survival.	Released alive with uncertain survivability.	Retained species, majority dead when released, interaction likely to result in death or life-threatening injuries.
Management strategy	Species-specific management of catch or effort (*e.g.* TACC limits) based on biomass estimates/reference points. Management regime able to actively address emerging issues within the current framework.	Catch or effort restricted in some capacity (*e.g.* species-specific TACC limits or analogous arrangements), restrictions not based on biomass estimates or reference points. Limited capacity to address emerging catch and effort trends without legislative amendments or reforms.	Harvested species do not have species-specific catch limits or robust input & output controls. Management regime based at the whole-of-fishery level.
Sustainability assessments	Sustainability confirmed through stock assessments / biomass estimates.	Sustainability confirmed through indicative sustainability assessments & weight of evidence approach *e.g.* national SAFS.	Not assessed, biomass depleted, declining or not conducive to meeting 2020 SFS targets.
Recreational desirability / other fisheries	<33% retention.	33–66% retention.	>66% retention.

**Scores vary by fishery. **The criteria for selectivity and post-capture mortality were broadened to account for variability across fisheries (i.e. net, pot, line).*

In the Crab Fishery Level 2 ERA, the three additional attributes considered the following.

- **Management strategy**—Considers the suitability of the current management arrangements including the ability to manage risk through time *e.g.* the presence of an effective control on total catch or effort (if appropriate), regional management, biomass estimates that are directly linked to species-specific TACCs *etc*. This attribute was considered to be of particular relevance to multi-species fisheries where the management regime often lacks species-specific control measures and for species where the risk has been reduced through (*e.g.*) the use of quotas based on biological reference points like Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY).

- **Sustainability assessments**—The *sustainability assessment* attribute is directly linked to the level of information that is available on the stock structure and status of harvested species. Species where sustainability status has been confirmed through stock assessments or the national *Status of Australian Fish Stocks* (SAFS) will be assigned a lower risk scores. Conversely, species that are being fished above key biomass reference points (*e.g.* MSY), have been assessed as depleting, overfished, or recovering in the most recent SAFS assessment and/or have no assessment will be assigned more precautionary risk scores.

- **Recreational desirability / other fisheries**—Specifically included in the PSA to account for the risk posed by other sectors of the fishery (*e.g.* recreational and charter fisheries) or other commercial fisheries that can retain the species for sale. The preliminary risk assessment focuses on retention rates according to recreational fishing surveys, with higher risks associated with species more frequently retained than released. Further consideration of the impacts of other sectors and fisheries will also be considered as part of the *Residual Risk Assessment* (RRA). In the Crab Fishery this will include the retention of blue swimmer crabs in the *East Coast Otter Trawl Fishery* (Department of Agriculture and Fisheries, 2019b; Walton & Jacobsen, 2019).

The three additional susceptibility attributes were only applied to retainable product and therefore were not include in assessments involving most of the SOCC subgroups.

2.4.2 PSA Scoring

Each attribute was assigned a score of 1 (low risk), 2 (medium risk) or 3 (high risk) based on the criteria outlined in Table 2 and Table 3 (Patrick *et al.*, 2010; Hobday *et al.*, 2011; Brown *et al.*, 2013). In instances where an attribute has no available data and in the absence of credible information to the contrary, a default rating of high risk (3) was used (Hobday *et al.*, 2011). This approach introduces a precautionary element into the PSA and helps minimise the potential occurrence of 'false negative' assessments. The inherent trade off with this approach is that the outputs of the Level 2 ERA can be conservative and may include a number of 'false positives' (Zhou *et al.*, 2016). Issues associated with 'false positives' or the overestimation of risk will be examined further as part of RRA.

Risk ratings (R) were based on a two-dimensional graphical representation of the productivity (x-axis) and susceptibility (y-axis) scores (Fig. 1). Cross-referencing of the productivity and susceptibility scores provides each species with a graphical location that can be used to calculate the Euclidean distance or the distance between the species reference point and the origin (*i.e.* 0, 0 on Fig. 1). This distance is calculated using the formula $R = ((P - X_0)^2 + (S - Y_0)^2)^{1/2}$ where P represents the productivity score, S represents the susceptibility score and X_0 and Y_0 are the respective x and y origin coordinates (Brown *et al.*, 2013). The further a species is away from the origin the more at risk it is considered to be. For the purpose of this ERA, cut offs for each risk category were aligned with previous assessments with scores below 2.64 classified as low risk, scores between 2.64 and 3.18 as medium risk and scores >3.18 classified as high risk (Hobday *et al.*, 2007; Brown *et al.*, 2013; Zhou *et al.*, 2016).

As the PSA includes an *'uncertainty'* assessment and RRA (refer to section *2.4.3 Uncertainty* and *2.4.4 Residual risk*), the initial risk ratings may be subject to change. To this extent, scores assigned as part of the PSA analysis can be viewed as a measure of the potential for risk each species may experience (Hobday *et al.*, 2007) with the final risk scores determined on the completion of the RRA.

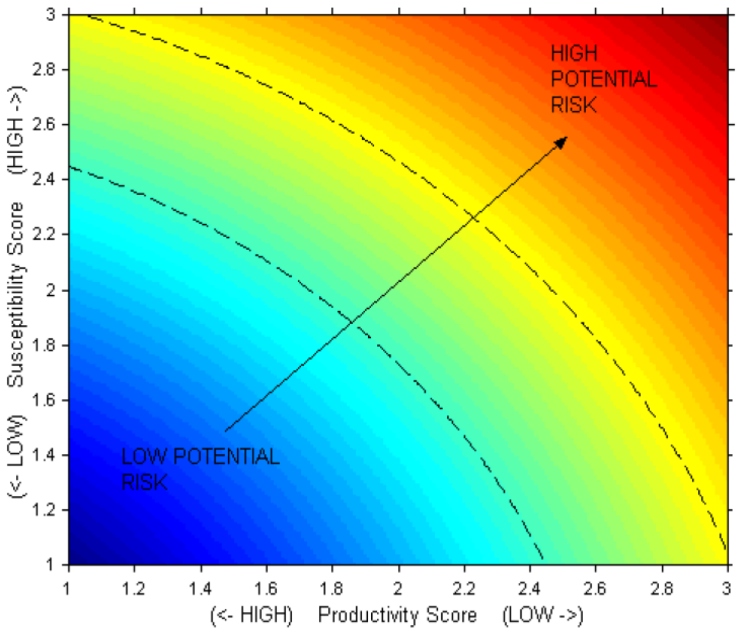

Figure 1. *PSA plot demonstrating the two-dimensional space which species units are plotted. PSA scores for species units represent the Euclidean distance or the distance between the origin and the productivity (x axis), susceptibility (y axis) intercept (excerpt from Hobday. et al., 2007).*

2.4.3 Uncertainty

A number of factors including imprecise or missing data and the use of averages or proxies can contribute to the level of uncertainty surrounding the PSA. Examples of which include the use of a default 'high score' for attributes missing data and the use of values based at a higher taxon (*i.e.* genera or family level; (Hobday *et al.*, 2011). In the Level 2 ERA uncertainty is examined through a baseline assessment of each risk profile to determine the proportion of attributes assigned a precautionary high risk rating due to data deficiencies. As species with greater data deficiencies are more likely to attract the default 'high risk' rating, their profiles are more likely to fall on the conservative side of the spectrum. In these instances, it may be more appropriate to address these risks and data deficiencies through measures like the *Queensland Sustainable Fisheries Strategy—Monitoring & Research Plan* (Department of Agriculture and Fisheries, 2018c).

2.4.4 Residual Risk

Precautionary elements in the PSA combined with an undervaluation of some management arrangements can result in more conservative risk assessments and a higher number of false positives. Similarly, the effectiveness of some attributes may be exaggerated and subsequent risks could be underestimated (false negatives). To address these issues, PSA results were subject to an additional residual risk analysis (RRA). The RRA gives further consideration to risk mitigation measures that were not explicitly included in the attributes and any additional information that may influence the risk status of a species (Australian Fisheries Management Authority, 2017). In doing so, the RRA provides management with greater capacity to differentiate between potential and actual risks (Department of Agriculture and Fisheries, 2018b) and helps refine risk management strategies.

The RRA framework was based on guidelines established by CSIRO and the *Australian Fisheries Management Authority* (AFMA) (Australian Fisheries Management Authority, 2018a). These guidelines identify six avenues where additional information may be given further consideration as part of a Level 2 assessment. Given regional nuances and data variability, a degree of flexibility was required with respect to how the RRA guidelines were applied to commercial fisheries in Queensland and the justifications used. The RRA was also expanded to include a seventh guideline titled '*Additional Scientific Assessment & Consultation'*. While a version of this guideline has been used in previous risk assessments involving Commonwealth Fisheries, it has since been removed as part of a broader RRA procedural review (Australian Fisheries Management Authority, 2018a). In Queensland, this guideline was retained as the broader ERA framework include a series of consultation steps that aid in the development and finalisation of both the whole-of-fishery (Level 1) and species-specific ERAs (Department of Agriculture and Fisheries, 2018h).

