Department of Agriculture and Fisheries

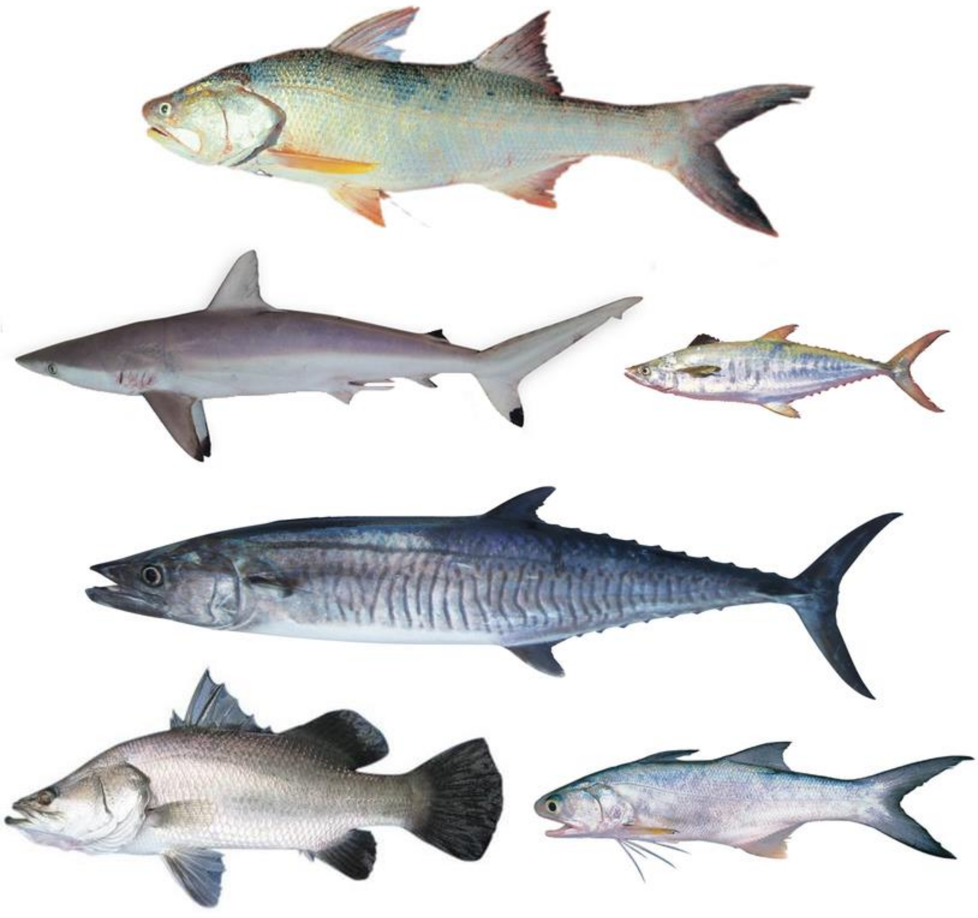
Sustainable Fisheries Strategy

2017–2027

Level 2 Ecological Risk Assessment

Gulf of Carpentaria Inshore Fishery

Target & Byproduct Species



Queensland Government

Gulf of Carpentaria Inshore Fishery Level 2 Ecological Risk Assessment

Target & Byproduct Species

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Executive Summary

In December 2019, a whole-of-fishery or Level 1 Ecological Risk Assessment (ERA) was released for the Gulf of Carpentaria Inshore Fishery (GOCIF; Jacobsen *et al.*, 2019b). The Level 1 ERA provided a broad risk profile for the GOCIF, 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 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 established a framework that can be built upon in subsequent ERAs.

The Level 1 ERA identified a number of high-risk elements that are to be progressed to a finer-scale or species-specific Level 2 ERA (Department of Agriculture and Fisheries, 2018a). This includes target and byproduct species, bycatch, marine turtles, dugongs, dolphins, batoids and sharks (Jacobsen *et al.*, 2019b). For the purpose of this ERA, the assessment focuses specifically on the risk posed to key target and byproduct species in the N3 (largely inshore) and N12/N13 (offshore) fisheries. Risk assessments for the remaining groups including species with ongoing conservation concerns have been addressed in separate ERAs (Jacobsen *et al.*, 2021). Similarly, the small mesh net (N11) was not assessed as part of the first iteration of the GOCIF Level 2 ERA process (Department of Agriculture and Fisheries, 2019b).

The Level 2 ERA was compiled using a *Productivity & Susceptibility Analysis* (PSA) and takes into consideration a range of biological (*e.g. age at maturity*, *maximum age*, *fecundity*, *maximum size*, *size at maturity*, *reproductive strategy*, and *trophic level*) and fisheries-specific attributes (*e.g. 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), this 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 is to minimise the number of false positives or instances where the risk level has been overestimated.

The scope of the Target & Byproduct Species Level 2 assessment was based on data compiled through the logbook program and considered catch reported against individual species and multi-species catch categories (Department of Agriculture and Fisheries, 2020a). A review of logbook records showed that around 95% of the catch (2017–2019 inclusive) was recorded against nine catch categories. These categories produced a preliminary list of 26 species that were considered for inclusion in the Level 2 ERA. This list was reduced to 15 species through a subsequent rationalisation process and included mackerels, barramundi, threadfins and sharks among others. The remaining 11 species were considered less of a priority and excluded from the current analysis.

When the outputs of the PSA and RRA were taken into consideration, nine species were categorised as high risk in the GOCIF. Risk scores for the remaining six species fell into the medium-risk category. Teleost risk profiles were heavily influenced by the *susceptibility* component with most species being assigned higher scores for *selectivity*, *encounterability* and *post-capture mortality*. While these risks applied to sharks, biological constraints were also identified as a significant risk factor for this subgroup. Across the study, management limitations and restricted *sustainability assessments* all contributed to the production of more conservative risk assessments. While not uniform, data

deficiencies were a factor of influence in a number of the risk profiles. These deficiencies were most evident in assessments involving the *sustainability assessments* and *recreational desirability / other fisheries* attributes.

Risk ratings for two species, the common blacktip shark (*Carcharhinus limbatus*) and the graceful shark (*C. amblyrhynchoides*) were viewed as precautionary and are considered to be more representative of the potential risk. For these species, fishing related impacts are likely to be smaller given their abundance in the Gulf of Carpentaria compared to other species (*i.e.* prevalence of *C. tilstoni verse C. limbatus*). Management of the risk posed to these species, beyond what is already being undertaken as part of the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017), is not considered an immediate priority. With improved information, these species could (potentially) be excluded from future iterations GOCIF Target & Byproduct Species Level 2 ERA.

For the remainder of the species (*n* = 13), the final rating is more representative of the risk posed by fishing activities in the GOCIF. These are viewed as higher priorities and the management of the risk may require more formal arrangements *e.g.* harvest strategies. For a number of these species, risk management strategies will need to consider actions at a whole-of-fishery and species-specific level. The outputs of the Target & Byproduct Species Level 2 ERA will assist in this process and the following have been identified as areas where risk profiles can be refined and the level of risk reduced. These recommendations are complimented within the report by complex-specific recommendations aimed at reducing risk or improving the accuracy of the assessments involving individual species. A number of these recommendations are already being actively considered and progressed as part of the *Queensland Sustainable Fisheries Strategy 2017–2027*.

1. *Review management arrangements employed in the fishery (e.g. minimum, maximum legal size limits) and identify areas where the biological risk can be minimised for key species.*

2. *Establish a mechanism to manage and minimise the long-term sustainability risk for key target and byproduct species, preferably through the introduction of a fishery-specific harvest strategy with clearly defined harvest control rules and sustainability assessment protocols.*

3. *Identify avenues/mechanisms that can be used to monitor the catch of target and byproduct species (preferably in real or near-real time) and minimise the risk of non-compliance.*

4. *Review the suitability, applicability and value of data submitted through the logbook program on the dynamics of the fishery (e.g. the type of gear being used, net configurations, soak times etc.). As part of this process, it is recommended that reporting requirements be extended to include information on what fishing symbol is being used.*

5. *Implement measures to improve the level of information on fine-scale effort movements, with particular emphasis on increasing our understanding of how gillnets are utilised in habitats critical to the survival of key species.*

6. *Review fisheries legislation to ensure that regulated species are afforded the correct level of management, to reduce uncertainty in the protection status of some species and clarify species definitions.*

7. *Establish a measure to estimate the gear-affected area and, when available, reassess the risk posed to teleosts species using a more quantitative ERA method e.g. base Sustainability Assessment for Fishing Effects (bSAFE).*

Summary of the outputs from the Level 2 ERA for Target & Byproduct species that interact with the Gulf of Carpentaria Inshore Fishery (GOCIF).

Common name	Species Name	Productivity	Susceptibility	*Risk Rating*
Teleosts				
Grey mackerel	*Scomberomorus semifasciatus*	1.71	2.43	Medium
Spanish mackerel	*Scomberomorus commerson*	1.71	2.86	High
Barramundi	*Lates calcarifer*	1.86	2.43	Medium
King threadfin	*Polydactylus macrochir*	1.86	2.86	High
Blue threadfin	*Eleutheronema tetradactylum*	1.43	2.57	Medium
Giant queenfish	*Scomberoides commersonnianus*	1.86	2.57	Medium
Scaly jewfish	*Nibea squamosa*	1.57	2.71	Medium
Black jewfish	*Protonibea diacanthus*	1.71	2.57	Medium
Sharks				
Australian blacktip shark	*Carcharhinus tilstoni*	2.43	2.43	High
Spot-tail shark	*Carcharhinus sorrah*	2.29	2.43	High
Common blacktip shark	*Carcharhinus limbatus*	2.57	2.57	Precautionary High
Graceful shark	*Carcharhinus amblyrhynchoides*	2.43	2.57	Precautionary High
Great hammerhead	*Sphyrna mokarran*	2.86	2.43	High
Scalloped hammerhead	*Sphyrna lewini*	2.86	2.43	High
Winghead shark	*Eusphyra blochii*	2.43	2.43	High

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Definitions & Abbreviations

AFMA	–	Australian Fisheries Management Authority.
AFZ	–	Australian Fishing Zone.
BMP	–	Bycatch Management Plan.
bSAFE	–	*base Sustainability Assessment for the Fishing Effects*. The *Sustainability Assessment for Fishing Effects* or SAFE is one of the two ERA methodologies that can be used as part of the Level 2 assessment. This method can be separated into a base SAFE (bSAFE) and enhanced SAFE (eSAFE). The data requirements for eSAFE are higher than for a bSAFE, which aligns more closely to a PSA.
CAAB	–	*Codes for Australian Aquatic Biota.*
CMS	–	*Convention on the Conservation of Migratory Species of Wild Animals.*
CITES	–	*Convention on International Trade in Endangered Species of Wild Fauna and Flora.*
CSIRO	–	*Commonwealth Scientific and Industrial Research Organisation.*
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.
Gillnets	–	Gillnets include general purpose mesh nets (excluding ring nets), set mesh nets, and nets that are neither fixed nor hauled *i.e.* general gillnet fishing under the N3, N12 and N13 fishery symbols including anchored and drifting gillnets. For the purpose of this ERA, the definition of gillnets does not include small mesh net fishing activities conducted under the N11 fishery symbol.
GOCIF	–	*Gulf of Carpentaria Inshore Fishery*. The fishery was formally referred to as the *Gulf of Carpentaria Inshore Fin Fish Fishery* or GOCIFFF.
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 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.

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 (Department of Agriculture and Fisheries, 2019d). This process has now been formalised as part of the *Queensland Sustainable Fisheries Strategy 2017–2027* and risk assessments are being completed for priority fisheries (Department of Agriculture and Fisheries, 2018a). Once completed, the ERAs will inform a range of management initiatives including the development of harvest strategies, identifying key research needs, and implementing detailed bycatch mitigation strategies (Department of Agriculture and Fisheries, 2018a; b; 2020d).

In December 2019, a whole-of-fishery or Level 1 ERA was released for the Gulf of Carpentaria Inshore Fishery (GOCIF; Jacobsen *et al.*, 2019b).[1] The Level 1 ERA provided a broad-scale assessment of the risks posed by this fishery including the key drivers of risk and the ecological components most likely to experience an undesirable event. These outputs were based on considerations given to the current fishing environment (*e.g.* catch and effort levels, participation rates) and actions that are permissible under the current management regime (*e.g.* shifting effort, increasing fishing mortality). In the context of the broader ERA, these results were used to differentiate between low and high-risk elements and determine what ecological components should be progressed to a finer-scale assessment (Department of Agriculture and Fisheries, 2018a).

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 Fishing Effects* (SAFE) (Department of Agriculture and Fisheries, 2018a; Hobday *et al.*, 2007; Zhou & Griffiths, 2008). 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).

Under the ERA Guidelines (Department of Agriculture and Fisheries, 2018a), species with ongoing conservation concerns including those classified as Threatened, Endangered and Protected (TEP) were prioritised for assessment (Jacobsen *et al.*, 2021). Following this assessment, the focus shifts to harvested species (Target & Byproduct). The primary aim of the Target & Byproduct Species Level 2 ERA is to identify the key drivers of risk for individual species and provide further advice on how harvesting within GOCIF may affect the long-term sustainability of regional stocks. Outputs of the Level 2 ERA will inform discussions surrounding the development of a regional harvest strategy and assist with highlighting priorities for monitoring and research programs.

[1] *The Gulf of Carpentaria Inshore Fishery (GOCIF) has historically been referred to as the Gulf of Carpentaria Inshore Fin Fish Fishery or GOCIFFF including in the Level 1 ERA (Jacobsen et al., 2019b).*

2 Methods

2.1 The Fishery

The GOCIF extends from Slade Point near the tip of Cape York Peninsula westward to the Queensland – Northern Territory border and operates in all tidal waterways. Due to the similarities in fishing methods and target species, the GOCIF is frequently compared to the net sector of the East Coast Inshore Fishery (ECIF; Jacobsen *et al.*, 2019a). The GOCIF though is much smaller in terms of licence numbers and annual catch and effort levels. The licencing system used in the GOCIF is also simpler; consisting of just four fishery symbols (N3, N11, N12 and N13) compared to 17 in the ECIF (Department of Agriculture and Fisheries, 2019b; h).

The GOCIF is a net only fishery with the majority of effort reported against the N3 and N12 fishery symbols. The N3 fishery operates in estuarine and foreshore waters out to a 7 nautical mile (nm) limit. The fishing area of the N12 fishery starts further offshore and is restricted to waters between the 7nm limit and the boundary of the Australian Fishing Zone (AFZ). The fishing area of the N13 fishery is more restricted, with operators not permitted to fish within 25nm of the Queensland coastline. While noting these nuances, the N12 and N13 fishery uses similar gear, targets similar species and will have similar risk profiles (Department of Agriculture and Fisheries, 2019b). For these reasons, the Level 2 ERA assesses the N12 and N13 fisheries as a single entity.

While operators retain a wide range of species, only licence holders with an N3 symbol can target barramundi (*Lates calcarifer*). Similarly only N12 and N13 operators are permitted to target sharks, the white shark (*Carcharodon carcharias*), the sand tiger shark (*Odontaspis ferox*), the grey nurse shark (*Carcharias taurus*) and the speartooth shark (*Glyphis glyphis*).[2] More broadly, the take of marine resources in the GOCIF is primarily managed through input controls and the regime for some species (*e.g.* sharks) is less developed when compared to the Queensland east coast (Department of Agriculture and Fisheries, 2019b; h). The notable exceptions being hammerhead sharks (*Sphyrna* spp.) which are managed under a combined Total Allowable Commercial Catch (TACC) limit (Department of Agriculture and Fisheries, 2018d).

In addition to the three large mesh net symbols, a fourth net symbol is permitted for use in the GOCIF; the N11. The N11 or small mesh net fishery, makes a comparatively small contribution to the annual catch and effort levels. Operators in this fishery are restricted to the use of a cast, scoop or seine net and are subject to more stringent provisions regarding the permitted mesh size, net length and attendance distances (Department of Agriculture and Fisheries, 2019b). The profile for this sector differs considerably from the N3, N12 and N13 fisheries and these operations are viewed as a lower risk to the species being assessed. For these reasons, the N11 fishery was not included in this iteration of the Target & Byproduct Species Level 2 ERA (Department of Agriculture and Fisheries, 2019b).

The management regime for the entire GOCIF is being reviewed as part of the *Queensland Sustainable Fisheries Strategies 2017–2027* (Department of Agriculture and Fisheries, 2017). As part of this process, alternate management strategies are being developed and considered for the fishery *e.g.* regional management, increased use of species-specific quotas and the development of a

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[2] N3 licence holders can retain shark product but only if it is caught as a byproduct while targeting other species e.g. barramundi, threadfin, jewfish etc.

dedicated bycatch management plan (Department of Agriculture and Fisheries, 2019f). This review is ongoing and a number of the alternative strategies are still in development, have yet to be adopted or fully implemented. For these reasons, the Level 2 ERA only considered arrangements that were in place and enforceable at the time of the assessment.

In addition to the management reforms, the Target & Byproduct Species Level 2 ERA includes species that interact with the recreational and charter fishing sectors or be impacted on by other marine-based activities. These cumulative risks were taken into consideration as part of the Level 1 ERA (Jacobsen *et al.*, 2019b) and, when and where appropriate, will be given further consideration as part of this assessment. It is noted though that these impacts or cumulative risks involve a wider range of stakeholders and can be difficult to address through a fisheries management framework. Accordingly, cumulative risk comparisons will only be used to provide further context on the extent of the risk posed by commercial fishing activities to key species or species complexes.

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 North Marine Parks Network, 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 was obtained through the fisheries logbook program, a previous *Fisheries Observer Program* (FOP), the *Fishery Monitoring Program* (FMP)[3] and the *Statewide Recreational Fishing Survey* (Department of Agriculture and Fisheries, 2020a; 2021; Webley *et al.*, 2015).

2.3 Species Rationalisation Processes

The scope of the Level 2 ERA program for the GOCIF was determined by the outcomes of the whole-of-fishery (Level 1) assessment (Jacobsen *et al.*, 2019b). This assessment identified a number of high-risk elements that are now being progressed through to a finer-scale (Level 2) ERA including target & byproduct species, bycatch, marine turtles, dugongs, dolphins, batoids and sharks (Table 1). Only the target & byproduct component was included in this assessment. The risk posed to the remaining ecological components (marine turtles, dugongs, dolphins, batoids and sharks) will be evaluated in a separate Level 2 ERA(Jacobsen *et al.*, 2021).

