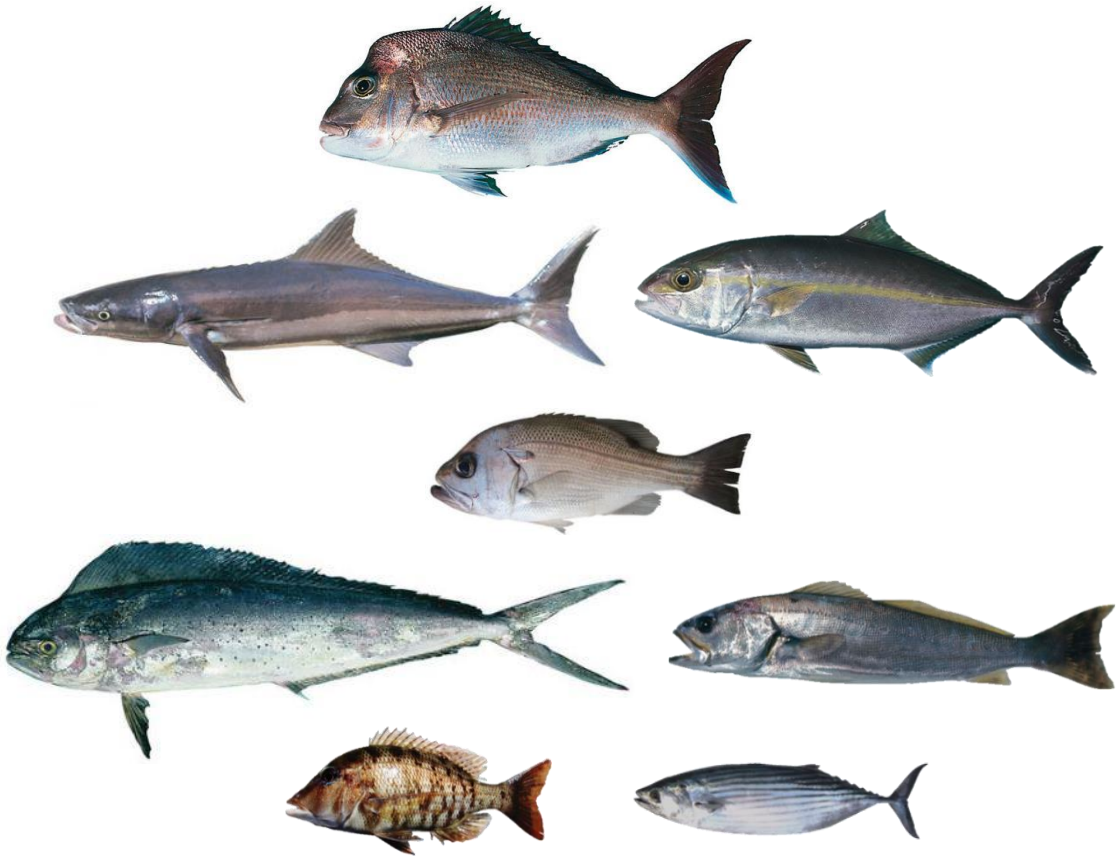
Sustainable Fisheries Strategy 2017–2027

Rocky Reef Fishery
Level 2 Ecological Risk Assessment

Productivity & Susceptibility Analysis (PSA)



Queensland Government

Level 2 Ecological Risk Assessment
Rocky Reef Fishery

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Executive Summary

The Rocky Reef Fishery (RRF) is a line-only fishery that targets a small number of demersal and pelagic fin fish. This includes recreationally important species like snapper (*Chrysophrys auratus*), pearl perch (*Glaucosoma scapulare*), grass emperor (*Lethrinus laticaudis*) and mahi mahi (*Coryphaena hippurus*). In July 2019, a whole-of-fishery or Level 1 ERA was released for the RRF (Jacobsen *et al.*, 2019a). The Level 1 ERA provided a broad risk profile for the RRF, identified the key drivers of risk and the ecological components most likely to experience an undesirable event. As part of this process, the Level 1 ERA considered both the current fishing environment and what can occur under the current management regime. In doing so, the outputs of the Level 1 ERA helped differentiate between low and high-risk elements and established a framework that can be built on in subsequent ERAs.