In instances where the RRA resulted in an amendment to the preliminary score, full justifications were provided (Appendix D) including the guidelines in which the amendments were considered. A brief summary of each guideline and the RRA considerations is provided in Table 4.

Table 4. *Guidelines used to assess residual risk including a brief overview of factors taken into consideration.*

Guidelines	Summary
Guideline 1*: Risk rating due to missing, incorrect or out of date information.*	Considers if susceptibility and/or productivity attribute data for a species is missing or incorrect for the fishery assessment, and is correct using data from a trusted source or another fishery.
Guideline 2*: Additional Scientific assessment & consultation.*	Considers any additional scientific assessments on the biology or distribution of the species and the impact of the fishery. This may include verifiable accounts and data raised through key consultative processes including but not limited to targeted consultation with key experts and oversite committees established as part of the *Sustainable Fisheries Strategy 2017–2027 e.g. Fisheries Working Groups* and the *Sustainable Fisheries Expert Panel*.
Guideline 3*: At risk with spatial assumptions.*	Provides further consideration to the spatial distribution data, habitat data and any assumptions underpinning the assessment.
Guideline 4*: At risk in regards to level of interaction/capture with a zero or negligible level of susceptibility.*	Considers observer or expert information to better calculate susceptibility for those species known to have a low likelihood or no record of interaction nor capture with the fishery.
Guideline 5*: Effort and catch management arrangements for target & byproduct species.*	Considers current management arrangements based on effort and catch limits set using a scientific assessment for key species.
Guideline 6*: Management arrangements to mitigate against the level of bycatch.*	Considers management arrangement in place that mitigate against bycatch by the use of gear modifications, mitigation devices and catch limits.

Guidelines	Summary
***Guideline 7**: Management arrangements relating to seasonal, spatial and depth closures.*	Considers management arrangements based on seasonal, spatial and/or depth closures.

2.5 Consultation & Review

The ERA framework has a number of feedback loops that help refine the scope of the assessment and the accuracy of the preliminary risk ratings. This feedback may include direct consultation with *Fisheries Working Groups*, targeted consultation with key stakeholders, obtaining additional information from members of the scientific community, and through the *Sustainable Fisheries Expert Panel.* This consultation will be done in accordance with the *Queensland Ecological Risk Assessment Guidelines* (Department of Agriculture and Fisheries, 2018b).

3 Results

3.1 Target & Byproduct Species

A review of the catch and effort data produced a preliminary list of seven target & byproduct species (Appendix B). Of those seven species, mud crabs (*Scylla serrata*) and blue swimmer crabs (*Portunus armatus*) accounted for the vast majority of the commercial catch and effort. This was to be expected given that the species are actively targeted by commercial (C1) crab operations. While the keeled mud crab (*S. paramamosain*), olive mud crab (*S. olivacea*), three-spotted crab (*P. sanguinolentus*), coral crab (*C. feriata*) and the hairyback crab (*C. natator*) are all classified as byproduct, they are not actively targeted by C1 fishers, have a lower probability of interacting with the fishery and/or are low value species with limited retention rates (annual combined catch = <5t for the 2016–2018 period) (Department of Agriculture and Fisheries, 2019b; 2020). The cumulative fishing pressures for these species will also be lower when compared to mud and blue swimmer crabs. Based on these factors, the five byproduct species were omitted from the PSA (Appendix B).

In the PSA, mud and blue swimmer crabs were assigned identical scores for all but one of the productivity attributes (Table 5). As mud crabs occupy a higher trophic level (T_L), the species received a higher risk score for this attribute; mud crabs = 3.17 T_L, blue swimmer crab = 2.48 T_L (Hill, 1979; de Lestang *et al.*, 2000) This difference was reflected in the productivity assessment with mud crabs registering a marginally higher score (1.14) when compared to the blue swimmer crab (1.00) (Table 5).

The susceptibility analysis for both species were identical with mud and blue swimmer crabs assigned the highest risk score for the majority of the attributes. As both species had a stock assessment (Sumpton *et al.*, 2015; Northrop *et al.*, 2019) and positive SAFS evaluations (Grubert *et al.*, 2018; Johnston *et al.*, 2018) they received lower risk scores for the *sustainability assessment* attribute (Table 5). Similarly, both species were assigned a lower risk rating for *recreational desirability* as the Queensland *Statewide Recreational Fishing Survey* indicates that they have relatively low rates of retention (<33%) (Webley *et al.*, 2015). When all of the attributes were taken into consideration, both target species had an average susceptibility score of 2.43 (Table 5).

When the productivity and susceptibility scores were considered, mud and blue swimmer crabs were assigned preliminary risk scores of 2.68 and 2.63 respectively. Based on the prescribed assessment criteria, mud crabs fall within the medium risk range and blue swimmer crabs the low risk range (Table 5; Fig. 1).

3.2 SOCC—Marine Turtles

Six marine turtle species are found in Queensland waters and their distributions have notable overlaps with the Crab Fishery. Data contained within the *Wildlife Stranding and Mortality Database* includes confirmed crab pot interactions and mortalities for at least four turtle species: the green turtle (*Chelonia mydas*), loggerhead turtle (*Caretta caretta*), hawksbill turtle (*Eretmochelys imbricata*) and olive ridley turtle (*Lepidochelys olivacea*) (Biddle *et al.*, 2011; Meager & Limpus, 2012)[2]. While there is no data on crab pot interactions with the flatback (*Natator depressus*) and leatherback turtle (*Dermochelys coriacea*), there is some potential for these species to interact with the Crab Fishery. Given the above considerations, all six marine turtle species were included in the Level 2 ERA (Appendix B).

All species were assigned the highest risk score for *size at maturity*, *age at maturity* and *fecundity* (Table 5). Of the remaining attributes, *maximum size* was considered to be a risk limiting factor for most of the species with *trophic level* displaying the highest degree of interspecific variability. When all attributes were taken into consideration, productivity scores for marine turtles ranged from 2.29–2.57 (Table 5). *Encounterability* and *post-capture mortality* were two susceptibility attributes that scored high for all six marine turtle species. Similarly, *availability* and *selectivity* were scored low for all species. As a result, all six species had identical average susceptibility scores of 2.0 (Table 5).

When the productivity and susceptibility scores were taken into consideration, marine turtles recorded PSA scores from 3.04 to 3.26 (Table 5). Based on the scoring criteria, one species fell within the high risk category (leatherback turtle) with the remaining five species found to be at medium risk.

3.3 SOCC—Speartooth Shark

The speartooth shark was assigned the highest risk score for all seven productivity traits. Of the criteria used, only *maximum size* and *reproductive strategy* had sufficient information to assign a score based on the prescribed criteria (Table 5). The remaining productivity attributes (*age at maturity, maximum age, fecundity, size at maturity* and *trophic level*) were assigned precautionary scores due to data deficiencies. This resulted in the speartooth shark receiving the maximum average score for the productivity component of the PSA (3.00) (Table 5).

Scores assigned to the susceptibility attributes were identical to marine turtles for *encounterability* (3), and *post-capture mortality* (3). Given this significant overlap between the distribution of the speartooth shark and crab fishing effort, particularly in the Gulf of Carpentaria, the species was assigned the highest score for the *availability* attribute (3) (Table 5) (Pillans *et al.*, 2008; Department of Agriculture and Fisheries, 2019b). While pots are less selective for larger animals, anecdotal and experimental evidence (*R. Pillans, unpub. data*) shows that neonate and juveniles are more susceptible to capture in a crab pot apparatus. Due to this susceptibility, the *selectivity* attribute received a higher risk score.

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[2] Marine Wildlife Stranding and Mortality Database provides little insight into the origins of the apparatus, the legality of the pots, and does not attribute marine turtle deaths to a particular sector (commercial/recreational) or fishery (e.g. Spanner Crab Fishery, Crab Fishery, illegal operations).

Table 5. **Preliminary risk ratings** compiled as part of the Productivity & Susceptibility Analysis (PSA) including scores assigned to each attribute used in the assessment. Risk ratings are solely based on criteria outlined in Table 2 and Table 3 and have not been subject to a Residual Risk Analysis. * *Denotes an attribute that was assigned a precautionary score in the preliminary assessment due to an absence of species-specific data.*

Common name	**Species name**	Age at maturity	Maximum age	Fecundity	Maximum size	Size at sexual maturity	Reproductive strategy	Trophic level	**Productivity**	Availability	Encounterability	Selectivity	Post-capture mortality	Management strategy	Sustainability assessments	Recreational desirability / other fisheries	**Susceptibility**	***PSA score***
Mud crab	*Scylla serrata*	1	1	1	1	1	1	2	**1.14**	3	3	3	3	3	1	1	**2.43**	**2.68**
Blue swimmer crab	*Portunus armatus*	1	1	1	1	1	1	1	**1.00**	3	3	3	3	3	1	1	**2.43**	**2.63**
Green turtle	*Chelonia mydas*	3	3	3	2	2	2	1	**2.29**	1	3	1	3	n/a	n/a	n/a	**2.00**	**3.04**
Loggerhead turtle	*Caretta caretta*	3	3	3	1	2	2	3	**2.43**	1	3	1	3	n/a	n/a	n/a	**2.00**	**3.15**
Hawksbill turtle	*Eretmochelys imbricata*	3	3	3	1	2	2	2	**2.29**	1	3	1	3	n/a	n/a	n/a	**2.00**	**3.04**
Flatback turtle	*Natator depressus*	3	3	3	1	2	2	3	**2.43**	1	3	1	3	n/a	n/a	n/a	**2.00**	**3.15**
Olive Ridley turtle	*Lepidochelys olivacea*	2	3	3	1	2	2	3	**2.29**	1	3	1	3	n/a	n/a	n/a	**2.00**	**3.04**
Leatherback turtle	*Dermochelys coriacea*	3	3	3	2	2	2	3	**2.57**	1	3	1	3	n/a	n/a	n/a	**2.00**	**3.26**
Speartooth shark	*Glyphis glyphis*	3*	3*	3*	3	3*	3	3*	**3.00**	1	3	2	3	n/a	n/a	n/a	**2.25**	**3.75**

When the productivity and susceptibility scores were taken into consideration, speartooth shark was found to have a PSA score of 3.75; placing it well within the high risk category (Table 5).