A preliminary list of target & byproduct species was compiled using catch data submitted through commercial logbooks from 2017–2019 (inclusive). Catch reported against each species or species complex was summed across years and ranked from highest to lowest. Cumulative catch comparisons

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

were then used to identify the species and species complexes that made up 95% of the total catch. *Codes for Australian Aquatic Biota* (CAAB; http://www.cmar.csiro.au/caab/) were used to expand multi-species catch categories. A secondary review was then undertaken to remove duplicates, species with low or negligible catches, species that have limited potential to interact with the fishery and species where risk is being effectively managed through harvest strategies or output controls (*e.g.* TACC limits linked to detailed stock assessments and biomass reference points). Species not contained within the 95% cumulative catch records with conservation or vulnerability concerns were also considered for inclusion (*e.g.* hammerhead sharks, black jewfish *etc.*).

A summary of the species rationalisation process and the justifications used to include or omit a species from the analysis has been provided in Appendix A and B respectively.

Table 1. *Summary of the outputs from the Level 1 (whole-of-fishery) ERA for the Gulf of Carpentaria Inshore Fishery (GOCIF). * Does not include Species of Conservation Concern or target & byproduct species that were returned for to the water due to (e.g.) regulations, product quality etc.*

Ecological Component	Level 1 Risk Rating	Progression
Target & Byproduct	High	Level 2 ERA (this report)
Bycatch*	Medium / High	Level 2 ERA
Species of Conservation Concern (SOCC)		
Marine turtles	High	Level 2 ERA
Dugongs	Medium / High	Level 2 ERA
Whales	Low / Medium	Not progressed.
Dolphins	High	Level 2 ERA
Sea snakes	Low	Not progressed.
Crocodiles	Low	Not progressed.
Protected teleosts	Low	Not progressed.
Batoids	High	Level 2 ERA
Sharks	High	Level 2 ERA (this report)
Syngnathids	Negligible	Not progressed.
Seabirds	Low	Not progressed.
Terrestrial mammals	Negligible	Not progressed.
Marine habitats	Low	Not progressed.
Ecosystem processes	Precautionary High	Not progressed, data deficiencies.

2.4 ERA Methodology

Methodology used to construct the Level 2 ERA aligns closely with the *Ecological Risk Assessment for the Effects of Fishing* (ERAEF) and includes two assessment options: the PSA and SAFE (Australian Fisheries Management Authority, 2017; Hobday *et al.*, 2011; Zhou & Griffiths, 2008). 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 limit the potential for false negatives or high-risk species being incorrectly assigned a lower-risk rating. However, the PSA tends to be more conservative and research has shown that it has a higher potential to produce false positives. That is, low-risk species being assigned a higher-risk score due to the conservative nature of the method, data deficiencies *etc.* (Hobday *et al.*, 2011; Hobday *et al.*, 2007; Zhou *et al.*, 2016).

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 comparison, 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.*, 2016; Zhou *et al.*, 2011). As SAFE is a quantitative assessment, the method provides an absolute measure of risk or a continuum of values that can be compared directly to the above reference points (Hobday *et al.*, 2011). 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 (Hobday *et al.*, 2011; Zhou *et al.*, 2009). 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.*, 2019; Zhou *et al.*, 2014).

In the GOCIF, the ability to determine the gear-affected area is limited by the complexity of the fishery. In the Gulf of Carpentaria, net operators are permitted the use of multiple nets providing that the total net length does not exceed that permitted under each symbol or within a particular region (Department of Agriculture and Fisheries, 2019b). For example, some N3 operations can use up to six nets in a river or creek system providing that a) their combined length is no longer than 360m and b) the distance between the first and last net is no longer than five nautical miles (Department of Agriculture and Fisheries, 2019b). These operational nuances are of some importance as the number of nets being used, their configuration, the distance between each net and the extent of any overlap will have a bearing on the gear-affected area.

At a whole-of-fishery level, commercial net fishers are only required to submit information on the mesh size, total net length used (or combined net length) and, if using a drift or set gillnet, soak times. Operators are not required to nominate the symbol they are fishing under and are only required to report the dominant mesh size used across the entire operation. These factors may also have a bearing on the accuracy of SAFE estimates involving the affected fishing area, net *selectivity* and the *encounterability* potential (Zhou *et al.*, 2011; Zhou *et al.*, 2008).

Given the complexity of the current fishing arrangements and uncertainty in determining the gear-affected area, the PSA was adopted for the first phase of the GOCIF Target & Byproduct Species Level 2 ERA. This decision aligns with corresponding assessment involving species with conservation concerns (Jacobsen *et al.*, 2021); meaning the entire GOCIF will be assessed under a single methodology. As a high number of the initiatives instigated under the *Queensland Sustainable Fisheries Strategy 2017–2027* are designed to improve information levels (Department of Agriculture and Fisheries, 2017), there may be more avenues to apply SAFE in subsequent ERAs. This includes the extended use of *Vessel Tracking* which will increase the level of information on fine-scale effort movements and aid in the transition to a SAFE assessment.

2.4.1 Productivity & Susceptibility Analysis (PSA)

The PSA was largely aligned with the ERAEF approach employed for Commonwealth fisheries (Australian Fisheries Management Authority, 2017; Hobday *et al.*, 2011). 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 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 species 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 Productivity & Susceptibility Analysis (PSA) utilised as part of the Target & Byproduct Species 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, 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.*, 2011; Hobday *et al.*, 2007). 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 (2017, 2018 and 2019) 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 (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 score 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 the *selectivity* score include the fishing method, the apparatus used and the body size of the species in relation to the mesh size. As the maximum mesh size used in the GOCIF is comparable to a Commonwealth managed shark gillnet fishery (Australian Fisheries Management Authority, 2018a), the same criteria were applied to large mesh net operations in the GOCIF (Table 3).

- **Post-capture mortality**—*Post-capture mortality* is one of the more difficult attributes to assess in a marine environment. In the PSA, this assessment has been simplified for target & byproduct species with all retainable product being assigned a high (3) risk rating for this attribute (Hobday *et al.*, 2011). The premise being that survival rates for these species will be zero as they will (most likely) be retained for sale.

In addition to the four baseline attributes, the Target & Byproduct Species Level 2 ERA included three additional *susceptibility* attributes: *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 (Furlong-Estrada *et al.*, 2017; Patrick *et al.*, 2010).

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 based on arbitrary or outdated biomass estimates / 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 Strategy targets.
Recreational desirability / Other fisheries	<33% retention.	33–66% retention.	>66% retention.

In the Level 2 ERA, the three additional attributes will be used to further reduce the influence of false positives or risk overestimations for key species. Summaries for each attribute are as follows:

- **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 has been confirmed through stock assessments or the national *Status of Australian Fish Stocks* (SAFS) will be assigned a lower-risk score. 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. In the PSA, preliminary risk ratings are based on retention rate estimates obtained through recreational fishing surveys (Department of Agriculture and Fisheries, 2020a; Webley *et al.*, 2015). Under the criteria used (Table 3), species with higher retention rates will be assigned more conservative risk scores.

  For the purpose of this ERA, recreational retention rates were used as an indicative assessment of a species popularity across sectors (*i.e.* recreational and charter fisheries). It is however acknowledged that the charter fishery is monitored and managed as a separate entity. When and where appropriate these impacts and those of other commercial fisheries will be given further consideration as part of the *Residual Risk Assessment* (RRA).

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 (Brown *et al.*, 2013; Hobday *et al.*, 2011; Patrick *et al.*, 2010). 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 and 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 (Brown *et al.*, 2013; Hobday *et al.*, 2007; 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.

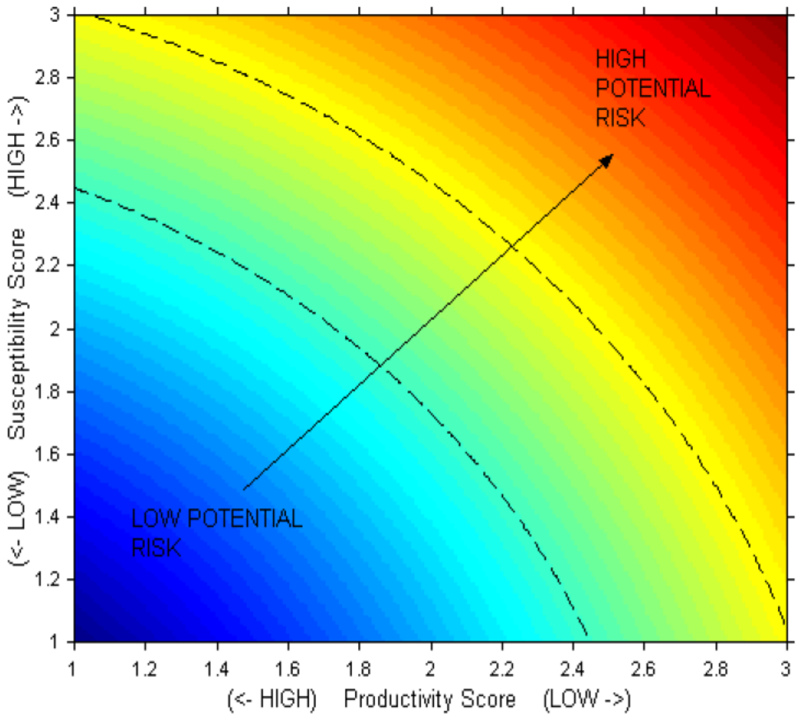

Figure 1. *PSA plot demonstrating the two-dimensional space which species units are plotted. PSA scores for species units represent the Euclidean distance or the distance between the origin and the productivity (x axis), susceptibility (y axis) intercept (excerpt from Hobday. et al., 2007).*

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 (3) 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 and Research Plan* (Department of Agriculture and Fisheries, 2018c).

2.4.4 Residual Risk Analysis (RRA)

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 a 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, 2018a) 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, 2018b). 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, 2018b). In Queensland, this guideline was retained as the broader ERA framework includes a series of consultation steps that aid in the development and finalisation of both the whole-of-fishery (Level 1) and species-specific (Level 2) 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. Summary represents a modified excerpt from the AFMA Ecological Risk Assessment, Residual Risk Assessment Guidelines (Australian Fisheries Management Authority, 2018b).*

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 corrected 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 *Queensland 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.

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

3 Results

3.1 PSA

The majority of the GOCIF catch (95%) was reported against nine categories including grey and Spanish mackerel (*Scomberomorus semifasciatus* and *S. commerson*), barramundi (*Lates calcarifer*), blue threadfin (*Eleutheronema tetradactylum*), king threadfin (*Polydactylus macrochir*), queenfish (*Scomberoides spp.*), scaly jewfish (*Nibea squamosa*), and blacktip sharks (*Carcharhinus spp.*). These nine catch categories produced a preliminary list of 14 target & byproduct species that were considered for inclusion in the Level 2 ERA. A subsequent species rationalisation process reduced this list to 11 species (Appendix B).

In addition to the above, four species that did not meet the initial 95% catch thresh hold (Appendix A) were included in the assessment. Harvest rates for black jewfish (*Protonibea diacanthus*) have increased substantially in recent years due to exponential growth in the value of their swim bladders. Similarly, scalloped hammerhead (*Sphyrna lewini*), great hammerhead (*S. mokarran*) and winghead shark (*Eusphyra blochii*) did not meet the 95% catch threshold but were included in the assessment due to ongoing conservation concerns (Simpfendorfer, 2014; Smart & Simpfendorfer, 2016). Following the addition and removal of species, a total of eight teleost and seven shark species were included in the assessment.

Productivity scores varied across teleosts and sharks (*average* = 2.14), with blue threadfin (1.43) generating the lowest *productivity* score and the scalloped and great hammerhead shark (2.86) having the highest. Of the seven *productivity* attributes assessed, *size at maturity* (average 2.20) and *trophic level* (average 3.00) were assigned the highest overall scores. Conversely, *age at maturity, fecundity* and *reproductive strategy* had the lowest *productivity* scores averaging 1.80, 1.93 and 1.93 respectively (Table 5).

In the *susceptibility* analysis, all species registered scores of between 2.29 and 3.00 with an average of 2.66 (Table 5). One teleost, scaly jewfish, was assigned the maximum score for all seven attributes. Two attributes, *encounterability,* and *post-capture mortality,* had an average score of 3.00. *Sustainability assessments* and *recreational desirability* had the highest degree of variability (Table 5).

Table 5. *Preliminary risk ratings compiled as part of the Productivity & Susceptibility Analysis (PSA) and the scores assigned to each attribute used in the assessment. Final PSA values are calculated using the scores assigned to each attribute and in accordance with the methods outlined in Hobday et al. (2007). * 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 maturity	Reproductive strategy	Trophic level	Productivity	Availability	Encounterability	Selectivity	Post-capture mortality	Management strategy	Sustainability assessments	Recreational desirability / other fisheries	Susceptibility	*PSA score*
Teleosts																		
Grey mackerel	*Scomberomorus semifasciatus*	1	2	1	2	2	1	3	1.71	2	3	3	3	3	2	3*	2.71	**3.21**
Spanish mackerel	*Scomberomorus commerson*	1	2	1	2	2	1	3	1.71	2	3	3	3	3	3	2	2.71	**3.21**
Barramundi	*Lates calcarifer*	2	2	1	2	2	1	3	1.86	2	3	3	3	3	1	1	2.29	**2.95**
King threadfin	*Polydactylus macrochir*	2	2	1	2	2	1	3	1.86	3	3	3	3	3	3	2	2.86	**3.41**
Blue threadfin	*Eleutheronema tetradactylum*	1	1	1	1	2	1	3	1.43	3	3	3	3	3	2	2	2.71	**3.07**
Giant queenfish	*Scomberoides commersonnianus*	2	2	1	2	2	1	3	1.86	2	3	3	3	3	3*	3*	2.86	**3.41**
Scaly jewfish	*Nibea squamosa*	3*	2	1	1	2	1	3*	1.86	3	3	3	3	3	3*	3*	3.00	**3.53**
Black jewfish	*Protonibea diacanthus*	1	2	1	2	2	1	3	1.71	2	3	3	3	2	3*	1	2.43	**2.97**

Common name	Species Name	Age at maturity	Maximum age	Fecundity	Maximum size	Size at maturity	Reproductive strategy	Trophic level	Productivity	Availability	Encounterability	Selectivity	Post-capture mortality	Management strategy	Sustainability assessments	Recreational desirability / other fisheries	Susceptibility	*PSA score*
Sharks																		
Australian blacktip shark	*Carcharhinus tilstoni*	2	2	3	2	2	3	3	2.43	2	3	3	3	3	1	3*	2.57	**3.54**
Spot-tail shark	*Carcharhinus sorrah*	1	2	3	2	2	3	3	2.29	2	3	3	3	3	1	3*	2.57	**3.44**
Common blacktip shark	*Carcharhinus limbatus*	2	2	3	2	3	3	3	2.57	2	3	3	3	3	3*	3*	2.86	**3.84**
Graceful shark	*Carcharhinus amblyrhynchoides*	3*	3*	3	2	2	3	3	2.71	2	3	3	3	3	3*	3*	2.86	**3.94**
Great hammerhead	*Sphyrna mokarran*	2	3	3	3	3	3	3	2.86	2	3	1	3	3	1	3*	2.29	**3.66**
Scalloped hammerhead	*Sphyrna lewini*	2	3	3	3	3	3	3	2.86	2	3	3	3	3	1	3*	2.57	**3.84**
Winghead shark	*Eusphyra blochii*	2	2	3	2	2	3	3	2.43	2	3	3	3	3	1	3*	2.57	**3.54**

When the *productivity* and *susceptibility* scores were taken into consideration, the graceful shark had the highest preliminary risk score (3.94), followed by the scalloped hammerhead shark and common blacktip shark (3.84). Blue threadfin, black jewfish, and barramundi generated the lowest scores (2.95–3.07) and were assigned medium-risk ratings. Based on these results, five teleosts and all seven shark species were assigned preliminary PSA scores in the high-risk category (Table 5). The remainder were assigned a preliminary risk scores of medium.

3.2 Uncertainty

Productivity assessments for teleosts and sharks were all largely supported by scientific evidence with limited data deficiencies identified in four attributes: *maximum age, age at maturity,* and *trophic level* (Table 5; Table 6).

In the *susceptibility* analysis, all scores assigned to the *availability, encounterability,* and *selectivity* attributes were supported by information on their morphology, habitat/bathymetric preferences, and distributional overlaps with the effort footprint (Table 6). *Post-capture mortality* and *management arrangements* attributes were assigned high (3) risk scores for all species given that they can be retained and are all managed within GOCIF's broader management regime. The remaining two *susceptibility* attributes, *sustainability assessments* and *recreational desirability / other fisheries*, were missing information for several teleosts and sharks (Table 6).

Table 6. *Summary of the number of attributes that were assigned a precautionary high (3) score due to data deficiencies.*

Productivity	**Age at maturity**	**Maximum age**	**Fecundity**	**Maximum size**	**Size at maturity**	**Reproductive strategy**	**Trophic level**
No. species with data	13	14	15	15	15	15	14
No. species with missing attribute data	2	1	0	0	0	0	1
% unknown information	13%	7%	0%	0%	0%	0%	7%
Susceptibility	**Availability**	**Encounterability**	**Selectivity**	**Post-capture mortality**	**Management strategy**	**Sustainability assessments**	**Recreational desirability / other fisheries**
No. Species with data	15	15	15	15	15	10	5
No. Species with missing attribute data	0	0	0	0	0	5	10
% unknown Information	0%	0%	0%	0%	0%	33%	67%

3.3 Residual Risk Analysis

The GOCIF Target & Byproduct Species Level 2 ERA covers a variety of species with varying life-history traits, habitat preferences and information gaps. This complexity was reflected in the RRA where a number of the risk profiles were amended to take into account additional information and mitigation measures. The following provides an overview of changes that were adopted as part of the RRA. A full overview of the RRA including the key considerations for each species has been provided in Appendix D.

3.3.1 Teleosts

One teleost, scaly jewfish, had missing information for two biological attributes; *age at maturity* and *trophic level* (Table 5). To address these deficiencies, precautionary high-risk (3) scores were replaced with proxy values from species from within the same genus or family (Table 7; Appendix D).

For the *susceptibility* component of the assessment, the majority of RRA changes involved the *recreational desirability / other fisheries* attribute (Table 7). In this instance, the RRA gave further consideration to the impacts of non-commercial fishing activities and the targeting of key species in the Gulf of Carpentaria Line Fishery (Table 7; Appendix D).

As a result of the RRA, final risk ratings for grey mackerel, scaly jewfish and queenfish were downgraded from high to medium (Table 7). The RRA did not alter the final risk rating for the remainder of the species (Table 5; Table 7).

3.3.2 Sharks

The RRA resulted in two amendments being made to the *productivity* component of the shark PSA. Both of these amendments (*age at maturity*, *maximum age*) involved the graceful shark and the use of proxies (Table 7; Appendix D).

The RRA for the *susceptibility* attributes was more substantive with all seven shark risk profiles having at least one amendment. The majority of these amendments involved the *recreational desirability / other fisheries* attribute and involved species with precautionary high (3) risk ratings. Scores for the other attributes were increased based on capture potential (*i.e.* hammerhead shark head morphology and their *susceptibility* to net entanglements; Ellis *et al.*, 2017; Harry *et al.*, 2011b) and caveats underpinning the stock *sustainability assessments*. In all instances, amendments made as part of the RRA did not alter the final risk ratings (Table 7).