In the Level 2 ERA, the focus of the assessment shifts to individual species with risk evaluations based on a *Productivity & Susceptibility Analysis* (PSA). It considers fishing activities across the commercial, charter and recreational fishing sectors, and evaluates risk through an assessment of seven biological attributes (*age at maturity*, *maximum age*, *fecundity*, *maximum size*, *size at maturity*, *reproductive strategy*, and *trophic level*) and up to seven fisheries-specific attributes (*availability*, *encounterability*, *selectivity, post-capture mortality, management strategy, sustainability assessments* and *recreational desirability / other fisheries*). As the PSA can over-estimate risk for some species (Zhou *et al.*, 2016), 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 Level 2 ERA was based on the outcomes of a whole-of-fishery (Level 1) assessment (Jacobsen *et al.*, 2019a) and focused specifically on target & byproduct species. A review of catch data for the RRF produced a preliminary list of 13 target & byproduct species that were considered for inclusion in the Level 2 ERA. This list was reduced to 10 species through a subsequent rationalisation process and included snapper, pearl perch, cobia (*Rachycentron canadum*), grass emperor, amberjack (*Seriola dumerili*), teraglin (*Atractoscion aequidens*), Australian bonito (*Sarda australis*), leaping bonito (*Cybiosarda elegans*), yellowtail kingfish (*Seriola lalandi*), and mahi mahi. As the grey nurse shark (*Carcharius tarus*) was a key driver of risk in the shark ecological component Level 1 ERA (Jacobsen *et al.*, 2019a), it was also included in the Level 2 ERA as a precautionary measure.

When the outputs of the PSA and RRA were taken into consideration, eight species were assessed as being at high risk from fishing activities in the RRF. Risk profiles for target & byproduct species were heavily influenced by the *susceptibility* component with management limitations (*e.g.* the absence of control on catch and effort at the whole-of-fishery level), stock status uncertainty, an absence of information on biological reference points and increased cumulative fishing pressures (commercial, recreational plus charter fishing), all identified as key drivers of risk. A number of these risks are already being addressed through the *Rocky Reef Fishery Working Group* and harvest strategy development process (Department of Agriculture and Fisheries, 2017a; b; 2020a).

Of the species assessed, the risk posed to snapper and pearl perch were viewed as more significant. However, outputs of the Level 2 ERA suggests that the risk posed to cobia, grass emperor and teraglin require further investigations. The remaining six species (amberjack, Australian bonito,

leaping bonito, yellowtail kingfish, mahi mahi, and grey nurse shark), were all assigned precautionary risk ratings as they are more representative of the potential risk. **Management of the risk posed to species with precautionary risk ratings, beyond what is already being undertaken as part of the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017b), is not considered an immediate priority.** With improved information, it is hypothesised that the risk ratings for a number of these species (*e.g.* bonito, and mahi mahi) could be reduced and/or they could be excluded from future risk assessments involving the RRF.

Outputs from the Level 2 ERA take into consideration the current dynamics of the commercial fishery (*e.g.* catch, effort and participation rates), the charter fishery, and available data on the recreational fishing sector. In doing so, the assessment provides insight into some of the more immediate risks posed by line fishing activities in Queensland. These results provide a sound baseline of assessments that can be reviewed and amended (where appropriate) to accommodate additional data or management reforms. In this context, the following measures would assist with respect to mitigating, managing and understanding risk in the RRF.

- *Identify avenues/mechanisms that can be used to a) improve catch monitoring in the RRF (preferably in real or near-real time), b) minimise the risk of non-compliance (e.g. black marketing), and c) validate information obtained through the logbook program (commercial and charter fishing).*
- *Improve the level of information on the biology, stock structure, and status of species other than snapper and pearl perch to better monitor catch against biological reference points and manage fishing pressures against target reference points.*
- *Review the suitability, applicability, and value of data submitted through the logbook program on the dynamics of the fishery. As part of this process, it is recommended that the logbook reporting requirements be extended to include information on what fishing symbol is being used.*
- *Reassess species with high-risk ratings once a harvest strategy has been fully implemented in the fishery, prioritising both snapper and pearl perch.*
- *Evaluate options for the extended use of output controls for secondary target & byproduct species noting that TACC limits are already applied to snapper and pearl perch.*
- *Implement measures to improve the level of information on fine-scale effort movements, with particular emphasis on increasing our understanding of regional fishing pressures / cumulative fishing risks e.g. the suitability, applicability, or necessity of having additional protections for key species in high-usage areas.*
- *Quantify the cumulative fishing pressures exerted on key species from the recreational fishing sector and, when and where appropriate, review the suitability/applicability of possession limits for rocky reef species, explore avenues to improve monitoring across sectors, and collect more information on recreational catch rates, discards, post-capture mortality, and non-compliance.*
- *Improve the level of information on discards, survival rates, and the extent of cryptic/unreported mortalities including shark depredation.*

– *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 such as the base Sustainability Assessment for Fishing Effects (bSAFE).*

Summary of the outputs from the Level 2 ERA for the Rocky Reef Fishery.