3.4 Uncertainty

Scores assigned in the PSA attributes for mud crabs (*n* = 14 attributes), blue swimmer crabs (*n* = 14 attributes) and marine turtles (*n* = 11 attributes) were supported by data on the biology of the species and their potential to interact with the fishery (Table 6). However, the speartooth shark has a number of information gaps which resulted in five *productivity* attributes being assigned precautionary high (3) scores assessment*: age at maturity, maximum age, fecundity, size at maturity* and *trophic level*. As such, these attributes were assigned precautionary high scores for the preliminary assessment.

3.5 Residual Risk Analysis

The following provides a brief overview of the key changes that were adopted as part of the RRA (Table 6). A full overview of the RRA including the key considerations for each species has been provided in Appendix D.

3.5.1 Target & Byproduct Species

No changes were applied to the productivity scores for mud and blue swimmer crabs as part of the RRA. However, scores assigned to *post-capture mortality* (susceptibility) were reduced for both species. These reductions can be attributed to a) mud and blue swimmer crabs having higher within pot survival rates and b) the improved capacity of fishers to differentiate between retainable and non-retainable product (Appendix D).

At the other end of the spectrum, the *recreational desirability / other fisheries* (susceptibility) attribute was increased from low (1) to medium (2) to account for unreported catch and its potential to impact regional stocks (*e.g.* recreational fishing data limitations, black marketing, non-reported catch from other commercial fisheries including discards). As these changes were counterbalanced, the susceptibility component of the mud and blue swimmer crab PSA remained the same (Table 5–6; Appendix D).

As the RRA did not result in a net change in either the productivity or susceptibility component of the PSA score, risk ratings for mud crabs (medium) and blue swimmer crabs (low) remained the same (Table 6).

3.5.2 Marine Turtles

Productivity scores for two of the marine turtle species were reduced as a result of the RRA: olive ridley turtle, 2.24 down to 2.14, and the leatherback turtle, 2.57 down to 2.43 (Table 5; Table 6). The downgrading of these scores was based on an expert review of available data on marine turtle fecundities and how it was assessed under the PSA criteria (Table 2; Appendix D). While amendments were also made to the loggerhead turtle productivity assessment, this did not alter the final score (Table 6; Appendix D). Productivity scores for three remaining marine turtle species were not altered as part of the RRA.

Table 6. **Residual Risk Analysis** (RRA) of the scores assigned to each attribute as part of the Productivity & Susceptibility Analysis (PSA). Attribute scores highlighted in blue represent those that were amended as part of the RRA.

Common name	**Species name**	Age at maturity	Maximum age	Fecundity	Maximum size	Size at sexual maturity	Reproductive strategy	Trophic level	**Productivity**	Availability	Encounterability	Selectivity	Post-capture mortality	Management Strategy	Sustainability assessments	Recreational desirability / other fisheries	**Susceptibility**	***PSA score***
Mud crab	*Scylla serrata*	1	1	1	1	1	1	2	**1.14**	3	3	3	2	3	1	2	**2.43**	**2.68**
Blue swimmer crab	*Portunus armatus*	1	1	1	1	1	1	1	**1.00**	3	3	3	2	3	1	2	**2.43**	**2.63**
Green turtle	*Chelonia mydas*	3	3	3	2	2	2	1	**2.29**	1	3	2	3	n/a	n/a	n/a	**2.25**	**3.21**
Loggerhead turtle	*Caretta caretta*	3	3	2	2	2	2	3	**2.43**	1	3	3	3	n/a	n/a	n/a	**2.50**	**3.49**
Hawksbill turtle	*Eretmochelys imbricata*	3	3	3	1	2	2	2	**2.29**	1	3	1	3	n/a	n/a	n/a	**2.00**	**3.04**
Flatback turtle	*Natator depressus*	3	3	3	1	2	2	3	**2.43**	1	1	1	3	n/a	n/a	n/a	**1.50**	**2.85**
Olive Ridley turtle	*Lepidochelys olivacea*	2	3	2	1	2	2	3	**2.14**	1	1	1	3	n/a	n/a	n/a	**1.50**	**2.62**
Leatherback turtle	*Dermochelys coriacea*	3	3	2	2	2	2	3	**2.43**	1	1	1	3	n/a	n/a	n/a	**1.50**	**2.85**
Speartooth shark	*Glyphis glyphis*	2	3	3	3	3	3	3	**2.86**	1	3	2	3	n/a	n/a	n/a	**2.25**	**3.64**

The RRA of the susceptibility component of the PSA resulted in five changes being made across two attributes*: encounterability* and *selectivity* (Table 6). Research indicates that flatback, olive ridley and leatherback turtles prefer deeper waters (relative to mud and blue swimmer crab fishing areas) and these species are less likely to be encountered in the Crab Fishery (Department of the Environment, 2019h; g; f). Accordingly, scores assigned to the *encounterability* attribute were reduced from a 3 to a 2 (Table 5, Table 6).

For the *selectivity* attribute, green and loggerhead turtles were increased from low (1) to medium (2) and low (1) to high (3) respectively. For loggerhead turtles, this change recognises the fact that this species has a broader diet and is more likely to interact with a crab pot *e.g.* trying to access the bait or invertebrates trapped in the pots (*pers. comm.* C. Limpus; Appendix D). For green turtles, this increase is due to the prevalence of the species in fisheries independent data on marine turtle – crab pot interactions and mortalities (Appendix D). This data demonstrates that the species is more susceptible to capture in the crab pot apparatus including in the float lines. As a result of these changes, susceptibility scores for the flatback, olive ridley, and leatherback turtles were reduced with the green and loggerhead turtles registering higher susceptibility scores (Table 5; Table 6).

On the basis of the RRA, overall risk scores assigned to five of the marine turtle species were amended. For one of the species, the flatback turtle, the amended scores did not alter their level of risk. However, the risk classification for leatherback and olive ridley turtles was reduced from high to medium and medium to low respectively. Conversely, risk ratings for green and loggerhead turtles increased their overall classification from medium to high risk (Table 6).

3.5.3 Speartooth Shark

The RRA resulted in a single amendment being made to the preliminary risk profile for the speartooth shark. In the PSA, the *age at maturity* attribute was assigned a precautionary high (3) risk rating due to data deficiencies. This score was downgraded to medium (2) on the back of further scientific advice (Appendix D).

While proxies can be used as part of the RRA to overcome data deficiencies, this was more difficult for the speartooth shark. The species has few close relatives and biological information for the family (as a whole) is limited (Last & Stevens, 2009; Last *et al.*, 2010; Li *et al.*, 2015; White *et al.*, 2017). The use of proxies from other genera was considered as a part of the RRA including from species within the *Family Carcharinidae* family. However, this family is extensive (approx. 60 species) and research has shown that the biology of these species varies between and within genera (Last & Stevens, 2009; Frick *et al.*, 2019). Given the lack of suitable proxy values and to avoid 'false negatives' in the assessment, speartooth shark retained its precautionary high scores for the remainder of the unknown productivity traits.

The change in score for the *age at maturity* reduced the *productivity* score from 3.00 to 2.86. This reduction was not sufficient to reduce the overall risk rating below 'high' (Table 6).

4 Risk Evaluation

When the results of the PSA and the RRA were taken into consideration, the Level 2 ERA indicated that fishing activities in the Crab Fishery presented a low or medium risk to most of the species assessed. For species with higher risk ratings, biological and life-history constraints were identified as a key driver of risk and in some instances were the main driver of risk. If for example, all of *susceptibility* attributes were assigned the lowest value possible (1), the speartooth shark would still register a 'medium' risk rating. This highlights the inherent challenge of managing fishing-related risks for species with *k*-selected life-histories.

It is important to highlight that risk ratings do not equal consequence, and that a high risk for one species or ecological component is not necessarily equal to another. The definition of an undesirable event for crabs will be quite different to that of marine turtles for example, and, drivers of risk behind ratings will also be very different between the complexes. The precautionary nature of the assessment will also mean that some ratings represent the potential risk rather than a real or actual risk.