4 Risk Evaluation

4.1 Gillnets (General)

When the results of the PSA and RRA were taken into consideration, the Level 2 ERA indicates that fishing activities in the GOCIF present a high risk to most of the target and byproduct species (Table 7). Biological and life-history constraints were a key driver of risk for a proportion of the species and, in the case of sharks, was the main contributor of risk. If for example, all of the *susceptibility* attributes were assigned the lowest value possible (1), three out of seven shark species would still register a medium-risk rating. This highlights the inherent challenge of managing fishing-related risks for species with *k*-selected life histories.

Table 7. *Residual Risk Assessment (RRA) of the preliminary scores assigned as part of the Productivity and Susceptibility Analysis (PSA). Pink shaded squares represent the attribute scores that were amended as part of the RRA. Refer to Appendix D for a full account of the RRA including key justifications.*

Common name	Species Name	Age at maturity	Maximum age	Fecundity	Maximum size	Size at maturity	Reproductive strategy	Trophic level	Productivity	Availability	Encounterability	Selectivity	Post-capture mortality	Management strategy	Sustainability assessments	Recreational desirability / other fisheries	Susceptibility	*PSA score*
Teleosts																		
Grey mackerel	*Scomberomorus semifasciatus*	1	2	1	2	2	1	3	1.71	2	3	3	3	3	2	1	2.43	**2.97**
Spanish mackerel	*Scomberomorus commerson*	1	2	1	2	2	1	3	1.71	2	3	3	3	3	3	3	2.86	**3.33**
Barramundi	*Lates calcarifer*	2	2	1	2	2	1	3	1.86	2	3	3	3	3	2	1	2.43	**3.06**
King threadfin	*Polydactylus macrochir*	2	2	1	2	2	1	3	1.86	3	3	3	3	3	3	2	2.86	**3.41**
Blue threadfin	*Eleutheronema tetradactylum*	1	1	1	1	2	1	3	1.43	3	3	3	3	3	2	1	2.57	**2.94**
Giant queenfish	*Scomberoides commersonnianus*	2	2	1	2	2	1	3	1.86	2	3	3	3	3	3	1	2.57	**3.17**
Scaly jewfish	*Nibea squamosa*	1	2	1	1	2	1	3	1.57	3	3	3	3	3	3	1	2.71	**3.14**
Black jewfish	*Protonibea diacanthus*	1	2	1	2	2	1	3	1.71	2	3	3	3	2	3	2	2.43	**3.09**

Common name	Species Name	Age at maturity	Maximum age	Fecundity	Maximum size	Size at maturity	Reproductive strategy	Trophic level	Productivity	Availability	Encounterability	Selectivity	Post-capture mortality	Management strategy	Sustainability assessments	Recreational desirability / other fisheries	Susceptibility	*PSA score*
Sharks																		
Australian blacktip shark	*Carcharhinus tilstoni*	2	2	3	2	2	3	3	2.43	2	3	3	3	3	2	1	2.43	**3.43**
Spot-tail shark	*Carcharhinus sorrah*	1	2	3	2	2	3	3	2.29	2	3	3	3	3	2	1	2.43	**3.34**
Common blacktip shark	*Carcharhinus limbatus*	2	2	3	2	3	3	3	2.57	2	3	3	3	3	2	1	2.43	**3.54**
Graceful shark	*Carcharhinus amblyrhynchoides*	2	2	3	2	2	3	3	2.43	2	3	3	3	3	3	1	2.57	**3.54**
Great hammerhead	*Sphyrna mokarran*	2	3	3	3	3	3	3	2.86	2	3	3	3	3	2	1	2.43	**3.75**
Scalloped hammerhead	*Sphyrna lewini*	2	3	3	3	3	3	3	2.86	2	3	3	3	3	2	1	2.43	**3.75**
Winghead shark	*Eusphyra blochii*	2	2	3	2	2	3	3	2.43	2	3	3	3	3	2	1	2.43	**3.43**

In the *susceptibility* analysis, the drivers of risk were more varied (Table 7). However, a number of common themes emerged from the study that increased the level of risk across multiple subgroups and/or the level of uncertainty. These include the absence of an effective mechanism to monitor catch and effort (*management strategy*), an inability to validate catch submitted through the logbook program (*management strategy*), the absence of biomass reference points or sustainability evaluations (*sustainability assessments*) and cumulative fishing pressures (*recreational desirability / other fisheries*). In most of these instances, the risks will need to be managed across the entire GOCIF and/or through the harvest strategy development process (Department of Agriculture and Fisheries, 2017; 2020d).

At the whole-of-fishery level, the target and byproduct ERA identified a number of areas where the accuracy of the profiles could be improved and risk reduced across multiple species or subgroups. As most of these measures relate to the collection of data, catch monitoring and validation, their implementation would benefit a wide range of species—not just those included in the Target & Byproduct Species Level 2 ERA. A number of the above recommendations are already being addressed or implemented as part of the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017) including mandating the use of *Vessel Tracking*, establishing a *Fisheries Data Validation Plan* and implementing fisheries-specific harvest strategies (Department of Agriculture and Fisheries, 2018b; f; 2020d). These initiatives though will take time to develop and implement; particularly in a multidimensional, multifaceted fishery like the GOCIF.

General recommendations

1. *Review management arrangements employed in the fishery (e.g. minimum, maximum legal size limits) and identify areas where the biological risk can be minimised for key species.*

2. *Establish a mechanism to manage and minimise the long-term sustainability risk for key target and byproduct species, preferably through the introduction of a fishery-specific harvest strategy with clearly defined harvest control rules and sustainability assessment protocols.*

3. *Identify avenues/mechanisms that can be used to monitor the catch of target and byproduct species (preferably in real or near-real time) and minimise the risk of non-compliance.*

4. *Review the suitability, applicability and value of data submitted through the logbook program on the dynamics of the fishery (e.g. the type of gear being used, net configurations, soak times etc.). As part of this process, it is recommended that reporting requirements be extended to include information on what fishing symbol is being used.*

5. *Implement measures to improve the level of information on fine-scale effort movements, with particular emphasis on increasing our understanding of how gillnets are utilised in habitats critical to the survival of key species.*

6. *Review fisheries legislation to ensure that regulated species are afforded the correct level of management, to reduce uncertainty in the protection status of some species and clarify species definitions.*

7. *Establish a measure to estimate the gear-affected area and, when available, reassess the risk posed to teleosts species using a more quantitative ERA method e.g. bSAFE.*

4.2 Species-Specific Assessments

4.2.1 Teleosts

Teleost risk profiles were heavily influenced by the available data and the importance of the species to the fishery. For instance, the Level 2 ERA included a number of teleosts that are retained in smaller quantities as byproduct. Due to their (comparatively) low rates of harvest, these species will not be prioritised for stock assessments or indicative sustainability evaluations. These deficiencies were given significant weighting in the Level 2 ERA and contributed to the production of more conservative risk assessments. This was of particular relevance to assessments involving the *management strategy* and *sustainability assessments* attributes (Table 7).

Including secondary target species in the Level 2 ERA provides the assessment with additional scope and will assist management if the current fishing environment changes. This approach also minimises the potential of an at-risk species being omitted from the analysis. With improved information, a number of the low-harvest species could (potentially) be excluded from future iterations of the GOCIF Target & Byproduct Species Level 2 ERA. It is however recognised that this situation could change as the management regime allows for catch and effort to increase for individual species *e.g.* due to increased market demand. If this were to occur, outputs of the Level 2 ERA provides a sound baseline of assessments that can be reviewed and amended (where appropriate) to accommodate additional data or management reforms.

The teleost subgroup received consistently high scores across the majority of the *susceptibility* attributes (Table 7). This was to be expected given that they are actively targeted across their preferred habitats and known distributions. The risk posed to a number of the species was further elevated by the absence of an effective mechanism to control catch or effort, and uncertainty surrounding key biomass reference points. These issues were compounded by the fact that it can be difficult to validate data submitted through the logbook program or quantify total rates of fishing mortality for individual species. These were considered key risk factors in the GOCIF and are areas where future ERAs could be refined and improved.

As noted, a number of the risks identified in the Level 2 ERA are being addressed as part of the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017). When compared to the Queensland east coast, the reform process for fisheries in the Gulf of Carpentaria is less advanced. For example, a draft harvest strategy has already been developed and released for the ECIF; the fishery most comparable to the GOCIF (Department of Agriculture and Fisheries, 2020d). The draft ECIF harvest strategy places greater emphasis on the use of output controls and regional management, and it is viewed as a more effective mechanism to address short and long-term risks within this fishery. In the absence of an analogous strategy, it will be more difficult to address some of the risks contained within this report.

The following provides an overview of the key drivers of risk for all teleosts included in the GOCIF Target & Byproduct Species Level 2 ERA. Where possible, these evaluations include recommendations on where risk may be reduced within a particular subgroup and avenues that could be used to improve the accuracy of the risk assessments for key species. When and where appropriate, precautionary high risks have been identified in recognition of the fact that these profiles are more conservative and are of low priority in terms of management intervention.

4.2.1.1 Mackerels

Common name	Sub-fishery	Risk Rating
Grey mackerel (*S. semifasciatus*)	N12/N13 fishery	**Medium**
Spanish mackerel (*S. commerson*)	N12/N13 fishery	**High**

Grey (*S. semifasciatus*) and Spanish (*S. commerson*) mackerel were included in the Level 2 ERA due to their prevalence as target species in the N12/N13 fishery. While these species may be encountered infrequently in the N3 fishery, the risk posed by this sector will be comparatively low. Similarly, school (*S. queenslandicus*) and spotted mackerel (*S. munroi*) were considered for inclusion in the Level 2 ERA but were omitted from the analysis due to the species having low to negligible catches in the Gulf of Carpentaria (Appendix B; Department of Agriculture and Fisheries, 2019b; Department of Agriculture and Fisheries, 2020a). As the structure of the Level 2 ERA easily accommodates the addition of new species, the inclusion of school and spotted mackerel will be given further consideration in subsequent GOCIF ERAs.

The commercial take of grey and Spanish mackerel in the GOCIF is not limited or managed under quota (*e.g.* ITQs or a TACC limit). This differs from the Queensland east coast where grey and Spanish mackerel are managed under a TACC limit and ITQs[4] respectively (Department of Agriculture and Fisheries, 2019a; h). Aside from minimum legal size limits and recreational in-possession limits, there is minimal capacity under the current management regime to address the risk of an overfishing event. This issue is compounded by the fact that mackerel species are targeted in the Gulf of Carpentaria Line Fishery (GOCLF) (Department of Agriculture and Fisheries, 2019e). As the GOCLF operates under a comparable management system (*i.e.* no quotas), catch and effort for grey and Spanish mackerel can increase within and across both commercial fisheries. These limitations were viewed as a significant risk factor for this subgroup and were assessed according as part of the *management strategy* attribute review (Table 7; Appendix D).

Harvest share for Spanish mackerel in the Gulf of Carpentaria is dominated by the commercial sector (97%) (Bessell-Browne *et al.*, 2020). This differs markedly from the east coast where the recreational and charter sectors account for 47% and 6% of the total Spanish mackerel catch respectively (Department of Environment and Energy, 2018). Most of the Spanish mackerel catch in the Gulf of Carpentaria is reported through the GOCLF (approx. 200–250t); although net fishers still make a sizable contribution to the total harvest (approx. 40–50t) (Department of Agriculture and Fisheries, 2019b; e; 2020a). These cumulative fishing pressures were given significant weighting in the RRA and were reflected in scores assigned to the *recreational desirability / other fisheries* attributes (Table 7; Appendix D). When compared, cumulative risks for grey mackerel tend to be smaller as the overwhelming majority are retained by commercial net fishers (Department of Agriculture and Fisheries, 2019b; e; 2020a).

[4] *Spanish mackerel also operates under a TACC limit which equals the combined catch permitted under the ITQs.*

Of the two, only Spanish mackerel has been the subject of a detailed stock assessment in the Gulf of Carpentaria (Bessell-Browne *et al.*, 2020).[5] While the assessment showed that the spawning biomass (32%) was above MSY (29%), a number of concerns were raised about the long-term sustainability of regional stocks. These concerns included declining standardised catch rates and a continued decline in relative spawning biomass estimates (Bessell-Browne *et al.*, 2020). More importantly, the assessment found that the collective commercial harvest of Spanish mackerel exceeded MSY (228t) several times over the last decade including within the most recent three years (234t, 2017; Department of Agriculture and Fisheries, 2020a).[6] These issues were taken into consideration as part of the latest stock status evaluation which assessed the Queensland Gulf of Carpentaria Spanish mackerel stock as 'depleting' (Roelofs *et al.*, 2020a). Both of these factors were instrumental in the species receiving a high-risk rating for the *sustainability assessment* attribute (Table 5; Table 7). While this risk may be more applicable to the GOCLF, net-harvest rates are considered sufficient to warrant further consideration of risk mitigation strategies for the GOCIF.

The sustainability of grey mackerel stocks has only been confirmed through indicative stock status evaluations (Helmke *et al.*, 2018; Roelofs *et al.*, 2020b). While the species has a stock assessment on the Queensland east coast (Bessell-Browne *et al.*, 2019), this process has yet to commence in the Gulf of Carpentaria. Grey mackerel (by weight) are the largest harvest component in the GOCIF and the species regularly reports annual catches in excess of 700t (Department of Agriculture and Fisheries, 2019b; 2020a). These values far exceed that reported from the Queensland east coast where annual grey mackerel catches fluctuate between 150t and 230t (post-2009 data; Department of Agriculture and Fisheries, 2019h; Department of Agriculture and Fisheries, 2020a). One of the key differences being that grey mackerel stocks on the Queensland east coast are managed through a 250t TACC limit (Department of Agriculture and Fisheries, 2019h; Pidd *et al.*, 2021). This is not the case in the Gulf of Carpentaria where stocks continue to be managed through input controls.

Grey mackerel received a lower score for *sustainability assessments* attribute due to the species having a positive sustainability evaluation (Helmke *et al.*, 2018; Roelofs *et al.*, 2020b). While noting this assessment, there are demonstrated benefits of undertaking stock assessments and establishing clearly defined sustainability reference points. This is perhaps best exemplified by Spanish mackerel where, prior to the stock assessment and in the absence of competing data, the species received a favourable sustainability evaluation (Langstreth *et al.*, 2018). Given that GOCIF is responsible for most of the regional grey mackerel catch, future ERAs would benefit from a more refined assessment of grey mackerel stock status in the Gulf of Carpentaria. This information would also be of assistance when assessing the suitability and applicability of alternate management arrangements including the (potential) use of quota.

Going forward, grey and Spanish mackerel will derive benefit from the introduction of a GOCIF-specific harvest strategy. For grey mackerel, a transition towards output controls would reduce the risk of an overfishing event and provide greater certainty that the fishery was being managed against key biological reference points. The situation for Spanish mackerel may be more complicated given that it is a key target in the GOCLF (Department of Agriculture and Fisheries, 2019e; Walton &

[5] *The sustainability of Spanish mackerel stocks in the Gulf of Carpentaria has previously been confirmed for through indicative stock status evaluations (Langstreth et al., 2018). This assessment was conducted prior to the completion of the Gulf of Carpentaria stock assessment (Bessell-Browne et al., 2020).*

[6] *https://qfish.fisheries.qld.gov.au/query/7fbf244a-5bf7-4956-a1f8-0a6fdc11b6b7/table?customise=True#*

Jacobsen, 2019). With that said, there is a clear need to refine the management of both species in order to a) minimise the long-term sustainability risk, b) establish a fishing environment that is more conducive to stock building and c) meet long-term objectives (*i.e.* B_{60}) under the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017).

Species-specific recommendations

1. *Undertake a quantitative stock assessment for grey mackerel in the Gulf of Carpentaria and establish a baseline of biological/biomass reference points that can be used to inform a future harvest strategy.*

2. *Prioritise grey mackerel for management reform in the harvest strategy development process with consideration given to the suitability and applicability of transitioning the species to output controls.*

3. *Establish a mechanism to manage the take of Spanish mackerel in the Gulf of Carpentaria and avenues to effectively manage cumulative fishing pressures across the key commercial fisheries e.g. across the GOCIF and GOCLF.*

4.2.1.2 Barramundi

Common name	Sub-fishery	Risk Rating
Barramundi (*L. calcarifer*)	N3 fishery	**Medium**

As barramundi (*L. calcarifer*) had one of the highest *productivity* scores, biological constraints exerted considerable influence on the final risk rating (Table 7). However, the key drivers of risk were still grounded in the *susceptibility* analysis; namely the *encounterability*, *selectivity* and *post-capture mortality* attributes. Reductions of these risks will be difficult to justify in future ERAs as the species will continue to experience high demand in the GOCIF. These risks are unlikely to be uniform and will be higher in inshore waters, estuaries and rivers (Balston, 2009; Saunders *et al.*, 2018; Streipert *et al.*, 2019). Risks will also be more prevalent in areas where there is greater overlap between commercial and recreational fishing effort.

The lowest score in the barramundi *susceptibility* assessment was assigned to the *recreational desirability / other fisheries* attribute (Table 7)*.* Across the state, barramundi attracts a significant level of attention from recreational fishers with the sector harvesting an estimated 131–161t each year (Grubert *et al.*, 2020; Streipert *et al.*, 2019; Webley *et al.*, 2015). Cumulative fishing pressures are lower in the Gulf of Carpentaria where the charter fishing sector harvests ~1t per year (2017–19) and the recreational sector retains around 18,000 fish *versus* 24,000 on the east coast, 2013–14 survey data (Department of Agriculture and Fisheries, 2020a). Regional cumulative risks are further reduced through a prohibition on the take of barramundi in other commercial fisheries (i.e. line, trawl etc.; Department of Agriculture and Fisheries, 2019e). This combined with an extended seasonal closure helps mitigate some of the more significant cumulative fishing risks.

When compared to pelagic species, barramundi have a more complicated stock structure. There are seven known stocks in Queensland, and at least two occur in the Gulf of Carpentaria (Saunders *et al.*, 2018). Of notable importance, a regional stock assessment indicates that both Gulf of Carpentaria stocks are very close to or above 40% exploitable biomass (relative to virgin biomass) (Streipert *et al.*, 2019). This value aligns well with the targets set out in the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017) and suggest that the sustainability risk is being managed within the current fishing environment. This was the catalyst behind barramundi receiving a preliminary low (1) risk score for *sustainability assessments* (Table 5).

In the RRA, further consideration was given to a number of confounding factors and their potential to affect the long-term sustainability of the Southern Gulf stock (Appendix D). This stock is responsible for around 73% of Queensland's commercial barramundi harvest and it accounts for 96% of the commercial barramundi catch in the Gulf of Carpentaria (Streipert *et al.*, 2019). For these reasons, the Southern Gulf stock holds considerable importance within Queensland's broader barramundi fishery. Based on the results of the most recent assessment, the Southern Gulf stock biomass sits just below the B_{40} threshold (Streipert *et al.*, 2019). However, this assessment also notes that a) the current fishing environment is not conducive to stock rebuilding and b) the species was unlikely to reach the long-term target of B_{60} without management intervention or an overall reduction in catch (Streipert *et al.*, 2019). As the Southern Gulf stock has previously been classified as 'depleting' and historically 'overfished' (Campbell *et al.*, 2017; Saunders *et al.*, 2018; Streipert *et al.*, 2019), this inability to rebuild stock biomass was identified as a key risk for the GOCIF (Appendix D).

Due to the above considerations, the *sustainability assessment* score for barramundi was increased from low (1) to medium (2) (Appendix D). This change increased the overall risk score from 2.95 (Table 5) to 3.06 (Table 7) which is on the cusp of a high-risk rating (>3.18). This threshold would have been exceeded if evidence supported the allocation of a higher-risk rating for the *sustainability assessment* attribute—as seen for Spanish mackerel (refer section 4.2.1.1.) A change of this magnitude was not considered necessary, as negative signals observed in the Spanish mackerel data (*e.g.* declining standardised catch and relative biomass) were not replicated in the barramundi stock assessment (Bessell-Browne *et al.*, 2020; Streipert *et al.*, 2019).

As barramundi are not managed under a quota system there is some capacity for catch and effort to increase through time. If this were to occur, a review of the *sustainability assessment* score may be required (Table 7). Without the use of quota, these risks are primarily managed through minimum and maximum legal size limits, seasonal/spatial closures and in-possession limits for non-commercial fishers (see Fisheries Declaration 2019) (Department of Agriculture and Fisheries, 2018g). These measures are designed to reduce fishing-effort across sectors during key spawning periods and provides key age/size cohorts with additional protections. Stocking of barramundi in Gulf of Carpentaria catchments also takes place sporadically, and may help to reduce the risk of an overfishing event by supplementing natural recruitment processes (Queensland Government, 2020a).

A number of the risks posed to barramundi in the Gulf of Carpentaria will be considered as part of the harvest strategy development process. While this process is still in its infancy, the draft ECIF harvest strategy (Department of Agriculture and Fisheries, 2020d) provides insight into the types of strategies that could be employed in the GOCIF. Under the draft ECIF harvest strategy, barramundi are classified as a *Tier 1* species and will be prioritised for transition to a more complicated system of output controls. An analogous change in the GOCIF would most likely facilitate a score reduction in the *management strategy* and *sustainability assessment* attributes. Depending on the extent of the reduction, this could see the species drop to an overall risk score that was on the cusp of a low-risk rating (Table 7; Fig. 1).

Outside of the harvest strategy process, the barramundi risk profile could be refined with additional information on the fine-scale distribution of large mesh net effort in biologically important areas/habitats. This information may open up avenues for further refinements, particularly within the *availability* attribute. With sufficient improvements, this information could be used to construct a more comprehensive assessment using a quantitative ERA method like SAFE (Hobday *et al.*, 2011; Zhou & Griffiths, 2008).

Species-specific recommendations

1. *Identify mechanisms to transition barramundi to an output controlled management system underpinned by detailed harvest control rules.*

2. *Explore avenues to improve information used to underpin regional stock assessments including but not limited to barramundi biology, catch dynamics, fine-scale effort movements and factors that influence regional recruitment e.g. environmental water flows, stocking* (Streipert *et al.*, 2019).

4.2.1.3 Threadfin

Common name	Sub-fishery	Risk Rating
King threadfin (*P. macrochir*)	Primary—N3 fishery Secondary—N12/N13 fishery	**High**
Blue threadfin (*E. tetradactylum*)	Primary—N3 fishery Secondary—N12/N13 fishery	**Medium**

The threadfin complex includes a range of species that have the potential to interact with the GOCIF including the king (*P. macrochir*), blue (*E. tetradactylum*), flat/Australian (*P. multiradiatus*) and striped (*P. plebeius)* threadfin. As the majority of the commercial and recreational catch consists of king and blue threadfin (Department of Agriculture and Fisheries, 2019b; 2020a), these two were prioritised for assessment (Appendix B). The remaining species, when and where appropriate, will be considered for inclusion in subsequent GOCIF ERAs.

While blue threadfin sustainability has been confirmed through indicative sustainability evaluations (Department of Agriculture and Fisheries, 2018e; Roelofs *et al.*, 2020c; Whybird *et al.*, 2018), it has yet to be the subject of a detailed stock assessment. Consequently, there is limited information on current biomass levels and sustainability reference points. Without this information, it is difficult to ascertain how harvest rates may impact regional stocks and/or if the species is on track to meet long-term objectives outlined in the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017).

The situation for king threadfin differs in that the Gulf of Carpentaria stock was assessed as 'depleting' in the *Status of Australian Fish Stocks* process (Roelofs *et al.*, 2020d). This species is now the subject of a quantitative assessment examining the health of the stocks on the Queensland east coast and in the Gulf of Carpentaria. Preliminary results from this assessment support the outputs of the indicative sustainability evaluation and indicates that the biomass of the Gulf of Carpentaria king threadfin stock sits below MSY (*pers. comm.* G. Leigh). These preliminary results were accounted for in the *sustainability assessments* attribute and contributed to king threadfin having a higher overall risk rating.

Neither threadfin species are managed under output controls (*e.g.* a TACC limit or ITQs) meaning catch and effort can increase under the current management regime. These risks are compounded by minimum legal size limits which are set below the *size at maturity* for both species.[7] This discrepancy will expose juveniles to additional fishing pressures and may undermine long-term recruitment rates. The adoption of more appropriates size limits should be considered as part of the GOCIF harvest strategy development process. These discussions though will need to consider how best to increase the MLS limit whilst minimising discard-waste for species with higher rates of *post-capture mortality* (Welch *et al.*, 2010). In the GOCIF Target & Byproduct Species Level 2 ERA, the above were viewed as notable risks in terms of the long-term management of these species (Table 7).

King threadfin have experienced a notable increase in demand in the Gulf of Carpentaria due to the marketability of their swim bladders (Bayliss *et al.* 2014). Market demand for king threadfin swim bladders is not as high as black jewfish (*P. diacanthus*), however the introduction of more stringent management arrangements for *P. diacanthus* could see the market shift to species with fewer protections (see section 4.2.1.5 Jewfish; Department of Agriculture and Fisheries, 2019c). The situation with blue threadfin mirrors that of silver jewfish (*N. soldado*) in that the species is considered to be less marketable; possibly due to their smaller *maximum size* (Queensland Government, 2018a). The marketability of swim bladders will transcend the commercial sector and increases the risk of black marketing. While black marketing is being addressed (Department of Agriculture and Fisheries, 2019i), these reforms have largely focused on species from outside the threadfin complex (Department of Agriculture and Fisheries, 2019i).

Blue and king threadfin are recreationally desirable species, likely due to their popularity as sportfish. Recreational surveys from the Gulf of Carpentaria indicate that this sector harvests around 19t and 34t of blue and king threadfin respectively (Roelofs *et al.*, 2020c; d). This compares to 23–25t for barramundi which is another popular species within the recreational fishing sector (*pers. comm.* J. Webley, unpublished data). While the recreational sector harvests considerable amounts of both threadfin species, harvest share is still dominated by the commercial sector (blue threadfin 71%; king threadfin 81%) (unpublished data; Department of Agriculture and Fisheries, 2020a). As no other commercial fisheries in the Gulf of Carpentaria are permitted to retain blue and king threadfin, cumulative fishing pressures are expected to be lower for these species (Table 7; Appendix D).

In considering avenues for future score reductions, any improvements in the management of these species and their *sustainability assessments* would likely result in a lowering of their risk rating. For example, development of a harvest strategy and a move to output controls would contribute to a lowering of the *management arrangement* scores. If this were to occur, then both species would be classified as medium risk. Completion of a positive stock assessment for blue threadfin would also lower the *sustainability assessment* score and place it closer too if not within the low-risk category. The situation for king threadfin is more complicated as stock status and biomass estimates are unlikely to improve in the near future. Nevertheless, development of the management regime for both threadfin species will assist in reducing the risk of over-harvesting due to (*e.g.*) cumulative fishing pressures and/or increased market demand.

[7] *In the Gulf of Carpentaria, MLS for blue and king threadfin are 400mm and 600mm respectively (see Fisheries Declaration 2019). Female blue threadfin reach sexual maturity at 208–465mm (Welch et al., 2010), and king threadfin at 960–1140mm for females and 710–765mm for males (Moore et al., 2011).*

Species-specific recommendations

1. *Review the management regime for threadfin species including minimum legal size limits, spatial/temporal controls and/or the use of species-specific output controls that take into consideration discard mortalities and (potential) product wastage.*
2. *Investigate how recent reforms for black jewfish may impact the marketability and demand of threadfin species, including the potential for catch to increase rapidly over the short-term, and avenues that may reduce the risk of regional stocks becoming overfished across sectors.*
3. *Explore mechanisms to improve our understanding of the stock status of secondary threadfin species (specifically blue threadfin) through (for example) indicative assessments or their potential inclusion in future stock assessments.*

4.2.1.4 Jewfish

Common name	Species name	Risk Rating
Black jewfish (*P. diacanthus*)	N3 & N12/13 fisheries	**Medium**
Scaly jewfish (*N. squamosa*)	N3 & N12/13 fisheries	**Medium**

Similarities in morphology and habitat/distribution among jewfish has led to the reporting of these species into broader-scale catch categories *e.g. jewfish—unspecified* (Department of Agriculture and Fisheries, 2019b). Though lacking species resolution, anecdotal evidence suggests that this portion of the catch is dominated by black jewfish (*P. diacanthus*). Demand for this species has increased in recent times due to the increased marketability of their swim bladders, and they are considered to be a primary target in the GOCIF. Harvest rates for scaly jewfish (*N. squamosa*) will be smaller, and their inclusion in the Level 2 ERA was precautionary. The inclusion of scaly jewfish reflects a broader need to consider potential demand shifts from black jewfish to secondary species (Appendix D).

As expected, jewfish scored highly across the *availability*, *selectivity* and *post-capture mortality* attributes. Reductions of these risks will be difficult to justify given that the price for black jewfish swim bladders remains high and is unlikely to decline over the short to medium term. The risk posed to these species in the GOCIF will not be uniform and they will be more prevalent in inshore waters and areas where the cumulative fishing pressures are more pronounced. Improving the level of information on jewfish catch compositions would assist in determining the extent of this risk in regional areas and inform discussions surrounding the need, suitability, and applicability of alternative management arrangements.

Of the two species, black jewfish have a more advanced management system due to their position as a high-value species.[8] It is also one of the first net-harvested species to have catch limits that directly impact their take across the commercial, recreational and charter fishing sectors (Department of Agriculture and Fisheries, 2019i). In the Gulf of Carpentaria, the commercial take of this species is restricted by a 6t TACC limit. While this limit only applies to the commercial sector, the species cannot be retained in any sector (commercial, recreational or charter) once this allocation has been

[8] *The market value of black jewfish has increased exponentially in recent years with swim bladders from this species reaching >$600 per kilogram.*

exhausted. This is primarily due to the value of the species and the risk posed by illegal, unreported and unregulated fishing *e.g.* black marketing of saleable product.

The use of a TACC limit and multi-sector closures resulted in black jewfish receiving a medium (2) risk rating for the *management strategy* attribute (Table 7). Some consideration was given to reducing the *management strategy* attribute score to low (1) as part of the RRA (Appendix D). These limits though were only introduced in September 2019, and additional time will be required to determine the efficacy of these measures and mechanisms used to monitor their take. Moreover, the species has not been the subject of a detailed stock assessment, and it is unclear how this limit relates to the current stock structure and key sustainability reference points. These limitations are now being addressed through a study to investigate the population biology of black jewfish which will improve the understanding of stock and age structures, genetic connectivity, and spawning.[9] This information may be used in a weight-of-evidence approach to facilitate potential score reductions in future ERAs.

Management of scaly jewfish aligns more closely with other teleosts, with harvest rates principally managed through gear restrictions (*i.e.* mesh size, net length restrictions *etc.*), minimum legal size limits and in-possession limits for recreational fishers (Queensland Government, 2018b). The broad-scale nature of these arrangements resulted in some of the attributes being assigned more precautionary scores. For instance, the high-risk rating assigned to *management strategy* may be an overestimate as scaly jewfish tend to be harvested in lower quantities. However, it is not currently clear how reforms introduced for black jewfish will affect the marketability of secondary species. For example, it is currently unclear if markets will shift towards other jewfish species to account for any (potential) shortfall in black jewfish product. This risk was heightened by an absence of data on jewfish catch compositions and species-specific rates of total fishing mortality (retained and discards). These factors were key drivers of risk for scaly jewfish and are reflected in the broader risk profile for this species (Table 7; Appendix D).

Outside of management limitations, a lack of *sustainability assessments* was identified as an underlying risk factor for both species (Table 7). Neither the black or scaly jewfish have a stock assessment and only one species (black jewfish) has been the subject of an indicative sustainability evaluation *e.g.* SAFS (Penny *et al.*, 2018; Saunders *et al.*, 2020). In the SAFS assessment, both of Queensland's black jewfish stocks were classified as 'undefined' due to data deficiencies. However, evidence from adjacent jurisdictions suggest that regional stocks are susceptible to overfishing including in the Northern Territory where the black jewfish stock was classified as 'recovering' in previous years (Penny *et al.*, 2018).

Future ERAs would benefit from additional information on the structure and status of black and scaly jewfish stocks in the Gulf of Carpentaria. For black jewfish, their marketability arguably advocates for the production of a more immediate and detailed quantitative stock assessment. Harvest rates for scaly jewfish suggest that a weight-of-evidence approach (*e.g.* SAFS) is a more appropriate course of action for this species. Neither of these actions are likely to occur without improved information on catch compositions, mechanisms to aid in the validation of logbook data, discard rates, and marketability information. Without this information, it will be difficult to assess how the harvest of these species compare to key sustainability reference points and/or what level of fishing mortality is required

[9] https://statements.qld.gov.au/statements/89924

to meet long-term targets under the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017).

The outputs of the Level 2 ERA indicate that risks posed to the jewfish complex is moderate. While the new management arrangements for black jewfish will help manage overfishing of stocks, the effectiveness of these measures remains unknown. The situation surrounding scaly jewfish is less certain, and this species would benefit from additional information on the impact of fishing activities (commercial, charter and recreational) on the broader stock and regional populations.

Species-specific recommendations

1. *Improve catch composition data and identify mechanisms to improve data on harvest rates for secondary species, allowing for refinements to be made to the ERA process.*
2. *When appropriate, undertake a stock assessment for black jewfish in the Gulf of Carpentaria and quantify key sustainability reference points for comparison with the current TACC limit.*
3. *Explore mechanisms to improve our understanding of stock status for secondary jewfish species (e.g.) through species-specific monitoring programs, and the inclusion of these species in indicative sustainability assessments or population biology studies.*
4. *Investigate catch rates/marketability of scaly jewfish to a) determine if catch trends observed in black jewfish are being replicated in this species and b) identify potential avenues to reduce risks posed to this species across sectors and through time.*

4.2.1.5 Queenfish

Common name	Sub-fishery	Risk Rating
Giant queenfish (*S. commersonnianus)*	Primary—N12/13 fishery Secondary—N3 fishery	**Medium**

Data for the queenfish complex has poor species resolution and the majority of the catch is reported under generic identifiers (*queenfish—unspecified*) (Department of Agriculture and Fisheries, 2019). This coarse-scale reporting extends to the recreational sector and, given their moderate popularity as a recreational sportfish, creates uncertainty in terms of the cumulative fishing pressures. While noting these deficiencies, most of the catch is expected to be giant queenfish (*S. commersonnianus*) with the remainder consisting of secondary species such as the lesser (*S. lysan*), needleskin (*S. tol*), and barred queenfish (*S. tala*) (*pers. comm*. M. Keag; T. Ham). Based on this advice and the available data, the giant queenfish was prioritised for assessment (Appendix B). When and where appropriate, additional species will be added to the complex for assessment in subsequent ERAs.

The outputs of the Level 2 ERA indicate that giant queenfish are at medium risk with management limitations and data deficiencies identified as the key drivers of risk. As the species are not managed under quota, there is some potential for catch and effort to increase under the current regime. The extent of any (potential) increase will be determined by external factors including market demand. In the Level 2 ERA, the potential for catch to increase unchecked contributed to the species receiving a higher *susceptibility* score (Table 7). While this is unlikely to occur in short term, king threadfin (*P. macrochir*) and black jewfish (*P. diacanthus*) provide good examples of how market demand can accelerate harvest rates for individual species.

In the Level 2 ERA, data deficiencies made it more difficult to assess the effectiveness of input controls used for queenfish. These deficiencies extend beyond species composition data to assessments of individual rates of fishing mortality, discards, and *sustainability assessments* (*e.g.* stock assessments, SAFS). Improving the level of information on one or more of these areas would improve the accuracy of subsequent ERAs. Avenues where this could be achieved include introducing a mechanism to effectively monitor catch in real or near-real time, initiatives to assist in the validation of logbook data and the use of harvest control rules that trigger a management review if and when queenfish catch exceeds a pre-defined level. Harvest control rules are considered to be of particular importance for this complex as they will be viewed as low priorities for transition to output controls.

At a species-specific level, the ERA identified further limitations in the current management regime. For example, the current MLS limit for giant queenfish is set below the *size at maturity* for females (Griffiths *et al.*, 2006). As a consequence, the MLS may not sufficiently protect a proportion of the spawning population prior to harvest. As the MLS is applied at the fishery level, this risk will transcend the commercial sector and include recreational and charter fishing. It is noted though that non-commercial sectors will make a smaller contribution to fishing mortality for queenfish in the Gulf of Carpentaria (Appendix D).

Species-specific recommendations

1. *Improve catch composition data and identify mechanisms to improve data on harvest/discard rates across sectors, including release fates.*
2. *Explore the need for the inclusion of giant queenfish in indicative sustainability evaluations (e.g. SAFS) to improve the understanding of the stock status of this species.*
3. *Depending on the timing and outputs of recommendation 2, evaluate the suitability and applicability of transitioning giant queenfish to a more specific management system—noting that queenfish may be viewed as a lower assessment priority when compared to other species. The effectiveness of any quota-based management system will also be dependent on management's ability to identify and establish an appropriate limit.*

4.2.2 Sharks

When the results of the PSA and RRA were taken into consideration, the Level 2 ERA indicates that fishing activities in the GOCIF present a higher risk to all seven shark species (Table 7). Biological and life-history constraints were a key driver of risk for most species and, in some instances, were the main contributor of risk. If for example, all of the *susceptibility* attributes were assigned the lowest value possible (1), three of the seven shark species would still register a medium-risk rating. Raising the score for just one of the *susceptibility* attributes from low (1) to medium (2), results in six of the seven species being classified as medium risk. This highlights the inherent challenge of managing fishing-related risks for species with *k*-selected life histories.