4.1 Target & Byproduct Species

Species	Sub-fishery / Apparatus	Risk Rating
Mud crab (*S. serrata*)	Crab pot	Medium
Blue swimmer crab (*P. armatus*)	Crab pot	Low

Risk profiles for both target species were closely aligned with mud crabs (*S. serrata*) receiving a higher score for the productivity component of the PSA. This difference, while marginal, placed mud crabs in a higher risk category (Table 6). Importantly, indicative sustainability evaluations and stock assessments (Sumpton *et al.*, 2003; Grubert *et al.*, 2018; Johnston *et al.*, 2018; Northrop *et al.*, 2019) indicate that these risks are being managed under current catch and effort levels (Department of Agriculture and Fisheries, 2019b). These results also suggest that the remaining byproduct species (Appendix B) are at low risk given that they have similar life history constraints, attract smaller amounts of effort and have comparatively low retention rates (Walton & Jacobsen, 2019; Department of Agriculture and Fisheries, 2020).

As invertebrates, mud and blue swimmer crabs have typical *r*-selected life-histories including faster rates of growth, higher levels of fecundity and an earlier onset of sexual maturity. These characteristics helped offset some of the more prominent fishing related risks including the absence of an overarching control on catch and effort (*management strategy* attribute). Other factors including the passive nature of the apparatus (*i.e.* trapping crabs attracted to the bait *verse* capturing in a trawl or enmeshing) and increased post-capture survivability (Sumpton *et al.*, 2003; Butcher *et al.*, 2012) also contributed to mud and blue swimmer crabs receiving a lower risk rating (Table 6).

In the Level 1 ERA, limited control of catch and effort was identified as one of the more significant risks for this fishery (Walton & Jacobsen, 2019). In the PSA, this was reflected in the *management strategy* attribute which was assigned the highest risk rating for both species (Table 6). Given that the fishery operates under provisions prohibiting the take of female crabs and undersized males, this rating is considered to be precautionary. However, there is limited capacity within the current management regime to manage catch and effort at a whole-of-fishery or regional level and/or prevent a significant increase in fishing mortality within the commercial/recreational fishing sectors including black marketing of crab product. Without these measures there is a heightened risk that catch or effort will exceed key biological reference points. This risk will arguably be of more significance at a regional level; particularly in areas like south east Queensland where there is a higher concentration of commercial and recreational effort (Walton & Jacobsen, 2019).

As crabs have comparatively high within-pot survival rates (Sumpton *et al.*, 2003; Butcher *et al.*, 2012), some consideration was given to reducing the *selectively* scores as part of the RRA. The premise being that fishers have an increased capacity to differentiate between live retainable and non-retainable product. This increases the likelihood that a crab will survive the initial interaction and improves the selectivity of operation over the entire fishing event. However, this type of selectivity only occurs once an undersized male or female is trapped within the apparatus. It is also noted that the fishery has limited measures in place to reduce the capture of non-target crabs. For example, commercial and recreational crab fishers are not currently required to install or use a bycatch reduction device. This risk is compounded by an absence of data on discard rates and release fates for undersized males and females. From an ERA perspective, these are two areas were risk could be further reduced across the collective crab fishery.

Recreational desirability / other fisheries was the only attribute to have the risk scores increased as part of the RRA. The majority of information on recreational catch and effort is obtained through voluntary localised monitoring programs (*e.g.* the boat ramp survey program) and more expansive voluntary recreational fisher surveys (Webley *et al.*, 2015). This data shows that a high proportion of the recreational caught mud (80%) and blue swimmer (59%) crabs are discarded due (mostly) to fisheries regulations. The dataset for this sector though has not evolved to a point where shifts in recreational catch and effort, participation rates and fishing mortality can be monitored effectively between years (Walton & Jacobsen, 2019). This uncertainty was given considerable weighting in the RRA and resulted in a more precautionary risk rating being assigned to this attribute (Appendix D).

In addition to the recreational data, the Level 2 ERA identified a number of confounding factors that cannot be easily accounted for in the PSA including the black marketing of valuable crab product, cryptic mortalities and ghost pot longevity / fishing power. All of these factors will contribute to the total rate of fishing mortality and, depending on the severity (negligible, moderate, high), will have a bearing on the health of regional crab populations. As these factors deal with unreported catch (*e.g.* black marketing, discards) and unreportable mortalities (*e.g.* post-interaction mortalities, predation, ghost pots), they will be more difficult to address within a management framework. With that said, some of these risks are being actively addressed through the *Queensland Sustainable Fisheries Strategy 2017–2027*. For example, recreational possession limits for both species were reduced on 1 September 2019 and mud crabs are now subject to a recreational boat limit. These measures aim to keep total fishing pressures (commercial and recreational) within sustainable levels and to minimise the black-market risk for mud crabs (Department of Agriculture and Fisheries, 2019c).

The Level 2 ERA provides a snapshot of the risks posed to mud and blue swimmer crabs based on current catch and effort levels. It is recognised that the dynamics of a fishery will change through time with the introduction of new management reforms and inter-annual catch and effort fluctuations. In the Crab Fishery where effort concentrates in key areas, these fluctuations may see regional risk levels increase beyond what is presented in the Level 2 ERA. There are however a number of areas where this risk could be reduced / mitigated and measures that would improve the level of understanding of the risk posed to target species at a finer scale. Mitigation measures that would assist in reducing risk in the fishery and refining subsequent ERAs include:

- Develop management strategies that better regulate catch and effort levels for mud and blue swimmer crabs at a whole-of-fishery, regional and species level.

- Obtain better information on the cumulative (commercial and recreational) fishing pressures exerted on mud and blue swimmer crabs including on regional variations in fishing intensities, rates of fishing mortality and unreported catch (*e.g.* discarding, illegal fishing).
- Examine fine-scale effort distribution trends including the level of overlap between key habitats, licence transfer trends into high effort areas and the potential for it to increase risk at a regional level *e.g.* in south east Queensland where there are well established commercial and recreational fishing sectors (*availability*).
- Improve the level of information on crab discards and survival rates across fisheries/sectors (*e.g.* commercial and recreational) and the extent of cryptic/unreported mortalities including black marketing (*post-capture mortality*).
- Examining the suitability and applicability of using bycatch reduction devices to improve the selectivity of the apparatus and minimise the capture of undersized or unwanted product (*selectivity*).

4.2 Marine Turtles

Species	Sub-fishery / Apparatus	Risk Rating
Green turtle *(C. mydas)*	Crab pot	High
Loggerhead turtle *(C. caretta)*	Crab pot	High
Hawksbill turtle *(E. imbricata)*	Crab pot	Medium
Flatback turtle *(N. depressus)*	Crab pot	Precautionary Medium
Olive ridley turtle *(L. olivacea)*	Crab pot	Low
Leatherback turtle *(D. coriacea)*	Crab pot	Precautionary Medium

PSA scores for marine turtles range from 2.62 to 3.21, with one species classified as low risk, three as medium risk and two as high risk (Table 6). This subgroup has conservative life-histories and their biological constraints were highly influential in the final risk ratings (Table 6). These life-history constraints limit the ability of this complex to rebound after potential decline; therefore increasing the risk that crab fishing will contribute to any long-term or detrimental impact on regional marine turtle populations. As marine turtles have experienced historical population declines (Department of the Environment and Energy, 2017), this could even occur at low levels of fishing related mortality.

While five of the species received elevated risk ratings, only the green turtle (*C. mydas*) and the loggerhead turtle (*C. caretta*) were identified as high risk. Research suggests that loggerhead turtles are more inclined to enter a pot to access bait or trapped crabs (Avissar *et al.*, 2009a; Avissar *et al.*, 2009b) and green turtles have higher rates of entrapment/entanglement (Biddle & Limpus, 2011; Meager & Limpus, 2012). These inferences are supported by data contained within *Marine Wildlife Stranding and Mortality Database* (StrandNET) which shows that almost two-thirds of the crab pot interactions involved green turtles. Loggerhead turtles accounted for a further 5–6% of reports followed by hawksbill turtles (1%, *n* = 3 interactions), olive ridley turtles (>1%, *n* = 1 interaction), flatback turtles (no interactions) and leatherback turtles (no interactions) (Biddle & Limpus, 2011; Meager & Limpus, 2012; Department of Environment and Science, 2017).[3]

StrandNET data provides useful information on the species that interact with crab pots and the likely consequences. However, the data is largely based on post-mortem reports and provides limited insight into the origin of the apparatus (commercial or recreational), the legality of the pots or its functionality (*i.e.* a pot that is actively fished *verse* a ghost pot). While complimentary data on the commercial fishery is collected through the SOCI logbook, there is limited capacity within the current management regime to validate this data or quantify the level of any (potential) under-reporting (Walton & Jacobsen, 2019).[4] Cross-comparisons of the data are also limited as the raw SOCI data is not made available for direct entry in StrandNET. While StrandNET cannot be used as a direct validation tool for fisheries data due to the above constraints, improving the level of connectivity between SOCI logbooks and ancillary programs would provide further context on the broader risks posed by crab fishing activities.