Promisingly, the level of information on shark biology has increased through time and the majority of the *productivity* assessments were informed by species-specific data. Despite these improvements, management of this complex would benefit from additional information on the taxonomy and biology of species that interact with the GOCIF; particularly in the N12 and N13 fisheries. In Queensland, these deficiencies are being actively addressed through a dedicated shark monitoring project instigated under the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017; 2019g). The primary purpose of this program is to improve our understanding of the exploited shark biomass through the collection of additional biological data (*e.g.* length, weight), genetic samples, and taxonomic analyses (pers. comm. L. Litherland; Department of Agriculture and Fisheries, 2019g).

When compared to the Queensland east coast, the system used to manage the take of sharks in the GOCIF is less advanced. In the ECIF, the take of sharks is restricted through the use of an ‘S’ fishery symbol and a TACC limit (Department of Agriculture and Fisheries, 2019h). The primary purpose of the S fishery symbol is to limit the number of operators that can actively target and retain sharks in larger quantities. Commercial net and line operators who do not hold an S fishery symbol are restricted by a combined in-possession limit of 10 sharks and/or rays (Department of Agriculture and Fisheries, 2019h). These provisions are used to support a 600t TACC limit which incorporates a 100t hammerhead shark TACC limit.[10]

The above provisions contrast with the GOCIF where there are no restrictions placed on the targeting of sharks in larger quantities by N12/N13 operations. Without these limits, the basis of the shark management regime is largely centred on the use of input controls. The notable exception to this is the hammerhead shark complex which is managed under a combined 50t TACC limit (Department of Agriculture and Fisheries, 2018d). This absence of controls on catch or effort is considered a significant risk factor for shark species that interact with the GOCIF. The extent of this risk will vary between complexes and be more prevalent in the N12/N13 fishery where sharks are actively targeted.

The absence of data on species-specific catch rates, discards, and an inability to quantify individual rates of fishing mortality, were also identified as key risk factors for this complex. This was of particular relevance to assessments involving the *management strategy* and *sustainability assessments* attributes (Table 7). These deficiencies are largely attributed to the absence of an effective measure to monitor shark catch in real or near-real time and a limited capacity to validate data submitted through logbooks (Jacobsen *et al.*, 2019a). These limitations are now being addressed through the logbook program, the *Data Validation Plan*, and the aforementioned shark monitoring program (Department of Agriculture and Fisheries, 2017; 2018b; 2019g; Queensland Government, 2018c). For example, all GOCIF operators are now required to report their shark catch through a dedicated *Shark and Ray Logbook*. This logbook contains more specific catch categories and facilitates the collection of more detailed information on whaler and hammerhead shark discards (Queensland Government, 2018c).

Fishers in the Gulf of Carpentaria are permitted to fillet and fin sharks prior to landing, provided certain storage conditions are met (*e.g.* a fins to trunks ratio must be maintained). While this is a practical solution for remote net fishing operations, this type of shark processing can limit the effectiveness of post-capture identification processes (fins, heads, and skin are used to identify species in the field) and creates challenges in terms of monitoring compliance with anti-finning provisions. In the Level 2 ERA, these risks can be linked with both the *management strategy* and *sustainability assessments* attributes. Of significance, this issue has now been addressed in the ECIF with the fishery moving to a fins-attached policy and a ban imposed on at-sea filleting of shark product

[10] *These in-possession limits apply to licence holders without an S-fishery symbol. These arrangements were updated as part of a broader management review announced on 30 September 2020. Both the broader shark TACC limit and the hammerhead shark TACC are being reviewed as part of this broader reform package (Department of Agriculture and Fisheries, 2020c).*

(Queensland Government, 2020b). Analogous measures have yet to be introduced for the Gulf of Carpentaria.

In 2015, a stock assessment was completed for a range of whaler and hammerhead shark species that are retained for sale in the Gulf of Carpentaria (Leigh, 2015). This assessment provided two MSY estimates for the species assessed: one representing the most likely value for MSY, and a more conservative estimate representing one of the lowest values produced by the population model.[11] The completion of this stock assessment was a significant step forward for the management of the resources as it allowed for the first direct comparisons of shark harvest rates and key biomass reference points. These comparisons indicate that harvest rates for the 11 shark species[12] were below the corresponding MSY estimate (Leigh, 2015). There were however a number of notable caveats surrounding the quality of the data for some species, the need to collect additional information on shark discards, and a lack of species composition data outside the period of the *Fisheries Observer Program* (2006–2012; Leigh, 2015).

Subsequent ERAs would benefit from improved information on catch compositions, catch dynamics (*e.g.* sex ratios, size classes etc.), species-specific discard rates, and catch variability in the N3, N12 and N13 fisheries. Used in an ERA context, this information would be most beneficial when assessing the suitability of the current management system, the species most likely to interact with gillnets, and any regional variability. Longer term, this information could be used to transition the complex to a SAFE ERA which produces fewer false-positive results (Zhou *et al.*, 2016). This move though would (again) be dependent on management's ability to quantify the gear-affected area across the entire fishery or within each of the respective sub-fisheries.

4.2.2.1 Hammerhead Sharks

Common name	Sub-fishery	Risk Rating
Great hammerhead (*S. mokarran)*	Primary—N12/13 fishery Secondary—N3 fishery	**High**
Scalloped hammerhead (*S. lewini*)	Primary—N12/13 fishery Secondary—N3 fishery	**High**
Winghead shark (*E. blochii*)	Primary—N12/13 fishery Secondary—N3 fishery	**High**

If the species rationalisation process was strictly adhered to (Appendix A), hammerhead sharks would not have been included in the Level 2 ERA as they did not meet the initial 95% cumulative commercial catch threshold. Accordingly, the decision to include hammerhead sharks in the GOCIF Target & Byproduct Species Level 2 ERA may be viewed as precautionary. These species though have a long catch history in the GOCIF which includes a number of high-harvest years (Department of Agriculture and Fisheries, 2019b; 2020a). Further, the scalloped hammerhead shark (*S. lewini*) is classified as *Conservation Dependent* on the EPBC threatened species list and there is an ongoing review into the sustainability of the species in Australian waters (Department of the Environment and Energy, 2019). While not listed, the great hammerhead shark (*S. mokarran*) and the winghead shark

[11] *Leigh (2015) recognised the limitations of commercial shark catch data and provided a lower MSY estimates.*

[12] *Data limitations required some species to be assessed as a complex including sharpnose & milksharks (Rizoprionodon spp.) and bull & pigeye sharks (C. leucas & C. amboinensis) (Leigh, 2015)*

(*E. blochii*) were included in the assessment as it can be difficult to differentiate between species in an active fishing environment, particularly for juveniles and sub-adults.

Outputs of the Level 2 ERA classified all three hammerhead sharks as being at high risk from fishing activities in the GOCIF (Table 7). While acknowledging these results, the risk posed to this subgroup is not expected to be as uniform. Under provisions governing the take of sharks in the Gulf of Carpentaria, only licence holders with a N12 or N13 fishing symbol are allowed to actively target sharks for commercial sale. While N3 licence holders can retain shark product, this can only occur if they are caught as byproduct while targeting other species *e.g.* barramundi, threadfin, jewfish *etc.* (Department of Agriculture and Fisheries, 2019b). Due to these restrictions, these species are more likely to be retained in higher quantities by operators in the N12 and N13 fisheries.

At a species-specific level, the more immediate risks and sustainability concerns involve the scalloped hammerhead shark and the great hammerhead shark. These two have widespread distributions and, as migratory species, have sustainability concerns that extend to waters outside of Australia (Rigby *et al.*, 2019a; Rigby *et al.*, 2019b). Evidently, the targeting of scalloped and great hammerhead sharks across jurisdictions (*i.e.* cumulative fishing pressures) was the catalyst for their inclusion on Appendix II of CITES and their listing as a migratory species under the CMS. As seen with the EPBC listing of scalloped hammerhead sharks, these global concerns can affect commercial fisheries operating in Queensland. By extension, the management of the species in Queensland waters will be considered as part of third-party assessments *e.g.* threatened species assessments conducted under the EPBC Act, *Wildlife Trade Operation* (WTO) approvals *etc.*

Datasets for the winghead shark are less complete but research suggests that the species has a patchy, localised distribution (Smart & Simpfendorfer, 2016). Given this, the winghead shark risk profile may be of more relevance when considering regional fishing pressures and risks. As winghead sharks are faster growing and experience lower levels of fishing pressure, there is also the possibility that the risk profile overestimates the level of risk posed to this species by the GOCIF (Table 7). This species though will interact with fisheries in adjacent jurisdictions (*e.g.* the Northern Territory Offshore Net and Line Fishery) and the GOCIF will be a contributor of risk for the winghead shark.

As with most shark species included in this ERA, life-history constraints were highly influential in the final risk ratings. These constraints were sufficient enough to assign the great hammerhead shark and the scalloped hammerhead shark with the highest risk score for all but one of the *productivity* attributes (Table 7). In addition to their biology, there are a number of traits that increase hammerhead shark's *susceptibility* to net fishing activities. For example, the distinctive shape of the hammerhead shark head makes them highly susceptible to net entanglements across a wide range of size classes (Department of the Environment and Energy, 2014; Harry *et al.*, 2011b). In other shark species, this risk is often mitigated by body size as larger animals tend to outgrow the *selectivity* of the net, therefore helping to minimise the number of entanglements. This risk if further compounded by the fact that hammerhead sharks have a low tolerance for net entanglements and are more likely to die without relatively rapid intervention (Ellis *et al.*, 2017; Harry *et al.*, 2011b).

Hammerhead sharks are retained for sale in the GOCIF and can be actively targeted by operators with an N12 or N13 fishery symbol (Department of Agriculture and Fisheries, 2019b). In the GOCIF, hammerhead shark catch is managed through a combined 50t TACC limit and it is one of the few complexes managed under output controls. This TACC applies to the scalloped and great hammerhead shark[13] and is supported by decision rules that restrict their take as the fishery approaches this limit (Department of Agriculture and Fisheries, 2018d). As the winghead shark belongs to a different genus (*Eusphyra*); they are not included in the hammerhead shark TACC and retention rates for this species are not subject to regional commercial limits. This difference is important as it (theoretically) allows the retained winghead shark catch to increase to levels not permitted under the *Sphyrna* spp. TACC limit. While this is unlikely to occur in the current fishing environment (Department of Agriculture and Fisheries, 2019b), it is a risk that can actively addressed through the management reform framework.

At a whole-of-fishery level, the introduction of a hammerhead shark TACC limit was a significant step forward with respect to managing the take of the resource in the Gulf of Carpentaria. This limit is based on a CITES-linked Non-Detriment Finding (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2019; Department of the Environment and Energy, 2014) and takes into consideration cross-jurisdictional fishing pressures *e.g.* Northern Territory, Gulf of Carpentaria and the Queensland east coast. It is also at the lower end of the spectrum with respect to MSY estimates derived for the scalloped hammerhead, great hammerhead and winghead shark in the Gulf of Carpentaria (*combined MSY* = 40.1–174t; Leigh, 2015).

Multi-species TACCs are useful for groups like hammerheads where morphological similarities make it difficult to differentiate between species in an active fishing environment. The disadvantage of this approach is that multi-species TACCs may not be flexible enough to respond to changing fishing environments or detect overfishing events for individual species. In the GOCIF, one of the more significant risks is that an overfishing event (*i.e.* fishing a hammerhead shark stock above sustainability reference points) will go undetected.

Depending on the catch compositions, the use of a multi-species TACC could lead to a scenario where the fishery is operating within the prescribed catch limits but still overfishing a regional stock. This risk will increase as annual catch levels approach and reach the TACC limit. As the TACC only accounts for retained catch, this situation is likely to be exacerbated by an inability to account for discards in annual catch limits. This again has the potential to undermine the effectiveness of the TACC limit as total catch, effort and fishing mortality (*e.g*. the commercial catch plus discards) will be higher than what is reported through the logbook program. While noting these risks, the best available data indicates that this is not currently occurring in the Gulf of Carpentaria (Department of Agriculture and Fisheries, 2018e; Department of the Environment and Energy, 2014; Leigh, 2015).

Catch data for the GOCIF shows that the fishery is operating well below the hammerhead shark TACC limit. While the data shows some variability, the annual catch of hammerhead sharks (*Sphyrna* spp.) tends to be less than 20t and is often below 10t. The two notable exceptions being 2013 and 2014 where the combined catch of *Sphyrna* spp. increased to 40 and 45t respectively (Department of Agriculture and Fisheries, 2019b; 2020a). Catch data for this complex has low species resolution and a high percentage is reported under more generic catch categories *e.g. Hammerhead Shark*. Of the species included in the TACC, only the scalloped hammerhead shark has species-specific data with annual catches ranging from <1 to 10t (Department of Agriculture and Fisheries, 2019b; 2020a).

[13] This TACC theoretically includes the smooth hammerhead shark (S. zygaena). The smooth hammerhead shark is considered to be a more temperate species and interactions are viewed as highly unlikely in the GOCIF. Catch reported as 'unspecified hammerhead shark' is also accounted for in the annual Gulf of Carpentaria hammerhead shark TACC limit.

While the great hammerhead shark has yet to be reported from the fishery, this anomaly is more than likely the result of misidentifications and the use of generic identifiers.

While the species is not included in the TACC limit, the GOCIF catch does include winghead sharks. Reported catch for this species tends to be lower than the scalloped hammerhead with most years registering catch levels of <2t (Department of Agriculture and Fisheries, 2019b; 2020a). These figures are expected to be an underestimate as a portion of the winghead shark catch will be reported as part of the *Hammerhead shark* catch category (Department of Agriculture and Fisheries, 2019b; 2020a). For this reason, it is difficult to assess how the fishery would operate against alternate TACC arrangements, including ones that include winghead sharks in the catch limits.

Uncertainties in the catch data makes it difficult to quantify individual rates of fishing mortality and assess the longer-term overexploitation risk. These risks are being actively addressed through the management framework, and fishers are now required to report all retained hammerhead shark catch to species level and document the number of discards (Department of Agriculture and Fisheries, 2018d). These measures are being built upon through the *Queensland Sustainable Fisheries Strategy 2017–2027* and efforts are being undertaken to validate the composition of the hammerhead shark catch, assess the sustainability of regional stocks, and document fine-scale catch and effort movements. Examples of which include the expanded use of *Vessel Tracking* (Department of Agriculture and Fisheries, 2018f), a dedicated shark monitoring project, an increased reliance on species-specific TACC limits, and efforts to support the real or near-real time monitoring of target and non-target species (Department of Agriculture and Fisheries, 2018b).

In the longer-term, it is envisaged that the majority of fishing-related risks for the hammerhead shark complex will be addressed through a formal harvest strategy and cross-jurisdictional management of the resource (*i.e.* by Queensland and the Northern Territory). On this basis, the Level 2 ERA should represent the worst case scenario in terms of the risk posed to this subgroup by the GOCIF. It will however take time to implement these measures and obtain the level of data needed to refine and inform the ERA process. As a consequence, some of the more prominent sustainability risks will remain for this subgroup. For example, there is still limited capacity to validate catch compositions or discard rates under the current management system. Without this validation, it is difficult to assess the accuracy of the logbook data and make informed decisions on where to set mortality rate limits. This situation is complicated by the fact that hammerhead sharks are retained in adjacent fisheries; namely the *Northern Territory Offshore Net and Line Fishery* (Northern Territory Government, 2020).

Species-specific recommendations

1. *Include the winghead shark in management arrangements targeted specifically at hammerhead sharks e.g. the 50t TACC limit.*

2. *Implement measures that: a) improve the effectiveness of the hammerhead shark catch reporting program and b) assists in quantifying total rates of fishing mortality (retained plus discards) for individual species.*

3. *Move towards species-specific TACC limits or introduce measures to minimise the risk that one or more hammerhead shark species are being fished above sustainability reference points.*

4. *Undertake a review of the resources made available to licence holders to assist in the identification of hammerhead shark species.*

4.2.2.2 Blacktip Sharks

Common name	Sub-fishery	Risk Rating
Australian blacktip shark (*C. tilstoni*)	Primary—N12/13 fishery Secondary—N3 fishery	**High**
Common blacktip shark (*C. limbatus*)	Primary—N12/13 fishery Secondary—N3 fishery	**Precautionary High**
Spot-tail shark (*C. sorrah*)	Primary—N12/13 fishery Secondary—N3 fishery	**Precautionary High**
Graceful shark (*C. amblyrhynchoides*)	Primary—N12/13 fishery Secondary—N3 fishery	**Precautionary High**

The blacktip shark complex[14] is the largest non-teleost catch component in the GOCIF with annual harvests ranging from 113–237t (2007–2019) (Department of Agriculture and Fisheries, 2019b; 2020a). The extent to which operators actively target blacktip sharks is not known, but historical catch rates indicate that the complex is an important component of the GOCIF. The N12 and N13 fisheries will again be the key drivers of risk as operators can actively target sharks in offshore waters. While the GOCIF has an inshore component (N3 fishery), operators in this sector can only retain sharks if caught incidentally while targeting teleosts *i.e.* barramundi, threadfin *etc.* (Department of Agriculture and Fisheries, 2019b). As their preferred habitats and distributions overlap with targeted teleosts, these small to medium sized carcharhinids will continue to be caught and harvested with regularity in the GOCIF (Bray, 2020b; c; Fishes of Australia, 2020; Reardon & Bray, 2020).

A key challenge with the blacktip shark complex is that the species can be difficult to differentiate between in an active fishing environment. This is reflected in historical catch data which contains a number of generic catch categories such as *blacktip whaler* (Department of Agriculture and Fisheries, 2019b). For the Australian (*C. tilstoni*) and common blacktip shark (*C. limbatus*), visual identification can be difficult as species differentiation (until recently) primarily relies on genetic analysis, vertebral counts, and a broader understanding of their regional distributions (Johnson *et al.*, 2017; Leigh, 2015; Morgan *et al.*, 2011; Morgan *et al.*, 2012). While the spot-tail shark (*C. sorrah*) and graceful shark (*C. amblyrhynchoides*) can be identified more readily, they share morphological traits that are similar to other blacktip sharks, especially as juveniles. These identification issues present challenges for determining the composition of the blacktip shark catch and quantifying individual rates of harvest.

Identification issues present challenges for determining what proportion of the catch is made up of each species, especially in the case of the Australian and common blacktip shark. This issue is compounded by the fact that the GOCIF does not have an effective mechanism to validate catch compositions and limited capacity to verify data submitted through logbooks. Without these mechanisms, it is likely that a portion of the blacktip shark catch will be misidentified and reported in the wrong category. This creates uncertainty surrounding species-specific rates of fishing mortality, and limits the extent of comparisons between harvest rates and biomass reference points (Leigh, 2015). These issues are being actively addressed through the *Queensland Sustainable Fisheries Strategy 2017–2027,* and initiatives like the *Data Validation Plan* and shark monitoring program will

[14] *For the purposes of this ERA, use of the term blacktip sharks collectively refers to Carcharhinus tilstoni, C. limbatus, C. sorrah, and C. amblyrhynchoides. Several commercial logbook categories will make up total blacktip shark catch, including 'Blacktip whaler shark', 'Shark—Australian blacktip', and 'Shark—sorrah'.*

help clarify regional shark catch compositions (Department of Agriculture and Fisheries, 2017; 2018b; 2019g).

Operators are now required to report spot-tail shark and graceful shark to the species level; a change that will improve the level of information on harvest rates in the Gulf of Carpentaria. Accurate field identification for the Australian and common blacktip shark still remains a challenge and they continue to be reported at the complex level (Queensland Government, 2018c). However, genetic analysis indicates that the Australian blacktip shark is more abundant in the Gulf of Carpentaria (Leigh, 2015; Welch *et al.*, 2011). Therefore, assuming that the spot-tail shark and graceful shark are reported to species level, a high proportion of the *Blacktip whaler shark* catch will consist of *C. tilstoni* (Australian blacktip shark). This inference is supported by species-specific catch data which shows that the average *C. tilstoni* catch (2017–2019) sits at around 128t per year compared to 16t for *C. sorrah* and 0t for *C. amblyrhynchoides*. These values, at the very least, provide an indicative account of blacktip shark catch compositions in the GOCIF.

The 2015 stock assessment provided MSY estimates for the spot-tail shark and the Australian blacktip shark. This assessment indicates that a) spot-tail shark harvest mortality is lower than the most conservative MSY estimate and b) the species is being fished sustainably. For the Australian blacktip shark, the relationship between harvest rates and MSY is less clear. Net harvest for this species (*average* = 154.2t; *range* = 91.5–216.4t; 2007–2019) has repeatedly exceeded the most conservative MSY estimate (95t). However, catch levels have not exceeded the most likely MSY estimate which, for the Gulf of Carpentaria, is notably higher (512t) (Leigh, 2015). MSY estimates could not be derived for the common blacktip shark and the graceful shark due to insufficient data on their distribution in the Gulf of Carpentaria. These deficiencies combined with the likelihood of over or underreporting (*e.g.* due to misidentifications), were the reasons why blacktip sharks were classified as 'undefined' as part of the SAFS process (Johnson *et al.*, 2018; Usher *et al.*, 2020a; Usher *et al.*, 2020b). In the Level 2 ERA, these deficiencies contributed to the species receiving more precautionary scores for the *sustainability assessments* attribute (Table 7).

In terms of catch volumes, the GOCIF remains the single, most significant source of risk for regional blacktip shark stocks. These species make up the majority of the shark catch reported from the Gulf of Carpentaria, and they are key targets in the offshore (N12/N13) fishery. Of the species retained, the risks are expected to be higher for Australian blacktip shark. The extent of the risk posed to the three remaining species is less certain and could (potentially) be overestimated by the Level 2 ERA. Going forward, future ERAs would benefit from additional data on catch compositions, release fates, and discards. Discards are considered to be a particular risk area requiring further investigation. As these species are taken in adjacent fisheries, future ERAs would also benefit from additional information on the stock connectivity and cumulative fishing pressures. For example, commercial blacktip shark harvests in the *Northern Territory Barramundi Fishery, Northern Territory Offshore Net and Line Fishery* and ECIF are almost double that of the GOCIF (Johnson *et al.*, 2018).

Species-specific recommendations

1. *Explore avenues to improve indicative sustainability assessments for blacktip shark species in the Gulf of Carpentaria.*

2. *Update the shark stock assessment to account for any additional information collected through the Shark & Ray logbook and initiatives instigated under the Queensland Sustainable Fisheries Strategy 2017–2027.*

3. *Improve the level of information on fine-scale effort movements and catch composition data.*

4. *Review shark management arrangements and implement measures that will assist in the management of individual species and minimise the long-term sustainability risk—preferably through a GOCIF-specific harvest strategy.*

5 Summary

The Level 2 ERA provides additional depth to the risk profiles of these species and further differentiates between potential and actual risks (Department of Agriculture and Fisheries, 2018a). Outputs from the Level 2 ERA will help inform initiatives instigated under the *Queensland Sustainable Fisheries Strategy 2017–2027* and strengthen linkages between the ERA process and the remaining areas of reform (Department of Agriculture and Fisheries, 2017).

Precautionary elements included in the methodology combined with data deficiencies have contributed to the development of more conservative risk profiles. For some of the species, the final risk ratings were considered precautionary and are unlikely to result in significant species-specific reforms. There were however a number of species where the risk requires further attention and the management of the risk is viewed as a higher priority. This will need to occur at both a whole-of-fishery and species-specific level.

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7 Appendices

Appendix A	–	Target & byproduct species rationalisation process.
Appendix B	–	Species Rationalisation Process: Justifications and Considerations.
Appendix C	–	Overlap percentages used in the PSA.
Appendix D	–	Residual Risk Analysis.
Appendix E	–	Likelihood & Consequence Analysis.

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 (2017–2019 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 (2017–2019 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 then 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 *Shark—whaler 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 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.

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 B—Species Rationalisation Process: Key Justifications and Considerations.

Common name / Catch category	*Scientific name (CAAB)*	*Include*	Notes, Comments & Catch Data
Mackerel			
Grey mackerel	*Scomberomorus semifasciatus* *37 441018*	**Y**	**<u>Notes</u>** Grey mackerel (*S. semifasciatus*) is the largest catch component in the GOCIF and the species was included in the Level 2 assessment as a primary target species. *<u>Catch data summary</u>* - Catch reported as *Grey mackerel* (CAAB 37 441007) 2017–2019 (inclusive): average = 605.7t, range = 553.1–709.0 t, three year total = 1817.1t.
Spanish mackerel	*Scomberomorus commerson* *37 441007*	**Y**	**<u>Notes</u>** Spanish mackerel (*S. commerson*) is mostly harvested by the Gulf of Carpentaria Line Fishery (143–196t per annum; 2017–2019). However, a notable portion of the Spanish mackerel catch is retained by net fishers and the GOCIF will be a contributor of risk for this species. *<u>Catch data summary</u>* - Catch reported as *Spanish mackerel* (CAAB 37 441007) 2017–2019 (inclusive): average = 39.1t, range = 37.4–41.8t, three year total = 117.4t.
School mackerel	*Scomberomorus queenslandicus* *37 441014*	**N**	**<u>Notes</u>** Annual historical harvests of school mackerel in the GOCIF have been sporadic, with many years recording <1t and most years recording no harvest at all (Department of Agriculture and Fisheries, 2019b; 2020a). This species has not been retained in this fishery since 2008, and therefore was not included in the Level 2 assessment.

Common name / Catch category	*Scientific name (CAAB)*	*Include*	**Notes, Comments & Catch Data**
			<u>*Catch data summary*</u> - No *School mackerel* (CAAB 37 441014) catch in recent years (2017–2019 inclusive). - 20 year annual average = 0.4t, range = 0–9t.
Spotted mackerel	*Scomberomorus munroi* *37 441015*	**N**	<u>**Notes**</u> Annual historical harvests of spotted mackerel in the GOCIF have been sporadic, with harvest never exceeding 1t per year (Department of Agriculture and Fisheries, 2019b; 2020a). This species has not been retained in this fishery since 2013 and it was not included in the Level 2 assessment. <u>*Catch data summary*</u> - No *Spotted mackerel* (CAAB 37 441015) catch in recent years (2017–2019 inclusive). - 20 year average = 49kg, range = 0–380kg.
Barramundi			
Barramundi	*Lates calcarifer* *37 310006*	**Y**	<u>**Notes**</u> Barramundi (*L. calcarifer*) is a key target species for net operators in the Gulf of Carpentaria and significant amounts are retained each year (Department of Agriculture and Fisheries, 2019b; 2020a). Relative to other species, there is substantial information on stock structure and sustainability of the fishery. The species is not managed through output controls and there is continued potential for catch and/or effort to increase into the future. Evidence also suggests that at least one of the Gulf of Carpentaria stocks (Southern) has been historically overfished (Saunders *et al.*, 2018). Accordingly, barramundi was included in the Level 2 ERA as a key target species.

Common name / Catch category	*Scientific name (CAAB)*	*Include*	**Notes, Comments & Catch Data**
			Catch data summary - Total reported *Barramundi* (CAAB 37 310006) catch 2017–2019 (inclusive): average = 577.8t, range = 490.5–667.8t, three year total = 1733.3t.
Threadfin			
King threadfin	*Polydactylus macrochir* *37 383005*	**Y**	**Notes** King threadfin (*P. macrochir*) was included in the Level 2 assessment as it is a primary target species. *Catch data summary* - Catch reported as *King threadfin* (CAAB 37 383005) 2017–2019 (inclusive): average = 208t, range = 141.1–247.1t, three year total = 624.1t.
Blue threadfin	*Eleutheronema tetradactylum* *37 383004*	**Y**	**Notes** Blue threadfin (*E. tetradactylum*) was included in the Level 2 assessment as it is a primary target species. *Catch data summary* - Catch reported as *Blue threadfin* (CAAB 37 383004) 2017–2019 (inclusive): average = 58t, range = 44.6–68.8t, three year total = 174.1t.
Jewfish			
Scaly jewfish	*Nibea squamosa* *37 354024*	**Y**	**Notes** Scaly jewfish (*N. squamosa*) are distributed across northern Australia and moderate amounts are retained annually in the GOCIF (Department of Agriculture and Fisheries, 2019b; 2020a). The species was included the

Common name / Catch category	*Scientific name (CAAB)*	*Include*	**Notes, Comments & Catch Data**
			Level 2 ERA as a byproduct species and in recognition of the fact that demand of scaly jewfish swim bladders may increase going into the future (see black jewfish). *Catch data summary* - Catch reported as *Jewel* (CAAB 37 354024) 2017–2019 (inclusive): average = 22.6t, range = 20.1–24.1t, three year total = 67.9t.
Black jewfish	*Protonibea diacanthus* *37 354003*	**Y**	**Notes** Black jewfish (*P. diacanthus*) has a history of comparatively small catches, and the species did not meet the initial 95% cumulative catch threshold (Department of Agriculture and Fisheries, 2019b; 2020a). However, annual catch for this species has increased in recent times across the state in both net and line fishing sectors. These increases are in direct response to market demand for black jewfish swim bladders which have increased in price exponentially. This increase in value and demand was the primary driver behind new management arrangements that came into effect on 26 April 2019 (Department of Agriculture and Fisheries, 2019c). Given this demand, cumulative fishing pressures, and the ongoing market appeal of the species, *P. diacanthus* was included in the initial GOCIF Target & Byproduct Species Level 2 ERA. *Catch data summary* - Catch reported as *Black jewfish* (CAAB 37 354003) 2017–2019 (inclusive): average = 2.55t, range = 0.13–5.27t, three year total = 7.65t. - Historical catch (last 20 years) average = 1.35t, range = 0–5.27t. - Some black jewfish may be reported un *Jewfish unspecified* (CAAB 37 354000): historical catch average = 4.34t, range = 0.2–13.45t.

Common name / Catch category	***Scientific name (CAAB)***	***Include***	**Notes, Comments & Catch Data**
Queenfish			
Giant queenfish	*Scomberoides commersonnianus* *37 337032*	**Y**	**<u>Notes</u>** The GOCIF queenfish catch is likely to include a mixture of species from the *Scomberoides* genus. Preliminary consultation suggests that the giant queenfish (*S. commersonnianus*) is the main species retained, with the lesser (*S. lysan*), needleskin (*S. tol*), and barred (*S. tala*) queenfish making smaller contributions to the total catch (*pers. comm.* M. Keag; T. Ham). The distribution of the giant queenfish extends across northern Australia (Bray, 2018; Smith-Vaniz & Williams, 2016a) and is readily retained in the GOCIF. While the distribution of the lesser, barred and needleskin queenfish also extends into the Gulf of Carpentaria (Smith-Vaniz & Williams, 2016b), fishing pressures exerted on these species will be less. Based on preliminary consultation, the giant queenfish was included in the initial target and byproduct species Level 2 ERA with the lesser, barred, and needleskin queenfish considered for inclusion in subsequent ERAs. *<u>Catch data summary</u>* - Total catch: no species-specific data reported for queenfish species. - Catch reported as *Queenfish—unspecified* (CAAB 37 337905) 2017–2019 (inclusive): average = 35.7t, range = 27.8–43.8t, three year total = 107.2t.
Lesser queenfish	*Scomberoides lysan* *37 337046*	**N**	
Needleskin queenfish	*Scomberoides tol* *37 337044*	**N**	
Barred queenfish	*Scomberoides tala* *37 337045*	**N**	
Javelin			
Silver javelin	*Pomadasys argenteus* *37 350009*	**N**	**<u>Notes</u>** The GOCIF javelin catch is likely to include a mixture of species from the *Pomadasys* genus (Department of Agriculture and Fisheries, 2019b; 2020a). Preliminary consultation suggests that the silver and barred javelin (*P.*

Common name / Catch category	*Scientific name (CAAB)*	*Include*	**Notes, Comments & Catch Data**
Barred javelin	*Pomadasys kaakan* *37 350011*	**N**	*argenteus* & *P. kaakan*) are the main species retained, with the remaining species making smaller contributions to the total javelin catch (*pers. comm.* M. Keag; T. Ham). While javelin have been retained with regularity in this fishery over the last 20 years, average annual harvest is less than 20t. In recent years (2017–2019), this has declined to less than 10t. Based on reliably lower historical catch records in the GOCIF, the javelin complex was not included in this iteration of the GOCIF Target and Byproduct Species Level 2 ERA. When and where appropriate, further consideration will be given to the inclusion of these species in subsequent ERAs. <u>*Catch data summary*</u> - Total catch: no species-specific data reported for javelin species. - Catch reported as *Grunter—unspecified* (CAAB 37350902) 2017–2019 (inclusive): average = 9.4t, range = 0.3–20.5t, three year total = 28.3t. - Historical catch for *Grunter—unspecified* (CAAB 37350902) 1999–2019 (inclusive): average = 19.6t, range = 0.3–51.4t.
Blacktip shark complex			
Graceful shark	*Carcharhinus amblyrhynchoides* *37 018033*	**Y**	**<u>Notes</u>** Blacktip sharks are the fourth largest catch component in the GOCIF with around 113–237t of product harvested from the region each year (2007–2019 inclusive) (Department of Agriculture and Fisheries, 2019b; 2020a). The graceful shark (*C. amblyrhynchoides*), common blacktip shark (*C. limbatus*), Australian blacktip shark (*C. tilstoni*), and spot-tail shark (*C. sorrah*) share a number of morphological similarities and this makes it difficult for operators to identify and report blacktip sharks to species level.
Common blacktip shark	*Carcharhinus limbatus* *37 018039*	**Y**	

<table>
<tr><th>Common name / Catch category</th><th>Scientific name (CAAB)</th><th>Include</th><th>Notes, Comments & Catch Data</th></tr>
<tr><td></td><td>(37 018903 CAAB Code in Fishing data is incorrect)</td><td></td><td rowspan="3">Given the use of broader catch categories and identification issues, it is unclear what proportion of catch pertains to each species. The spot-tail shark has been recorded at the species level since 2004. On the contrary, there are no historical catch records of C. amblyrhynchoides in the GOCIF due, in part, to logbook data limitations i.e. the logbook system has only recently (2018) been updated to include a graceful shark category (Shark—graceful). Similarly, C. limbatus and C. tilstoni cannot be easily differentiated and obtaining species-specific catch records for these two species is difficult. Despite this, fisheries observer data and genetic studies on the blacktip complex indicate that C. tilstoni is the more commonly caught species in the Gulf of Carpentaria when compared to C. limbatus.

While C. tilstoni and C. sorrah are likely to dominate the blacktip shark harvest, catch levels for C. limbatus and C. amblyrhynchoides are less certain. Given this, all four were included in the Level 2 assessment as a precautionary measure.

<u>Catch data summary</u>

- Catch reported as Blacktip whaler shark (CAAB 37 018903) 2017–2019 (inclusive): average = 89.2t, range = 75.1–101t, three year total = 267.6t. Historical catch (since 2007) average = 72t, range = 37.8–119.4t.

- Catch reported as Shark—sorrah (CAAB 37 018013) 2017–2019 (inclusive): average = 15.8t, range = 9.2–26.7t, three year total = 47.4t. Historical catch (since 2007) average = 21.6t, range = 9.2–34.7t.

- Catch reported as Australian blacktip shark* (CAAB 37 018014) 2007–2016 (inclusive): average = 97.1t, range = 53.7–160t. *This catch category has been removed and all Australian blacktip shark is reported under the Blacktip whaler sharks (C. limbatus and C. tilstoni) category. The final year catch was reported under the Australian blacktip category was 2016.