Of the species included in the Level 2 ERA, research indicates that the green turtle has the largest population on the Queensland east coast (Department of the Environment, 2019h; b). This partly explains why green turtles have a higher representation in SOCI data (Department of Agriculture and Fisheries, 2019b) and in the *Marine Wildlife Stranding and Mortality Database* (Biddle & Limpus, 2011; Meager & Limpus, 2012). A larger population size suggests that the green turtle is in a better position (compared to the other marine turtle species) to absorb mortalities incurred due to crab fishing. To this extent, the final risk rating for this species may be precautionary as it (potentially) reflects population differences *verse* a higher susceptibility to capture or entanglement in the crab pot apparatus. It is recognised though that marine turtle populations have declined through time (*pers. comm*. C. Limpus) and concerns still remain about the long-term sustainability of species within this complex. Consequently, mortalities incurred in the Crab Fishery may still have longer term implications for regional populations; particularly when the cumulative risks are taken into consideration (discussed below).

When addressing the *selectivity* risk, it is important to understand the nature of marine turtle interactions with the crab pot apparatus. In Queensland, commercial and recreational fisheries operate under gear restrictions that impose limits on the number of pots and dillies that can be used (Department of Agriculture and Fisheries, 2019b). There are however few restrictions placed on the design of the apparatus, the size of the trap entrance or the use of bycatch reduction devices. From an ERA perspective, this allows for the use of pot designs and entrance sizes that are more accessible to marine turtles. For example, anecdotal evidence suggests that marine turtles are more susceptible to capture in collapsible rectangular pots due to the apparatus having a wider entrance (NSW Department of Primary Industries; Great Barrier Reef Marine Park Authority, 2014). As information on crab pot designs and their usage is limited, subsequent ERAs would benefit from

[3] *Based on 2000–2011 data (inclusive) and will include interactions with commercial and recreational apparatus. When unidentified specimens are excluded from the data, green turtles (C. mydas) make up more than 90% of the reported interactions and mortalities. Note that the Marine Wildlife Stranding and Mortality Database provides little insight into the origins of the apparatus, the legality of the pots, and does not attribute marine turtle deaths to a particular sector (commercial/recreational) or fishery (e.g. Spanner Crab Fishery, Crab Fishery, illegal operations).*

[4] *The limitations of the SOCI data were explored in more detail as part of the Level 1 (whole-of-fishery) ERA (Walton & Jacobsen, 2019).*

additional information on the type of pots being used (commercial and recreational), the preferred entrance dimensions and their potential to entrap marine turtles.

Bycatch reduction devices (BRD) are available for crab pots and there is some evidence that the use of a BRD improves gear selectivity and reduces the amount of bycatch (Roosenburg & Green, 2000; Grubert & Lee, 2013). As with pot designs, there is limited information on the use, prevalence and effectiveness of BRDs in Queensland's commercial and recreational crab fisheries. However, options to mandate the use of a BRD are being considered as part of a broader reform package for the fishery (Department of Agriculture and Fisheries, 2019a). With marine turtle interactions extending to the float lines, future risk mitigation measures will need to consider technologies outside of pot-based excluder devices. In the context of this ERA, mitigating the entanglement risk posed by float lines would have notable benefits for at least one of the high risk species; the green turtle (Table 6).

In the PSA, the potential for a marine turtle to interact with a fishery was addressed through an assessment of the overlap between the species distribution and commercial fishing effort (<10%, 10–30%, >30%). While the *availability* attribute provides an indication of the level of overlap, it does not take into consideration the level of fishing intensity or quantify effort levels in critical marine turtle habitats. Research has shown that the marine turtle life cycle will exert significant influence on the size, distribution and density of regional populations (Department of the Environment, 2019h; b; c; d; f; g). A consequence of which is that marine turtles are less likely to be uniformly or homogeneously distributed throughout the prescribed C1 fishing area (*pers. comm.* C. Limpus). These factors place added importance on obtaining additional information on fine-scale effort movements to determine the extent of the overlap between fishing effort and biologically important areas and/or habitats considered to be critical to the survival of the species (Department of the Environment and Energy, 2017). This process has already commenced with the introduction of *Vessel Tracking* (Department of Agriculture and Fisheries, 2018e) in the Crab Fishery and information obtained from this programme will help determine if regional risks (*e.g.* in south-east Queensland) vary from those obtained at a whole-of-fishery level.

As with target & byproduct species, there are a number of confounding factors that cannot easily be assessed as part of the PSA. For marine turtles, the most significant risks relate to the impact of ghost pots on regional populations (Department of Agriculture and Fisheries, 2019b). This issue extends across the commercial and recreational fishing sectors and lost gear arguably presents as a greater risk when compared to pots being actively fished and monitored. When lost, crab pots will continue to fish and in most-instances will self-bait and attract predators or scavengers including loggerhead turtles. Ancillary equipment including float lines and ropes also persist within the marine environment and can be encountered by marine turtles on the surface, in the water column or attached to the benthos. Marine turtles are highly susceptible to float line/rope entanglements and this type of interaction can result in the death of the animal (Gregory, 2009; Meager & Limpus, 2012). This risk will be applicable to all six marine turtle species; not just the green and loggerhead turtle. The extent of the risk will be dependent on the region, the intensity of fishing effort, the type of fishing (*e.g.* commercial, recreational), participation rates and accessibility. Based on the spread of the population and effort distributions, it is expected that ghost pots will be a more prominent risk in central / south east Queensland and in high-use areas of the Gulf of Carpentaria (Department of Agriculture and Fisheries, 2019b).

Information on pot loss rates in the commercial and recreational fishing sector is limited (Sumpton *et al.*, 2015; Department of Agriculture and Fisheries, 2019b). However, it is anticipated that the recreational sector makes a significant contribution to the number of pots lost over a 12-month period. While not universal, crab pots used in the recreational fishing sector are often of lower value, consist of lightweight materials and are more likely to be swept away (*e.g.*) in currents, bad weather or due to tidal fluctuations (Grubert & Phelan, 2007; Department of Employment Economic Development and Innovation, 2010; 2011; Department of Agriculture and Fisheries, 2018d). In contrast, pots used by commercial operators tend to be heavier, have improved longevity and are less likely to move significant distances without intervention *e.g.* pot or product theft, being dragged behind a passing vessel (*pers. comm.* S. Barry; Grubert & Phelan, 2007; Oceanwatch Australia, 2007).

As lightweight pots are inexpensive and readily accessible, they are highly appealing to the recreational fishing sector. They provide members of the public with an economically efficient way to access the crab resources with minimal financial consequences if one or more of the pots go missing. This accessibility extends to people with limited experience in crab fishing. With less experience, there is a higher risk of the apparatus being displaced (*e.g.* due to the float lines being too short for tidal range, setting pots in areas with strong currents or trawl paths *etc.*) and becoming a ghost pot. In regions with higher populations and improved infrastructure, there is also a risk that ghost pots will accumulate in waters with greater accessibility (Walton & Jacobsen, 2019). These elements are important when considering the broader risks posed to marine turtles (Department of Agriculture and Fisheries, 2019b).

A second and arguably more pressing issue for the marine turtle complex relates to cumulative risks. Marine turtle populations have undergone historical declines and the subgroup is exposed to a range of fishing and non-fishing related risks. Some of the more notable risks posed to this subgroup include their capture in other commercial fisheries, the negative consequences of habitat degradation (*e.g.* urban development, runoff), disease and injuries or mortalities stemming from boat strike (*pers. comm.* C. Limpus; Walton & Jacobsen, 2019).

As cumulative risks involve a wide range of stakeholders they cannot easily be accounted for in a fisheries-specific ERA. For most of the above examples, risks associated with the activity will be higher than that posed by the Crab Fishery. To this extent, the Crab Fishery will be a contributor of risk *verse* the main driver of risk. It is recognised though that marine turtles have experienced notable population declines and even smaller rates of fishing mortality can lead to longer term implications *e.g.* reduced capacity to maintain or build regional populations due to the loss of sexually mature adults. For these reasons reducing both the direct (*e.g.* capture, entanglement) and indirect (*e.g.* post-capture mortalities, ghost pots) of crab fishing on marine turtle populations will remain an issue of importance.

The results of the Level 2 ERA indicate that the risk posed by crab fishing to the marine turtle complex will vary. Going forward, risk assessments for marine turtles could be refined with more accurate data on total interaction rates, an improved understanding of the current fishing dynamics in habitats classified as critical to their survival and the extent/impact of ghost pot fishing (Department of the Environment and Energy, 2017). While the green and loggerhead turtles should be prioritised in this process, this data could be used to refine the assessments of all six marine turtle species. Similarly there are a range of measures that could be implemented in the fishery that would assist in the management of risk and/or improve the accuracy of future ERAs.

- Implement strategies to improve and validate data on marine turtle catch/interaction rates release fates across the commercial and recreational fishing sectors.
- Examine fine-scale commercial effort patterns and the extent of the overlap with marine turtle habitats identified as a) critical to the survival of a species and b) biologically important areas, prioritising green and loggerhead turtles.
- Streamline permissible gear provisions for the Crab Fishery and restrict high-risk pot designs that are more readily accessed by marine turtles / pose an increased entrapment risk.
- Explore avenues to prevent marine turtles entering the pot and minimise the entanglement risk *e.g.* development of BRDs for both the pot and the ancillary equipment like float lines.
- Increase the level of information on the prevalence of ghost pots in key areas, their origin and strategies to reduce pot-loss rates across the commercial and recreational fishing sectors.
- Identifying avenues to provide a greater synthesis of data on marine turtle interactions collected through the *Species of Conservation Interest* (SOCI) logbooks and ancillary programs *e.g.* StrandNET.