- There are no species-specific records for graceful shark in the Gulf of Carpentaria, however some C. amblyrhynchoides may be contained within the Blacktip whaler shark, Shark—whaler unspecified or Shark—unspecified catch categories.</td></tr>
<tr><td>Australian blacktip shark</td><td>Carcharhinus tilstoni

37 018014</td><td>Y</td></tr>
<tr><td>Spot-tail shark</td><td>Carcharhinus sorrah

37 018013</td><td>Y</td></tr>
</table>

Common name / Catch category	*Scientific name (CAAB)*	*Include*	**Notes, Comments & Catch Data**
			Additional notes Given the identification issues between *C. tilstoni* and *C. limbatus*, the two species are often reported on as a single complex. As mentioned above, most blacktip shark catch from the Gulf of Carpentaria region will be *C. tilstoni*. A new shark and ray logbook (SR02) was introduced in 2018 for all of Queensland's commercial fisheries wanting to retain shark. With this came a number of changes to catch categories including the addition of *Shark—graceful*, and the removal of *Australian blacktip shark*. Given the identification issues with *C. limbatus* and *C. tilstoni*, it is expected both species will be reported under *Blacktip whaler sharks* moving forward.
Hammerhead shark complex			
Great hammerhead	*Sphyrna mokarran* *37 019002*	**Y**	**<u>Notes</u>** Hammerhead sharks have been harvested historically in greater numbers in the GOCIF. Since 2007, average annual catch of the hammerhead shark complex (*S. mokarran, S. lewini* and *E. blochii*) has fluctuated, averaging around 19t per year. More recently, this figure has declined to around 8t (2017–2019). Species-specific catch records for hammerhead sharks have improved through time. In earlier years (prior to 2007), commercial fishers recorded all harvested hammerhead sharks (including winghead) under *Shark—scalloped hammerhead*. However, catch in recent years has been recorded in three different categories: *Winghead shark*, *Hammerhead shark*, and *Shark—scalloped hammerhead.* At this level around 1.7t, 5.4t and 0.8t great hammerhead, scalloped hammerhead and winghead shark (respectively) are retained in the GOCIF each year (2017–2019 annual average). There are a number conservation concerns for hammerhead shark species on a more global scale. While there are less sustainability concerns at a regional level (*i.e.* catch harvest is well below MSY; Leigh, 2015), broader classifications under the EPBC Act and CITES may impact the management and export of these species. Currently, scalloped hammerhead is listed as conservation dependant under the EPBC Act and both great and scalloped hammerhead are listed under CMS (Appendix II) and CITES (Appendix II).
Scalloped hammerhead	*Sphyrna lewini* *37 019001*	**Y**	
Winghead shark	*Eusphyra blochii* *37 019003*	**Y**	

Common name / Catch category	*Scientific name (CAAB)*	*Include*	**Notes, Comments & Catch Data**
			None of the three hammerhead shark species are retained in great enough numbers to be contained within the 95% cumulative catch component. However, given the ongoing conservation concerns for some species (*S. lewini* & *S. mokarran*), in addition to the information gaps around discard rates and *post-capture mortalities*, scalloped hammerhead (*S. lewini*), great hammerhead (*S. mokarran*) and winghead shark (*E. blochii*) were included in the GOCIF Target & Byproduct Species Level 2 assessment. A fourth species, the smooth hammerhead shark (*S. zygaena*) was not included in the assessment as the distribution of this species does not overlap with the GOCIF (Gallagher & Klimley, 2018; Last & Stevens, 2009). _Catch data summary_ - Catch reported as *Shark—scalloped hammerhead* (CAAB 37 019001) 2017–2019 (inclusive): average = 5.4t, range = 0–8.2t, three year total = 16.2t. - Catch reported as *Hammerhead shark* (CAAB 37 019002) 2017–2019 (inclusive): average = 5.4t, range = 0–8.2t, three year total = 16.2t. Note—As both scalloped and winghead shark have species-specific catch categories, it is assumed that great hammerhead will be reported under the broader *Hammerhead shark* grouping. It is noted that other hammerhead shark species may be recorded under this category given the CAAB code includes both genera, or some great hammerhead shark catch will be misidentified as scalloped hammerhead. - Catch reported as *Winghead shark* (CAAB 37 019003) 2017–2019 (inclusive): average = 5.4t, range = 0–8.2t, three year total = 16.2t. - Catch reported for all three species 2017–2019 (inclusive): average = 8t, range = 5.2–10.5t, three year total = 23.9t.

<table>
<tr><th>Common name / Catch category</th><th>Scientific name (CAAB)</th><th>Include</th><th>Notes, Comments & Catch Data</th></tr>
<tr><td colspan="4">Guitarfish / Shovelnose ray complex</td></tr>
<tr><td>Bottlenose wedgefish</td><td>Rhynchobatus australiae
37 026005</td><td>N</td><td rowspan="3"><u>Notes</u>
In Queensland, commercial operators cannot take or possess more than five guitarfish (Family Rhinidae*) and/or shovelnose rays (Family Rhinobatidae) for trade or commerce (total). Recreational fishers are limited to an in-possession limit of one. There are no species-specific catch records for guitarfish and shovelnose rays in the GOCIF as they are reported under a single catch category (Guitarfish—shovelnose unspecified (37 027000)) (Department of Agriculture and Fisheries, 2019b; Queensland Government, 2018c). Commercial catch for this complex is frequently <2t per year, with the notable exception being 14t in 2014 (Department of Agriculture and Fisheries, 2019b; 2020a).
While these species are not afforded additional protections under the EPBC Act, R. australiae has been included in the CMS list. Further, the wedgefish complex (Family Rhinidae, inc. Rhynchobatus spp.) and guitarfish (Glaucostegus spp.) have been listed under CITES. While difficult to assess at this point in time. the listing of wedgefish and guitarfish on CMS or CITES may have implications for commercial fisheries in Queensland.
As this complex has a smaller presence in the catch data, especially in recent years (2017–19; average 0.7t per annum), these three batoids were not included in the Target & Byproduct Species Level 2 ERA for this fishery. When and where appropriate, consideration will be given to the including these species in subsequent ERAs. Until then, risk profiles compiled as part of the GOCIF SOCC Level 2 ERA provides an appropriate overview of the risk posed to these species (Jacobsen et al., 2021).
*A taxonomic review of these species has resulted in a change to the nomenclature. These changes have yet to be reflected in legislation which still refers to the Family Rhynchobatidae. The intent of the legislation though still provides Rhynchobatus species with additional protections.</td></tr>
<tr><td>Eyebrow wedgefish</td><td>Rhynchobatus palpebratus
37 026004</td><td>N</td></tr>
<tr><td>Giant shovelnose ray</td><td>Glaucostegus typus
37 027010</td><td>N</td></tr>
</table>

Common name / Catch category	*Scientific name (CAAB)*	*Include*	**Notes, Comments & Catch Data**
			Catch data summary - Catch reported as *Guitarfish—shovelnose unspecified* (CAAB 37 027000) 2017–2019 (inclusive): average = 0.7t, range = 0–2.1t, three year total = 2.1t.
Stingrays			
Estuary stingray	*Hemitrygon fluviorum* *37 035008*	**N**	**Notes** The estuary stingray (*H. fluviorum*) was included on the preliminary species list due to its classification as *Near Threatened* under the Queensland *Nature Conservation Act 1992*. However, the species is not afforded additional protections under fisheries legislation and is not listed as a threatened or migratory species under the EPBC Act. As a consequence, the species is not classified (internally) as a Species of Conservation Interest (SOCI) and it can be retained for sale in the GOCIF. The known distribution of *H. fluviorum* extends along the Queensland east coast and west through the Gulf of Carpentaria and Northern Territory. The species can be found in a range of environments from mangrove-fringed rivers/estuaries and in offshore waters down to at least 28m deep (Kyne *et al.*, 2016; Last *et al.*, 2016). However, *H. fluviorum* is more common in inshore waters. There are no species-specific catch records of *H. fluviorum* in the GOCIF and catch (if applicable) will be recorded as part of the *Ray—sting unspecified* catch category (Department of Agriculture and Fisheries, 2019b; 2020a). The species' preference for intertidal, riverine, and estuarine waters increases the likelihood of interactions occurring when operators are targeting key inshore species *e.g.* barramundi. While noting the potential for interactions to occur, *H. fluviorum* was assessed as a part of the SOCC Level 2 ERA for the GOCIF (Jacobsen *et al.*, 2021). As negligible amounts of this species have been harvested historically and in recent years, it was not included within the Target & Byproduct Species Level 2 ERA.

Common name / Catch category	*Scientific name (CAAB)*	*Include*	**Notes, Comments & Catch Data**
			<u>*Catch data summary*</u> - Catch reported as *Ray—sting unspecified* (CAAB 37 035000) 2017–2019 (inclusive): average = 0.2t, range = 0–0.5t, three year total = 0.5t.

Appendix C—Overlap percentages used in the PSA.

Where available, overlap percentages were based on species distribution maps sourced from the *Commonwealth Scientific and Industrial Research Organisation* (CSIRO) and, where possible, were refined using bathymetry and topographical data (Whiteway, 2009).

Common name	Species	CAAB	2017	2018	2019	Highest %	Highest score of the 3 years
			% Overlap	% Overlap	% Overlap		
Teleosts							
Grey mackerel	*Scomberomorus semifasciatus*	37 441018	11.7	9.3	8.9	11.7	**2**
Spanish mackerel	*Scomberomorus commerson*	37 441007	11.7	9.3	8.9	11.7	**2**
Barramundi	*Lates calcarifer*	37 310006	27.1	21.6	20.6	27.1	**3**
King threadfin	*Polydactylus macrochir*	37 383005	70.3	51.5	43.4	70.3	**3**
Blue threadfin	*Eleutheronema tetradactylum*	37 383004	33.1	25.2	24.3	33.1	**3**
Giant queenfish	*Scomberoides commersonnianus*	37 337032	11.7	9.3	8.9	11.7	**2**
Scaly jewfish	*Nibea squamosa*	37 354024	39.1	24.1	21.1	39.1	**3**
Black jewfish	*Protonibea diacanthus*	37 354003	15.2	12.7	12.3	15.2	**2**
Sharks							
Australian blacktip shark	*Carcharhinus tilstoni*	37 018014	11.7	9.4	8.9	11.7	**2**
Spot-tail shark	*Carcharhinus sorrah*	37 018013	11.7	9.3	8.9	11.7	**2**
Common blacktip shark	*Carcharhinus limbatus*	37 018039	11.7	9.4	8.9	11.7	**2**
Graceful shark	*Carcharhinus amblyrhynchoides*	37 018033	11.7	9.3	8.9	11.7	**2**
Great hammerhead	*Sphyrna mokarran*	37 019002	11.7	9.3	8.9	11.7	**2**
Scalloped hammerhead	*Sphyrna lewini*	37 019001	12.5	10.1	9.5	12.5	**2**
Winghead shark	*Eusphyra blochii*	37 019003	12.5	10.1	9.4	12.5	**2**

Appendix D—Residual Risk Analysis.

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
Teleosts Scaly jewfish (*Nibea squamosa*)	*Age at maturity (Productivity)*	3	1	Information gaps in the life history of scaly jewfish (*N. squamosa*) resulted in the species receiving a preliminary high-risk (3) rating for *age at maturity*. In the RRA, proxy species from within the same genus or family were used to assign more accurate *productivity* scores. The *age at maturity* attribute for the other members of the Sciaenidae family (black jewfish, *P. diacanthus*) were assessed as low (1), reaching sexual maturity at around 4 years of age (Bray, 2020a). Species from within the *Nibea* genus that did not form part of this assessment were also considered as proxies, with *age at maturity* estimates placing these species within the low-risk category (*N. albiflora*; 2–3 years) (Han *et al.*, 2018). Based on the available information, it is unlikely that the *age at maturity* attribute for scaly jewfish would differ markedly from what is known about other species in the genus or family. ***Key changes to the PSA scores*** Default high-risk scores assigned to the *age at maturity* attribute were reduced to match other species within the *Nibea* genus and Sciaenidae family. These changes were done in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of date information* and *Guideline 2: Additional scientific assessment & consultation*.
Teleosts Scaly jewfish (*Nibea squamosa*)	*Trophic level (Productivity)*	3	3	*Trophic level* is currently unknown for the scaly jewfish (*N. squamosa*) and the species was assigned precautionary high (3) risk rating in the PSA. The RRA gave further consideration to the score assigned to this attribute and the potential for it to be reduced. While noting the absence of data, this species will likely have similar dietary preferences to all other assessed harvested teleost species. Because of this, a high score for the *trophic level* attribute is not likely to be an overestimate. ***Key changes to the PSA scores*** The high (3) risk score assigned to *trophic level* was retained based on other harvested species.

Teleosts Barramundi (*Lates calcarifer*)	*Sustainability assessments (Susceptibility)*	1	2	Barramundi (*L. calcarifer*) have a stock assessment and positive stock status assessments for both Gulf of Carpentaria stocks (*i.e.* northern and southern Gulf of Carpentaria) (Grubert *et al.*, 2020; Streipert *et al.*, 2019). Based on the criteria used, barramundi was assigned a low-risk score for the *sustainability assessment* attribute (1). While noting the reasons behind the above decision, at least one of the barramundi stocks has been the subject of a (historical) negative stock status assessment —the Southern Gulf of Carpentaria stock was previously classified as 'depleted' (Saunders *et al.*, 2018). The northern and southern Gulf of Carpentaria stocks are now estimated to be at 73% and 39% biomass respectively relative to unfished levels (Streipert *et al.*, 2019). The northern stock makes up a small proportion of all barramundi harvest in the Gulf of Carpentaria (4%), and there are negligible sustainability concerns for this stock (Grubert *et al.*, 2020; Streipert *et al.*, 2019). Similarly, the southern stock is very close to the B_{40} threshold, suggesting that the sustainability risk is being managed within the current fishing environment. However, the assessment also notes that the current fishing environment is not conducive to stock rebuilding and that the species was unlikely to reach the long-term target of B_{60} without a reduction in catch (Streipert *et al.*, 2019). While historically consistent fishing pressure has contributed to these biomass levels not increasing, barramundi recruitment is strongly influenced by environmental conditions, and the region has experienced a spate of unfavourable conditions over the last decade (Halliday *et al.*, 2012; Robins *et al.*, 2006; Staunton-Smith *et al.*, 2004). These factors contributed to a 'depleting' stock status assessment in previous years, particularly the southern Gulf of Carpentaria stock (Saunders *et al.*, 2018). ***Key changes to the PSA scores*** While the health of this stock has improved, previous assessments show that stocks in the Gulf of Carpentaria are susceptible to overfishing and/or have previously experienced sustained periods of adverse recruitment conditions *e.g.* due to environmental conditions. Most recent assessments also suggest that biomass levels are not conducive to stock rebuilding. Due to these reasons, the score assigned to this attribute was increased from low (1) to medium (2). This decision is precautionary and

				was done in accordance with *Guideline 2: Additional scientific assessment & consultation* and *Guideline 5: Effort and catch management arrangements for target and byproduct species.*
Teleosts Grey mackerel (*Scomberomorus semifasciatus*) Giant queenfish (*Scomberoides commersonnianus*) Scaly jewfish (*Nibea squamosa*)	*Recreational desirability / other fisheries (Susceptibility)*	3	1	Grey mackerel (*S. semifasciatus*), giant queenfish (*S. commersonnianus*) and scaly jewfish (*N. squamosa*) were assigned precautionary high-risk scores (3) for the *recreational desirability* attribute due to data deficiencies (*i.e.* no species-specific information in the survey or low confidence estimates) (Webley *et al.*, 2015). All three are likely to be caught and retained by non-commercial fishers in the Gulf of Carpentaria, however indicative data from the most recent recreational fishing survey suggests that cumulative fishing pressures will be lower for these species. Gulf of Carpentaria waters are less urbanised and the region is less accessible to travellers, including those participating in angling-based tourism. The 2013/14 recreational fishing survey estimated that the Gulf catchment fishing region experienced around 60,000 fishing days (±12,000), compared to 2.5 million for the whole state (±114,000) (Webley *et al.*, 2015). The Gulf of Carpentaria also supports fewer charter operators (*n* = 9 active licences *verse n* = 134 on the east coast; 2019 data). Fishing mortality driven by the charter sector is likely to be low for queenfish (approx. 1t per annum retained, 2017─2019) and negligible for grey mackerel and scaly jewfish (Department of Agriculture and Fisheries, 2020a). Based on these values and estimates, the recreational and charter fishing sectors will make a minor contribution to fishing mortality rates for these three species in the Gulf of Carpentaria. It is recognised that other commercial fisheries will contribute to cumulative risks for these species; namely the Gulf of Carpentaria Line Fishery (GOCLF) and the Gulf of Carpentaria Developmental Fin Fish Trawl Fishery. While noting these risks, the impacts of these fisheries on regional stocks are expected to be low. The fin-fish trawl fishery has been inactive since 2016 and line fishers are not permitted to harvest most of GOCIF's primary target species (Department of Agriculture and Fisheries, 2020b). Of the three, only grey mackerel can be harvested by the GOCLF and recent catch records indicate that this fishery harvests smaller quantities (2.8t total, 2017─19) (Department of Agriculture and Fisheries, 2019e; 2020a).

				Key changes to the PSA scores Risk ratings assigned to the *recreational desirability / other fisheries* attributes were decreased from high (3) to low (1) for three species; *S. semifasciatus, S. commersonnianus,* and *N. squamosa*. This change was made in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of date information* and *Guideline 5: Effort and catch management arrangements for Target & Byproduct species* with consideration given to *Guideline 4: At risk in regards to level of interaction/capture with a zero or negligible level of susceptibility*.
Teleosts Black jewfish (*Protonibea diacanthus*)	*Recreational desirability / other fisheries (Susceptibility)*	1	2	While black jewfish (*P. diacanthus*) are a valued recreational species, they are not retained in great numbers (15.8%; Webley *et al.*, 2015). As retention rates for this species are below 33% it was assigned a low (1) risk score in the *recreational desirability* attribute. In the RRA, further consideration was given to two risk factors that are not easily accounted for in the PSA; 1) the comparative value of this species and the increased potential for black marketing and 2) how cryptic mortalities / post-release mortalities may increase the impact of this sector on regional stocks. In recent times, the market value of black jewfish has increased exponentially with swim bladders from this species exceeding $600 a kilogram. While the sale of recreationally caught product is illegal, at these prices, there is an increased risk that fish will be sold on the black market. This risk was recognised in management changes introduced in September 2019 which included boat limits for nine priority black market species including black jewfish. While noting these management changes, cost-per-kilogram for black jewfish bladders remains high, and the black marketing of this product by recreational fishers remains a relatively unquantified risk. Of notable importance, recreational catch was taken into consideration as part of broader management of the commercial black jewfish TACC limit. This limit prohibits the retention of the species in any sector (commercial & non-commercial) once this allocation is exhausted. This measure will have a direct impact on the number of black jewfish that is harvested from the recreational fishing sector. The inherent trade-off being that a higher number of fish will be discarded. Research suggests that discarded jewfish experience higher rates of *post-capture mortality* due, in part, to their *susceptibility* to

				barotrauma, predation *etc.* (Phelan, 2008; Tobin *et al.*, 2010). As a consequence, cryptic mortalities will be a contributing factor for this species and will likely result in higher rates of fishing mortality. ***Key changes to the PSA scores*** Changes to the black jewfish management system are a significant step forward in terms of the management of the risk posed to this species in GOCIF. These measures though are relatively new and further time is required to determine their broader effectiveness at managing catch across sectors and addressing the risk posed by black marketing. The risk profile of this species would also benefit from additional information on post-interaction survival rates and how cryptic mortalities contribute to total rates of fishing mortality. For these reasons, the score assigned to the *recreational desirability* attribute was increased from a low (1) to a medium (2) risk score. The decision to increase the score for this attribute was precautionary and minimises the risk of the Level 2 ERA producing a false-negative result. This change was done in accordance with *Guideline 2: Additional scientific assessment & consultation* and *Guideline 5: Effort and catch management arrangements for target and byproduct species.*
Teleosts Blue threadfin (*Eleutheronema tetradactylum*)	*Recreational desirability / other fisheries (Susceptibility)*	2	1	Blue threadfin (*E. tetradactylum*) was assigned a medium-risk score based on 57% retention rates in the recreational fishing survey. While the species is a desirable target for non-commercial fishers, this score is likely to be an over-estimate for the Gulf of Carpentaria. Gulf of Carpentaria waters are less urbanised than the east coast and the region is less accessible to travellers, including those participating in angling-based tourism. The 2013/14 recreational fishing survey estimated that the Gulf catchment fishing region experienced around 60,000 fishing days (±12,000), compared to 2.5 million for the whole state (±114,000) (Webley *et al.*, 2015). It is unlikely the recreational sector is a significant source of risk for this species in the Gulf of Carpentaria. The Gulf of Carpentaria supports fewer charter operators than on the east coast (*n* = 9 active licences *verse n* = 134 on the east coast; 2019 data). Fishing mortality driven by the charter sector is far lower than the commercial sector with less than 19t caught collectively between 2017 and 2019 (Department of Agriculture and Fisheries, 2020a). Operators in the Gulf of Carpentaria Line Fishery or the Gulf of

				Carpentaria Developmental Fin Fish Trawl Fishery are not permitted to retain blue threadfin (Department of Agriculture and Fisheries, 2019e; 2020b). ***Key changes to the PSA scores*** Risk ratings assigned to the *recreational desirability / other fisheries* attributes decreased from medium (2) to low (1) for blue threadfin. This change was made in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of date information* and *Guideline 5: Effort and catch management arrangements for target and byproduct species.*
Blacktip sharks Graceful shark *(C. amblyrhynchoides)*	*Age at maturity (Productivity)* *Maximum age (Productivity)*	3	2	*Age at maturity* and *maximum age* is currently unknown for the graceful shark (*C. amblyrhynchoides*) and the species was assigned a precautionary high (3) risk rating in the PSA. While noting the absence of data, this species will likely exhibit traits seen in other similar sized whaler species including the two blacktip sharks (*C. tilstoni* and *C. limbatus*). Research on the age and growth of sharks and rays suggest that a high proportion reach sexual maturity before 15 years (Cortés, 2000; Geraghty *et al.*, 2013). Based on this research, it is likely that the preliminary risk score for these two attributes are too high for this species. ***Key changes to the PSA scores*** Default high (3) risk scores assigned to *age at maturity* and *maximum age* was reduced to medium (2). This score better reflects what is known about the biology of whaler sharks and is viewed as more appropriate for this species. This change was made in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of date information.*
Hammerhead sharks *Great hammerhead (S. mokarran)*	*Selectivity (Susceptibility)*	1	3	In the PSA, body size was used as the primary determinant for scores assigned to the *selectivity* attribute. As the great hammerhead (*S. mokarran*) has a maximum total length of 6m the species was assessed as low risk (1) for this attribute. However, research has shown that the morphology of the hammerhead shark cephalofoil makes them highly susceptible to net entanglements across a wide range of size classes (Harry *et al.*, 2011a; Tobin *et al.*, 2010). As a consequence, criteria used to evaluate the *selectivity* risk are less suited to this subgroup of species.