4.3 Speartooth Shark

Species	Sub-fishery / Apparatus	Risk Rating
Speartooth shark (*G. glyphis*)	Crab pot	High (GoC)

The PSA score for the speartooth shark (3.64) was at the higher end of the risk spectrum (Table 6), and close to the maximum that can be attained using this methodology (Table 6). While information on the biology of the speartooth shark is limited, the species will have *k*-selected life history traits *e.g.* a comparatively slow rate of growth, late onset of sexual maturity and lower reproductive outputs / fecundity levels (*pers comm.* I. Jacobsen, B. Wueringer; Last & Stevens, 2009; White *et al.*, 2017). These life-history constraints will limit the ability of the species to rebound after fishing induced population declines and exacerbate the extent of any cumulative risks. As speartooth sharks already have smaller population sizes and restricted home ranges, even low levels of fishing mortality could have detrimental impacts on this species.

The geographical distribution of the speartooth shark is highly contracted and the species is known from a few scattered locations in northern Australia and New Guinea (Peverell *et al.*, 2006; Compagno *et al.*, 2009; Last *et al.*, 2016; Department of the Environment, 2019e). On the Queensland east coast, the reported distribution of the speartooth shark is largely confined to rivers north of Cairns and Cape Tribulation (Last & Stevens, 2009). This information may now be outdated with regional surveys of their preferred habitats failing to detect the species on the Queensland east coast. These results have led to suggestions that the species may now be extirpated from the region (Pillans *et al.*, 2009) with the Gulf of Carpentaria identified as an area of significance (Peverell, 2005).

Information on the extent of speartooth shark – crab pot interactions is limited and further research is required into the risk posed by crab fishing in the Gulf of Carpentaria. Based on ongoing experimental research being conducted by CSIRO, commercial and recreational fishing for mud crabs in the Wenlock River (and in particular Tentpole Creek) poses a significant ecological risk to the species. This is based on high catch rates of neonates in crab pots combined with the species small adult population size and high juvenile mortality (*pers. comm.* based on *unpublished data* R. Pillans). The full extent of this risk though is still being explored including any temporal/spatial variations in speartooth shark interactions, post-interaction rates and the level of overlap between regional populations and commercial/recreational crab fishing effort.

Based on the available information and the above considerations, the rating assigned to this species is viewed as being more representative of a real or actual risk *verse* the potential risk. This risk is of particular relevance in the Gulf of Carpentaria mud crab fishery and will apply to both the commercial and recreational fishing sectors. Going forward, future ERAs would benefit from the inclusion of additional data on the biology of the species, the extent of the overlap between key habitats and commercial/recreational fishing effort and the catch dynamics *e.g.* size compositions, sex ratios and release fates. Depending on the outcomes of key research being undertaken or consideration, further management intervention may be required. As part of this process, consideration should be given to:

– Improving the level of information on speartooth shark interactions in both the commercial and recreational mud crab fishery in the Gulf of Carpentaria *e.g.* total interaction rates, catch dynamics, release fates and fine-scale effort movements in high value habitat areas.
– Identify mechanisms that will assist in the minimisation of speartooth shark interactions and mortalities in the Gulf of Carpentaria including avenues to improve the effectiveness of spatial/temporal closures and suitability/applicability of bycatch reduction devices.

5 Summary

The Level 2 (species-specific) ERA examines the level of risk for each species under the current fishing environment. In doing so, the Level 2 ERA identifies some of the more immediate risks posed to mud crabs, blue swimmer crabs, marine turtles and speartooth sharks. Based on the results obtained, crab fishing presents a low to moderate risk to most of the complexes and species assessed as part of the whole-of-fishery (Level 1) and species-specific (Level 2) ERA. There are however a number of areas where direct management or intervention may be required to reduce the level of risk for key species; namely speartooth sharks in the Gulf of Carpentaria, green turtles and loggerhead turtles.

Of significance, a number of reforms are being developed and implemented in the Crab Fishery as part of the broader Strategy (Department of Agriculture and Fisheries, 2017; 2019a). These reform initiatives have the potential to reduce the risk posed to a number of the species assessed as part of the Crab Fishery Level 2 ERA. For example, *Vessel Tracking* has been required on all commercial crab fishing boats since January 2019 (Department of Agriculture and Fisheries, 2018e). This measure alone will improve the level of information on regional fishing intensities and fine-scale movements of effort. In a fishery where licences can be readily transferred, this information will be of value when determining how the risk of over-exploitation differs at a regional level (see points above).

In addition to *Vessel Tracking*, a number of new management arrangements came into effect on 1 September 2019 (Department of Agriculture and Fisheries, 2019c). These reforms were primarily aimed at managing the recreational take of the two target species, reducing risks associated with the black marketing of mud crabs and taking steps to address risks associated with ghost pots. These measures include reducing in-possession limits for both species, imposing a boat limit for mud crabs and improved pot identification measures. As these measures have only been implemented recently, there is limited information on how these measures will influence risk ratings. Nevertheless, these initiatives have the potential to reduce risks posed to mud & blue swimmer crabs in the short and long term.

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7 Appendix

Appendix A	–	Summary of the species rationalisation process for target & byproduct species and SOCC.
Appendix B	–	Outputs of the species rationalisation process summary for the Crab Fishery.
Appendix C	–	Overlap percentages used to assess *availability*.
Appendix D	–	Residual Risk Assessment for the Crab Fishery.

APPENDIX A*—Target & Byproduct Species Rationalisation Process.*

Catch data submitted through the commercial logbook system was used to construct a preliminary list of target & byproduct species that were considered for inclusion in the Level 2 ERA. Logbook data was considered over a three year period (2016–2018 inclusive) with the final species list refined using the following steps.

1. Data for each catch category (*i.e.* species or species groupings) was summed across the relevant period (2016–2018 inclusive) and ranked in order from highest to lowest.

2. Cumulative catch analysis was used to identify all of the categories that made up 95% of the total catch reported from the fishery over this period.

3. Species that fell below the 95% catch threshold were reviewed and, if no anomalies were detected, omitted from the initial list of target & byproduct species. Retention rates for most of these species are low and they are generally viewed as secondary byproduct species. When and where appropriate, these secondary species will be considered for inclusion in subsequent ERAs.

4. Species above the 95% catch threshold (*i.e.* those that were not omitted from the analysis) were than reviewed and the following steps undertaken:

    a. Where possible, multi-species catch categories were expanded using the relevant CAAB codes (*e.g.* blacktip shark CAAB code 37 018903 includes *Carcharhinus limbatus* and *C. tilstoni*). All additions took into consideration the operating area of the fishery and the potential for the species to interact with the fishery. In some instances, this required the re-inclusion of species that fell below the initial 95% cut-off.

    b. Duplications resulting from expansion of multi-species catch categories were then removed.

    c. Catch categories that could not be refined to species level such as '*Unspecified fish'* or *'Crabs–Unspecified'* were excluded from the analysis.

    d. Species managed under Total Allowable Commercial Catch (TACC) limits that are directly linked to biomass estimates or managed under harvest strategies (*e.g.* coral trout) were also removed. The premise being that the risk posed to this species is currently addressed through management controls. As a precautionary measure, any species whose TACC was not based on a stock assessment or had a stock assessment >5 years old was retained in the assessment.

    e. When and where appropriate, the draft species list will be forwarded on to key stakeholders including the fisheries managers and the *Fisheries Working Groups* for further feedback and consultation. In large multi-species fisheries, this process may include the identification of primary and secondary assessment priorities.

5. A summary of the species rationalisation process was then completed and justifications provided for why each a target or byproduct species was included or omitted from the analysis.

APPENDIX A cont. *—Species of Conservation Concern Rationalisation Process.*

The preliminary list of *Species of Conservation Concern* (SOCC) was established through a review of State and Commonwealth legislation and international conventions with the potential to influence fishing activities in Queensland.

As SOCC review was regionally specific and included species that had the potential to interact with the fishery in Queensland waters, species that have been included in international conventions but are subject to reservations (*e.g.* thresher shark, *Alopias* spp.) and species afforded specific protections under legislation governing the use of resources in state and commonwealth marine parks. The preliminary species list did not include species whose distributions did not extend into Queensland (including the Gulf of Carpentaria).

While not exhaustive, the preliminary SOCC list provided a strong overview of the species afforded additional protections under State legislation, Commonwealth legislation and species included or being considered for inclusion in international conventions. The following was reviewed as part of this process:

- *Fisheries Declaration 2019* (Qld)*;*
- *Nature Conservation Act 1992* (Qld);
- *Marine Parks (Moreton Bay) Zoning Plan 2008* (Qld);
- *Marine Parks (Great Sandy) Zoning Plan 2017* (Qld);
- *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth);
- *Great Barrier Reef Marine Park Regulations 1983* (Commonwealth);
- *Convention on the Conservation of Migratory Species of Wild Animals* (CMS) (International Convention); and
- *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES) (International Convention).