				Key changes to the PSA scores The preliminary score assigned to the *selectivity* attribute for the great hammerhead shark was increased from low (1) to high (3). These amendments were done in accordance with *Guideline 2: Additional scientific assessment & consultation*.
<u>Hammerhead sharks</u> *Winghead shark (E. blochii)* *Scalloped hammerhead (S. lewini)* *Great hammerhead (S. mokarran)*	*Management strategy (Susceptibility)*	3	3	The take of hammerhead shark in the Gulf of Carpentaria is currently managed through maximum legal size (MLS) limits, in-possession limits (recreational fishing), and a combined TACC limit of 50t. As this 50t limit only includes *Sphyrna* species, it does not cover the winghead shark. The responsiveness of the TACC system is limited as it does not include a mechanism that prevents people from fishing for and retaining hammerhead sharks once the 50t limit is reached. This issue is compounded by the fact that discards are not included in the TACC. For these reasons, the winghead shark (*E. blochii*), scalloped hammerhead (*S. lewini*), and great hammerhead (*S. mokarran*) were assigned a high (3) risk score. Catch data for hammerhead sharks in the Gulf of Carpentaria has poor species resolution (Department of Agriculture and Fisheries, 2019b). Based on historical catch data, it is likely that the scalloped and great hammerhead shark are being fished at or below conservative MSY estimates (25.7t for scalloped hammerhead; 10.4t for great hammerhead) (Leigh 2015). This in turn suggests that these two species are being fished sustainably under the current fishing environment. There is however some capacity within the current management regime for catch and effort to increase for one or more of these species *e.g.* due to increased demand in the overseas market. Outside of the commercial fishing sector, the take of hammerhead sharks is restricted in the recreational fishery to an in-possession limit of one shark smaller than 1.5m. These measures and the increased potential of a hammerhead shark surviving a line interaction reduces the cumulative fishing pressures exerted on these species. ***Key changes to the PSA scores*** No changes were made to the PSA scores, however it is recognised that a high (3) risk rating may be precautionary for some of the species. A score reduction could not be supported in the current ERA

				due to limitations in the current regime, the absence of species-specific catch and effort controls, management's inability to validate catch data, and limited information on discards. With further information, the score assigned to this attribute could potentially be reduced.
<u>Blacktip sharks</u> *Australian blacktip shark (C. tilstoni)* *Spot-tail shark (C. sorrah)* ***<u>Hammerhead sharks</u>*** *Winghead shark (E. blochii)* *Scalloped hammerhead (S. lewini)* *Great hammerhead (S. mokarran)*	*Sustainability assessments (Susceptibility)*	1	2	The most recent shark stock assessment included MSY estimates for *C. tilstoni, C. sorrah, S. lewini, S. mokarran* and *E. blochii*. As catch for these species remains below their MSY estimates they were all assigned a preliminary low-risk rating (1) for the *sustainability assessments* attribute. While the listed shark species are being fished below sustainability reference points, the assessment identified a number of concerns surrounding the quality and amount of catch data. For example, there are inherent challenges collecting data on Australian blacktip sharks which can be difficult to differentiate between in an active fishing environment. Similar identification issues exist for hammerhead sharks; particularly when they are juveniles. Uncertainties in the catch data make it difficult to quantify individual rates of fishing mortality and assess how the fishery is tracking against key sustainability reference points. These deficiencies have also limited the scope of indicative sustainability evaluations (*i.e.* SAFS) with blacktip sharks (*C. tilstoni,* and *C. limbatus*) in the Gulf of Carpentaria classified as 'undefined' (Usher *et al.*, 2020a; Usher *et al.*, 2020b). Hammerhead sharks have not been assessed through the SAFS process. While Leigh (2015)'s assessment provides insight into how harvest levels compare to sustainable yields, it was based on data from several years ago. Stock status assessments and future ERAs would significantly benefit from an updated assessment, one that utilises new data collected by the *Shark Monitoring Program* (Department of Agriculture and Fisheries, 2019g). ***Key changes to the PSA scores*** The low-risk rating for *C. tilstoni, C. sorrah, S. lewini, S. mokarran,* and *E. blochii* were increased to medium (2). This increase was done as a precautionary measure and may be an overestimate for some species. It was however considered the most appropriate course of action given that the fishery has limited capacity to validate data submitted through the logbook program and/or accurately

				document total rates of fishing mortality. This change was made in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of date information*.
Sharks *Blacktip sharks (Family Carcharhinidae)* *Hammerhead sharks (Family Sphyrnidae)*	*Recreational desirability / other fisheries (Susceptibility)*	3	1	While whaler sharks (*Family Carcharhinidae*) and hammerheads (*Family Sphyrnidae*) were included in the Statewide Recreational Fishing Survey (Department of Agriculture and Fisheries, 2020a; Webley *et al.*, 2015), they were all assigned precautionary high risk ratings due to an absence of species-specific catch estimates. Sharks are not highly targeted by recreational fishers and the sector has a strong preference for teleosts. In the most recent recreational fishing survey, fishers registered a combined retention rate for *Sharks—unspecified* and *Whaler and Weasel sharks—unspecified* of just 4% (Webley *et al.*, 2015). Across surveys, the recreational catch and harvest of the *Whaler and Weasel sharks—unspecified* has also decreased (50,468 caught and 45,840 released in 2010–11, Taylor *et al.*, 2012; 24,000 caught and released in 2013–14, Webley *et al.,* 2015). Current MLS limits and in-possession limits further reduce the recreational take of sharks, with hammerheads afforded added protection as 'no take' species (*Fisheries Declaration 2019*). The absence of information surrounding discard mortality of sharks involved in recreational fishing activities creates uncertainty surrounding total fishing mortality. Available information on discard mortality identifies hook type, hook location, time on the line, and damage during hook removal as key predictors of post-release survival (Barnes *et al.*, 2016; Curruthers *et al.*, 2009). While this is of particular concern given the associated high release rates, the most recent stock assessment operated under the assumption of high survival rates for catch by hook and line (Leigh, 2015). ***Key changes to the PSA scores*** Based on the available information, the preliminary score assigned to the *recreational desirability* attribute in the PSA was reduced to a low (1). The decision was based on the low and decreasing recreational interest of sharks coupled with consistently high release rates. While discard mortality remains unknown across species groupings, the release of sharks landed by hook and line is not expected to pose a significant risk to the post-interaction mortality of the species. Moreover,

				protections are in place for the recreational take of whalers and hammerheads, further reducing the risks posed by recreational fishing pressures. This change was done in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of date information* and *Guideline 2: Additional scientific assessment & consultation.* While the RRA represents a notable downgrade of the score assigned to this attribute, it is not expected to contribute to a false-negative result.

Appendix E—Supplementary Risk Assessment: Likelihood & Consequence Analysis.

1. Overview & Background

The *Productivity & Susceptibility Analysis* (PSA) includes a number of elements to minimise the risk of a false-negative result *i.e.* high-risk species being incorrectly assigned a lower-risk rating. However, the PSA tends to be more conservative, and research has shown that it has a higher potential to produce false positives. That is, low-risk species being assigned a higher-risk score due to the conservative nature of the method, data deficiencies *etc.* (Hobday *et al.*, 2011; Hobday *et al.*, 2007; Zhou *et al.*, 2016). In the Level 2 Ecological Risk Assessment (ERA), false positives are addressed through the *Residual Risk Analysis* (RRA) and the assignment of precautionary risk ratings.

To inform the assignment of precautionary risk ratings, each species was subjected to a *Likelihood & Consequence Analysis* (LCA). The LCA, in essence, provides a closer examination of the magnitude of the potential consequence and the probability (*i.e.* likelihood) that those consequences will occur given the current management controls (Fletcher, 2014; Fletcher *et al.*, 2002; Fletcher *et al.*, 2005). A flexible assessment method, the LCA can be used as a screening tool or to undertake more detailed risk assessments (Fletcher, 2014).

In the Level 2 ERA, a simplified version of the LCA was used to provide the risk profiles with further context and evaluate the applicability of the assessment to the current fishing environment. More specifically, the LCA was used to assist in the allocation of precautionary risk ratings which are assigned to species with more conservative risk profiles. The benefit of completing a fully qualitative assessment following a more data-intensive semi-quantitative assessment is the reduction of noise in the form of false-positives. This was considered to be of particular importance when identifying priority risks for this fishery.

As the LCA is qualitative and lacks the detail of the PSA, the outputs should not be viewed as an alternate or competing risk assessment. To avoid confusion, the results of the PSA/RRA will take precedence over the LCA. The LCA was only used to evaluate the potential of the risk coming to fruition over the short to medium term.

2. Methods

The LCA was constructed using a simplified version of the *National ESD Reporting Framework for Australian Fisheries* (Fletcher, 2014; Fletcher *et al.*, 2002; Fletcher *et al.*, 2005) and focused specifically on the *Risk Analysis* component. It is recognised that the *National ESD Reporting Framework* incorporates additional steps including ones that establish the context of the assessment and identifies key risks. As these steps were fulfilled with the completion of a *Scoping Study* (Department of Agriculture and Fisheries, 2019b) and whole-of-fishery (Level 1) assessment (Jacobsen *et al.*, 2019b), they were not replicated for the Level 2 ERA. For a more comprehensive overview of the *National ESD Reporting Framework for Australian Fisheries* consult Fletcher *et al.* (2002) and Fletcher (2014).

Risk Analysis considers a) the potential consequences of an issue, activity or event (Table E1) and b) the likelihood of a particularly adverse consequence occurring due to these activities or events (Table E2). Central to this is the establishment of a Likelihood *x* Consequence matrix that estimates the risk based on scores assigned to each component (Table E3).

***Table E1**. Criteria used to assign scores to the Consequence component of the analysis.*

Level	Score	Definition
Negligible	0	Almost zero harvest/mortalities with impact unlikely to be detectable at the scale of the stock/regional population.
Minor	1	Assessed as low risk through the PSA and/or fishing activities will have minimal impact on regional stocks or populations.
Moderate	2	Assessed as a medium risk through the PSA / harvest levels or mortalities at, near or approaching maximum yields (or equivalent).
Severe	3	Species assessed as high risk through the PSA / harvest or mortalities at levels that are impacting stocks and/or has high vulnerability and low resilience to harvest.
Major	4	Species assessed as high risk through the PSA / harvest levels or mortalities has the potential to cause serious impacts with a long recovery period required to return the stock/population to an acceptable level.

***Table E2**. Criteria used to assign indicative scores of the likelihood that fishing activities in the Gulf of Carpentaria Inshore Fishery (GOCIF) will result in or make a significant contribution to a Severe or Major consequence.*

Level	Score	Definition
Likely	5	Expected to occur under the current fishing environment / management regime.
Occasional	4	Will probably occur or has a higher potential to occur under the current fishing environment / management regime.
Possible	3	Evidence to suggest it may occur under the current fishing environment / management regime.
Rare	2	May occur in exceptional circumstances.
Remote	1	Has never occurred but is not impossible.

***Table E3**. Likelihood & Consequence Analysis risk matrix used to assign indicative risk ratings to each species: blue = negligible risk, green = low risk, orange = medium risk and red = high risk.*

		Consequence				
Likelihood		**Negligible**	**Minor**	**Moderate**	**Severe**	**Major**
		0	1	2	3	4
Remote	1	0	1	2	3	4
Rare	2	0	2	4	6	8
Possible	3	0	3	6	9	12
Occasional	4	0	4	8	12	16
Likely	5	0	5	10	15	20

For the consequence analysis (Table E2), criteria used to assign scores (0–4) were based on the outputs of the semi-quantitative assessment (*e.g.* PSA/RRA results outlined in section 4, Table 7). In the likelihood assessment (Table E1), scores reflect the likelihood of the fishery causing or making a significant contribution to the occurrence of the most hazardous consequence (Fletcher *et al.* 2002). Once scores are assigned to each aspect of the LCA, they are used to calculate an overall risk value (Risk = Likelihood *x* Consequence) for each species (Table E3).

As the Level 2 ERA uses the LCA as a supplementary assessment, risk scores and ratings were not linked to any operational objective; as per the *National ESD Reporting Framework* (Fletcher, 2014; Fletcher *et al*., 2005). Instead, these issues are addressed directly as part of the Level 2 ERA through fisheries-specific recommendations. Criteria used to assign scores for likelihood and consequence are outlined in Table E1 and E2 respectively. The Likelihood *x* Consequence matrix used to assign risk ratings is provided as Table E3.

3. Results & Considerations

When compared to the PSA/RRA, risk estimates generated through the LCA were generally lower. This was to be expected as the LCA gives greater consideration and equal waiting to the probability (likelihood) of a fishery contributing to or causing a severe or major event under the current conditions (*e.g.* catch, effort and interaction trends). In a number of instances, the outputs of the LCA supported the assignment of precautionary risk ratings.

Teleosts

LCA risk estimates for the eight teleost species ranged from low to high. Scores for grey mackerel, blue threadfin, giant queenfish, scaly jewfish, barramundi and black jewfish were at the lower end of the spectrum (Table E4). Barramundi and black jewfish had LCA estimates that aligned with the PSA/RRA; the remainder were below that reported in the main report.

Spanish mackerel and king threadfin had the highest risk estimate in the LCA (Table E4). This assessment was influenced by signals contained in regional stock assessments that show current fishing pressures are greater than what is required to increase biomass back to Maximum Sustainable Yield (MSY) levels (Leigh unpub. data; Bessell-Browne *et al.*, 2020).

In all eight instances, the extent of the difference between the LCA and the PSA/RRA were not viewed as sufficient to warrant the assignment of a precautionary risk rating. While the LCA did produce lower estimates for some species, these results did not over-ride some of the more pressing drivers of risk *e.g.* the potential for effort to increase under the current management regime (*e.g.* grey mackerel) and potential changes in marketability (*e.g.* threadfins, jewfish, barramundi).

Sharks

All LCA risk estimates for the shark complex were lower (medium) than the PSA/RRA (high) (Table E4). While it is unlikely that all seven shark species are being fished beyond sustainability reference points, catch for some species (*C. tilstoni, S. mokarran,* and *S. lewini*) has been much higher (historically). In some instances, catch for key species (*C. tilstoni, C. sorrah, S. mokarran, S. lewini,* and *E. blochii*) have repeatedly exceeded conservative MSY[15] estimates (Department of Agriculture

[15] *Leigh (2015) recognised the limitations of commercial shark catch data and provided a lower MSY estimate as a precaution.*

and Fisheries, 2019b; Leigh, 2015). Further, there is room within the current management regime for catch to increase for one or more of these species. These factors were reflected in the likelihood scores and contributed to the species receiving higher matrix scores and risk ratings (Table E4).

When the results of the LCA were considered in conjunction with the key drivers of risk and the interaction potential, two species were assigned precautionary risk ratings: the common blacktip shark and the graceful shark. The results for the remaining species were inconclusive and did not adequately support the assignment of a precautionary risk rating.

Table E4. *Results of the Likelihood & Consequence Analysis for species assessed as part of the GOCIF Level 2 ERA.*

Common name	Species name	Likelihood	Consequence	Matrix score	Risk category
Teleosts					
Grey mackerel	*Scomberomorus semifasciatus*	2	2	4	**Low**
Spanish mackerel	*Scomberomorus commerson*	4	3	12	**High**
Barramundi	*Lates calcarifer*	3	3	9	**Moderate**
King threadfin	*Polydactylus macrochir*	4	4	16	**High**
Blue threadfin	*Eleutheronema tetradactylum*	2	2	4	**Low**
Giant queenfish	*Scomberoides commersonnianus*	1	2	2	**Low**
Scaly jewfish	*Nibea squamosa*	2	2	4	**Low**
Black jewfish	*Protonibea diacanthus*	3	3	9	**Moderate**
Sharks					
Australian blacktip shark	*Carcharhinus tilstoni*	2	3	6	**Moderate**
Spot-tail shark	*Carcharhinus sorrah*	2	3	6	**Moderate**
Common blacktip shark	*Carcharhinus limbatus*	2	3	6	**Moderate**
Graceful shark	*Carcharhinus amblyrhynchoides*	2	3	6	**Moderate**
Great hammerhead	*Sphyrna mokarran*	3	3	9	**Moderate**
Scalloped hammerhead	*Sphyrna lewini*	3	3	9	**Moderate**
Winghead shark	*Eusphyra blochii*	2	3	6	**Moderate**