Once established, the preliminary SOCC list was refined using the following steps:

1. All SOCC subgroups that were not classified as intermediate/high or high risk in the whole-of-fishery (Level 1) ERA (Walton & Jacobsen, 2019) were removed from the analysis.

2. Species with no or low overlap with the known distribution of fishing effort, with low interaction potential or low likelihood of capture within the apparatus were removed. Any species where the distribution and interaction potential was uncertain were retained in the assessment and further advice sought from scientific experts / key stakeholders.

3. The preliminary list and justifications were then sent to key stakeholders including (if applicable) the relevant *Fisheries Working Group*.

4. The SOCC list was finalised for assessment once feedback had been received and the consultation process had been completed.

5. A summary of the species rationalisation process was then completed and justifications provided for why a species was included or omitted from the analysis.

APPENDIX B*—Species rationalisation process summary for the Crab Fishery. *Codes for Australian Aquatic Biota* (http://www.marine.csiro.au/data/caab/)

Ecological component	Common name	Species name	CAAB*	Level 2 ERA	Justifications & Comments
Target & Byproduct species	Mud crab	*Scylla serrata*	28 911008	Assessed	• Key target species
	Keeled mud crab	*Scylla paramamosain*	28 911122	Not Assessed	• Species not found in Australia (Le Vay, 2001).
	Olive mud crab	*Scylla olivacea*	28 911007	Not Assessed	• Northern distribution and low abundance in Australian waters (Le Vay, 2001). • Seldom grows to the prescribed legal size limits (Le Vay, 2001).
	Blue swimmer crab	*Portunus armatus*	28 911005	Assessed	Key target species
	Three-spotted crab	*Portunus sanguinolentus*	28 911006	Not Assessed	• Catch data for the species from 2016–2018 (inclusive) was <5t (Department of Agriculture and Fisheries, 2020). • While species may incur some mortalities (*e.g.* fatal injuries, extended periods of exposure), post-release survival rates for this fishing method are expected to be high.
	Coral crab	*Charybdis feriata*	28 911001	Not Assessed	• Catch data for the species from 2016–2018 (inclusive) was <1t (Department of Agriculture and Fisheries, 2020). • While species may incur some mortalities (*e.g.* fatal injuries, extended periods of exposure), post-release survival rates for this fishing method are expected to be high
	Hairyback crab	*Charybdis natator*	28 911002	Not Assessed	• Catch data for the species from 2016–2018 (inclusive) was <5t (Department of Agriculture and Fisheries, 2020).

Ecological component	Common name	Species name	CAAB*	Level 2 ERA	Justifications & Comments
					• While species may incur some mortalities (*e.g.* fatal injuries, extended periods of exposure), post-release survival rates for this fishing method are expected to be high.
Marine turtles	Green turtle	*Chelonia mydas*	39 020002	Assessed	• Notable overlap between the known distributions and fishing effort. • Evidence that the subgroup will interact with crab pots (commercial, recreational, ghost) and can become trapped in the pot or floatlines including in ancillary datasets (*e.g.* StrandNET). • Interactions have a high potential to result in mortalities and the cumulative risk for this subgroup is high.
	Loggerhead turtle	*Caretta caretta*	39 020001	Assessed	
	Hawksbill turtle	*Eretmochelys imbricata*	39 020003	Assessed	
	Flatback turtle	*Natator depressus*	39 020005	Assessed	
	Olive ridley turtle	*Lepidochelys olivacea*	39 020004	Assessed	
	Leatherback turtle	*Dermochelys coriacea*	39 021001	Assessed	
Sharks	Speartooth shark	*Glyphis glyphis*	37 018041	Assessed	• Notable overlap between the known distribution and fishing effort; particularly in the Gulf of Carpentaria. • Evidence of interactions with commercial and recreational pots (*pers. comm.* R. Pillans). • Interactions with juveniles and neonates have a high potential to result in mortalities (*pers. comm.* R. Pillans).

APPENDIX C—*Overlap percentages used to assess the availability component of the PSA*.

Common name	Species	% overlap			Highest overlap	Availability score
		2016	2017	2018		
Mud crab	*Scylla serrata*	N/A	N/A	N/A	N/A	N/A
Blue swimmer crab	*Portunus armatus*	N/A	N/A	N/A	N/A	N/A
Green turtle	*Chelonia mydas*	6.1	6.4	5.4	6.4	1
Loggerhead turtle	*Caretta caretta*	6.1	6.4	5.4	6.4	1
Hawksbill turtle	*Eretmochelys imbricata*	6.1	6.4	5.4	6.4	1
Flatback turtle	*Natator depressus*	6.1	6.4	5.4	6.4	1
Olive Ridley turtle	*Lepidochelys olivacea*	6.1	6.4	5.4	6.4	1
Leatherback turtle	*Dermochelys coriacea*	6.1	6.4	5.4	6.4	1
Speartooth shark	*Glyphis glyphis*	2.1	4.2	3.7	4.2	1

APPENDIX D*—Residual Risk Assessment for the Crab Fishery.*

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
Mud crab (*Scylla serrata*) Blue swimmer crab (*Portunus armatus*)	*Selectivity*	3	3	Given the passive nature of the crab apparatus and the limited use of bycatch reduction devices (BRDs), there is high potential for the commercial fishery to interact with and capture undersized males and female crabs. Based on this and the prescribed susceptibility criteria (Table 3) both mud crabs and blue swimmer crabs were assigned the highest risk scores for the *selectivity* attribute. In the RRA, a reduction to the *selectivity* attribute score was considered as a high percentage of the crabs caught within the pot will survive until they are sorted or processed by the fisher. To this extent, operators in the Crab Fishery will have greater capacity to differentiate between retainable and non-retainable product. While these factors will improve post-release survival rates (see below), they only improve the selectivity of the fishery once the animal has been caught. Due to the above considerations, scores assigned to the *selectivity* attribute were not amended as part of the RRA. This decision was largely based on the selectivity of the apparatus used *vs.* the ability of an operator to improve post-capture selectivity rates. This decision is considered to be precautionary in nature and the assessment could be refined with additional information on BRD usage in the fishery. ***Key changes to the PSA scores*** Not applicable, although this is an area where the accuracy of the Level 2 ERA could be refined and/or where risk could be further mitigated in this fishery.
Mud crab (*Scylla serrata*) Blue swimmer crab (*Portunus armatus*)	*Post-capture mortality*	3	2	Criteria used to assign scores to the *post-capture mortality* attribute allocates high risk ratings to all retained species (Hobday *et al.*, 2011). Based on these criteria, both the mud crab and blue swimmer crab were assigned a score of 3 for this attribute (Table 3). This however was considered to be an overestimate for this fishery.

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				Pots are highly selective for crab species and there is a high probability that fishers will catch both retainable and non-retainable product *e.g.* legal sized crabs, female crabs and undersized males. However, a high proportion of the captured crabs will survive the fishing event until they can be assessed and processed by the fisher (Sumpton *et al.*, 2003; Butcher *et al.*, 2012). This factor is important as it increases the capacity of the fisher to select and harvest legal crabs (males over the minimum legal size limit) and return illegal product (undersized males and females) to the water. If handled correctly, post-interaction survival rates for returned product will be comparatively high. As the fishery operates under management arrangements that prohibit the take of females or undersized crabs, this means that a high proportion of the affected population (potentially >50%) will be returned to the water with a high probability of surviving the fishing event. ***Key changes to the PSA scores*** Risk scores assigned to the *post-capture mortality* attribute were reduced from 3 to 2 for both target species. These changes were largely done in accordance with *Guideline 2, additional scientific assessment & consultation*. However, *Guideline 5, effort and catch management arrangements for target & byproduct species* were also a catalyst for change due to prohibitions on the take of female crabs and undersized males.
Mud crab (*Scylla serrata*) Blue swimmer crab (*Portunus armatus*)	*Recreational desirability / other fisheries*	1	2	The *'recreational desirability / other fisheries*' attribute was assessed as low risk (1) in the PSA due to the recreational sector having a high discard rates. This is primarily due to current provisions that prohibit the take of female crabs and undersized males. Both mud and blue swimmer crabs hold strong social significance and are targeted in higher numbers by the recreational fishing sector. For example, current estimates place the annual recreation harvest of mud and blue swimmer crabs in Queensland at 346t and 36t respectively

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				(Grubert *et al.*, 2018; Johnston *et al.*, 2018). At these levels, the recreational sector makes a notable contribution to the overall rate of fishing mortality. In Queensland, a number of measures are used to manage the recreational take of mud and blue swimmer crabs including a prohibition on the take of female crabs, a minimum legal size limit for male crabs plus gear, in-possession and boat limits (Department of Agriculture and Fisheries, 2019b; c). These regulations reduce the extent of the risk posed to this subgroup and were the primary reasons why this attribute was not assigned a high (3) risk rating. There are however some notable information gaps with respect to recreational catch and effort levels, participation rates, recreational pot numbers (total), the level of non-compliance (*e.g.* black marketing) and the extent of between and within year catch/effort variability. In addition to the recreational fishing sector, the net and trawl fisheries are able to retain incidentally caught crab species. For example, both mud and blue swimmer crabs can be retained if incidentally caught when using a netting apparatus. The situation in the trawl fishery is slightly different as operators can only retain blue swimmer and three-spot crabs. In this instance, trawl fishers operating in Moreton Bay are allowed a 100 blue swimmer crab in possession limit. Trawl fishers (excluding fish trawl) operating outside this area can retain up to 500 blue swimmer crabs for every seven days (Department of Agriculture and Fisheries, 2019b). While net discards are considered to be less of an issue, a portion of the blue swimmer crabs caught by prawn trawls will be discarded in a dead, moribund or injured state. Preliminary research on trawl caught blue swimmer crabs indicates that mortality rates for this complex varied with trawl shot duration and exposure/sorting times (Sumpton *et al.*, 2015). More information is required on the extent of blue swimmer crab discards in the trawl fishery and the release fate (*i.e.* dead, moribund and injured).

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				Key Changes to the PSA scores To account for the above uncertainties, risk scores assigned to the *Recreational desirability / other fisheries* were increased from 1 (low) to 2 (medium). This change is precautionary and helps minimise the risk of a '*false negative*' result. Future ERA would benefit from having additional information on the impact of recreational fishing (mud crab) and catch/discard rates in other commercial fisheries; particularly the trawl fishery (blue swimmer crabs). Changes to the PSA score for this attribute were based on the *Guideline 1, rating due to missing, incorrect or out of date information*.
Loggerhead turtle *(C. caretta)* Olive ridley turtle *(L. olivacea)* Leatherback turtle *(D. coriacea)*	*Fecundity*	3	2	The precautionary nature of the PSA meant that fecundity scores for marine turtles were based on the most precautionary range values published for number of eggs per year, years between reproductive events and number of batches per reproductive season. For some species, these values were well below the mean and therefore were considered to be an unrealistic account of the species fecundity. The leatherback turtle (*D. coriacea*) provides a good example of this, where the precautionary estimate for number of eggs per year was *n* = 5, versus *n* = 237 based on mean values. ***Key Changes to the PSA scores*** To address these discrepancies, the number of offspring per year was recalculated using mean values for number of eggs per clutch, number of years between reproductive events, and number of clutches per season. As a result of these amendments, risk ratings assigned to the fecundity attributes decreased from high (3) to medium (2) for three species; *C. caretta, L. olivacea and D. coriacea*. This approach was supported by members of the scientific community (*pers. comm.* C. Limpus & J. Meager) and the changes were done in accordance with *Guideline 1, rating due to*

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				missing, incorrect or out of date information and *Guideline 2, additional scientific assessment & consultation*.
Loggerhead turtle *(C. caretta)*	*Maximum size*	1	2	The loggerhead turtle (*C. caretta*) was initially assigned a low (1) risk score for this attribute. During the consultation process, it was advised that this score should be increased (*pers. comm*. C. Limpus). ***Key Changes to the PSA scores*** Due to this feedback, the score assigned to this attribute was increased from low (1) to medium (2). This change was done in accordance with *Guideline 2, additional scientific assessment & consultation.*
Flatback turtle *(N. depressus)* Olive ridley turtle *(L. olivacea)* Leatherback turtle *(D. coriacea)*	*Encounterability*	3	1	The PSA criteria assigns a default high risk score to the *encounterability* attribute for all birds, mammals and reptiles. The premise being that as air-breathing animals these species have a higher potential to interact with the gear while it is being set and retrieved (Hobday *et al.*, 2007). In-line with this methodology, all marine turtles were assigned a high risk (3) score for the *encounterability* attribute. In reality, the potential or likelihood that all marine turtle species will interact with or encounter a crab pot is less uniform. For example, green, loggerhead, and hawksbill turtles frequently occur in Queensland's shallow coastal waters (Department of the Environment, 2019h; b; d) and have a higher chance of interacting with the crab fishery (commercial or recreational). However, leatherback and olive ridley turtles inhabit deeper, pelagic waters, and are less frequently encountered in Queensland waters (pers comm. C. Limpus & J. Meager; Department of the Environment, 2019c; f). While flatback turtles inhabit shallower inshore waters, their distribution has less overlap with central and southern Queensland where the majority of the crab fishing effort occurs (Department of Agriculture and Fisheries, 2019b; Department of the Environment, 2019g). The above is partly supported by the *Stranding and Mortality database* which shows the

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				overwhelming majority of turtle interactions with anthropogenic activities are with green, loggerhead, and hawksbill turtles (Meager & Limpus, 2012). ***Key Changes to the PSA scores*** The *encounterability* risk ratings for *L. olivacea*, *N. depressus* and *D. coriacea* were downgraded from high (3) to a low (1). This reduction was in recognition of the fact that these species prefer deeper water environments (relative to mud and blue swimmer crab fishing areas) and are less likely to interact with the Crab Fishery. Amendments to the *encounterability* scores were based on *Guideline 4: At risk in regards to level of interaction/capture with a zero or negligible level of susceptibility* and *Guideline 2, additional scientific assessment & consultation*. The assumption that air-breathing animals are more likely to encounter gear when it is being set or retrieved (Hobday *et al.*, 2011; Australian Fisheries Management Authority, 2017) may be less suited to the Crab Fishery. When compared to (*e.g.*) the large mesh net, trawl and long-line fisheries, the C1 gear deployment and retrieval process occurs over a smaller time and spatial scale. As a consequence, marine turtles are more likely to interact with a crab pot once it has settled on the substrate and the fisher has moved out of the immediate area.
Green turtle *(C. mydas)* Loggerhead turtle (*C. caretta*)	*Selectivity*	1	2 and 3	All species of marine turtle were scored low for the *selectivity* attribute. This was based on the premise that crab fishing is relatively passive; relying on animals that are small enough to fit through the pot becoming trapped in the apparatus. The diets of most marine turtles suggest they will not actively seek out or engage with a working pot (*e.g.* try to access the crab pots to eat the bait or trapped animals). The notable exception to this is the loggerhead turtle (*C. caretta*) which occupies a higher trophic level and has a diet consisting of dead and live crustaceans, fish, and other invertebrates (Tomas *et al.*, 2001; Seney & Musick, 2007; Casale *et al.*, 2008). Research carried out by Fisheries Queensland on the Spanner Crab

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				Fishery observed loggerhead turtles consuming live spanner crabs from commercial dillies (Brown *et al.*, 2001). The species is also known to take bait from drumlines employed as part of the shark control programme (Greenland *et al.*, 2002). This suggests that loggerhead turtles will be more attracted to crab pot bait and/or animals that have become trapped. This inference is supported by research from America that has shown loggerhead turtles will interact with crab pots and try to access caught product (Avissar *et al.*, 2009a; Avissar *et al.*, 2009b). Green turtles are understood to be the most abundant species living in Queensland waters with population estimates of around 49,000 on the Great Barrier Reef alone (Department of the Environment, 2019b). Unsurprisingly, green turtles are also the most common species reported dead, injured or rescued in the *Stranding and Mortality Database* (Department of Environment and Science, 2017). As far as interactions go with crab fishing gear specifically, green turtles far out-number other species (Biddle & Limpus, 2011; Meager & Limpus, 2012). While green turtles are less likely to try and access the bait, the species (due to population numbers or other factors) features heavily in crab pot – marine turtle interaction data. These interactions are not restricted to active pots (*i.e.* those being regularly checked) and ghost pots will be a key driver of risk for this species. These risks will extend to secondary equipment including float lines and ropes (*pers. comm.* C. Limpus). ***Key Changes to the PSA scores*** To account for dietary and behaviour differences, the *selectivity* score for loggerhead turtles was increased from low (1) to high (3). This change recognised the increased likelihood of that the species will attempt to access the bait and was made on the back of further scientific advice (*pers. comm.* C. Limpus).

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				Selectivity scores for the green turtle were also increased from low (1) to medium (2) in recognition of their prevalence in the interaction data; particularly float lines. For green turtles, this increase is precautionary and helps minimise the risk of the PSA producing a '*false negative*' result. Amendments to the *selectivity* scores were primarily done under *Guideline 2, additional scientific assessment & consultation*.
Speartooth shark (G. glyphis)	*Age at maturity*	3	2	There is limited information on the biology of the speartooth shark (Compagno *et al.*, 2009; Department of the Environment, 2015) including on the age at sexual maturity. As no data was available on the biology of this species, this attribute was assigned a precautionary high (3) risk score in the PSA. While not universal, research on the growth and development of sharks and rays indicate that a high proportion reach sexual maturity before 15 years (Cortés, 2000; Jacobsen & Bennett, 2011; Geraghty *et al.*, 2013). Based on this research, it is likely that the score assigned to this attribute is an overestimate—particularly since *G. glyphis* is found in the tropics and growth in these regions tends to be faster when compared to species found in temperate waters. This inference was supported in subsequent discussions on the biology of this species where 5–15 years was nominated as the most likely age of sexual maturity (*pers. comm.* B. Wueringer, *Sharks and Rays Australia Research Organisation*. ***Key Changes to the PSA scores*** The preliminary score assigned to the *age at maturity* attribute was reduced from high (3) to medium (2). Changes made as part of the RRA were done in accordance with *Guideline 2, additional scientific assessment & consultation.*