Common name	Species name	Productivity	Susceptibility	Risk rating
Target & Byproduct				
Snapper	*Chrysophrys auratus*	1.71	2.86	**High**
Pearl perch	*Glaucosoma scapulare*	1.43	2.86	**High**
Cobia	*Rachycentron canadum*	1.71	2.86	**High**
Grass emperor	*Lethrinus laticaudis*	1.43	2.86	**High**
Amberjack	*Seriola dumerili*	1.71	2.71	**Precautionary High**
Teraglin	*Atractoscion aequidens*	1.86	3.00	**High**
Australian bonito	*Sarda australis*	1.43	2.57	**Precautionary Medium**
Leaping bonito	*Cybiosarda elegans*	1.43	2.57	**Precautionary Medium**
Yellowtail kingfish	*Seriola lalandi*	1.71	2.86	**Precautionary High**
Mahi mahi	*Coryphaena hippurus*	1.57	2.57	**Precautionary Medium**
Other				
Grey nurse shark	*Carcharias taurus*	2.71	2.25	**Precautionary High**

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Definitions & Abbreviations

AFMA	–	*Australian Fisheries Management Authority*.
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.*
ECIF	–	East Coast Inshore Fishery. Previously referred to as the East Coast Inshore Fin Fish Fishery or ECIFFF.
Ecological Component	–	Broader assessment categories that include *Target & Byproduct* (harvested) species, *Bycatch*, *Species of Conservation Concern*, *Marine Habitats* and *Ecosystem Processes.*
Ecological Subcomponent	–	Species, species groupings, marine habitats and categories included within each Ecological Component.
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.
FAD	–	Fish Aggregation Device.
False positive	–	The situation where a species at low risk is incorrectly assigned a higher risk rating due to the method being used, data limitations *etc.* In the context of an ERA, false positives are preferred over false negatives.
False negative	–	The situation where a species at high risk is assigned a lower risk rating. When compared, false-negative results are considered to be of more concern as the impacts/consequences can be more significant.

FMP	–	*Fishery Monitoring Program*. This replaced Queensland Fisheries' *Long-Term Monitoring Program*.
FOP	–	Fisheries Observer Program. Queensland Fisheries' ceased this program in 2009.
ITQ	–	*Individual Transferable Quotas.*
MEY	–	Maximum Economic Yield.
MSY	–	Maximum Sustainable Yield.
PSA	–	*Productivity & Susceptibility Analysis.* One of the two ERA methodologies that can be used as part of the Level 2 assessments.
RLF	–	*Reef Line Fishery*. Previously referred to as the Coral Reef Fin Fish Fishery or CRFFF. A line-only fishery which primarily operates within the Great Barrier Reef Marine Park (L2 & L3 fishing symbols) targeting a range of bottom-dwelling coral reef fin fish.
RRA	–	Residual Risk Analysis.
RRF	–	*Rocky Reef Fishery*. Previously referred to as the Rocky Reef Fin Fish Fishery or RRFFF. A line-only fishery which operates within the L1, L2 and L3 fishing symbol areas and targets a small number of demersal and pelagic fin fish species.
SAFE	–	*Sustainability Assessment for Fishing Effects*. One of the two ERA methodologies that can be used as part of the Level 2 assessments. This method can be separated into a base SAFE (bSAFE) and enhanced SAFE (eSAFE). The data requirements for eSAFE is higher than for a bSAFE, which aligns more closely to a PSA.
SAFS	–	The National *Status of Australian Fish Stocks*. Refer to www.fish.gov.au for more information.
Species of Conservation Concern (SOCC)	–	Broader risk assessment category used in the Level 1 assessments that incorporates marine turtles, sea snakes, crocodiles, dugongs, cetaceans, protected teleosts, batoids, sharks, seabirds, syngnathids and terrestrial mammals. These species may or may not be subject to mandatory reporting requirements.
Species of Conservation Interest (SOCI)	–	A limited number of species subject to mandatory reporting requirements as part of the Queensland logbook reporting system. Any reference to SOCI refers specifically to the SOCI logbook or data compiled from the SOCI logbook.
TACC	–	Total Allowable Commercial Catch limit.

1 Introduction

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

The Rocky Reef Fishery (RRF) is a line-only fishery that targets a small number of demersal and pelagic fin fish. This includes recreationally important species like snapper (*Chrysophrys auratus*), pearl perch (*Glaucosoma scapulare*), grass emperor (*Lethrinus laticaudis*) and mahi mahi (*Coryphaena hippurus*). In July 2019, a whole-of-fishery or Level 1 ERA was released for the RRF (Jacobsen *et al.*, 2019a).[1] The Level 1 ERA provided a broad risk profile for the RRF, identifying key drivers of risk and the ecological components most likely to experience an undesirable event. As part of this process, the Level 1 ERA considered both the current fishing environment and what can occur under the current management regime. In doing so, the outputs of the Level 1 ERA helped differentiate between low and high-risk elements and established a framework that can be built on in subsequent ERAs.

For the Level 2 ERA, the focus of the analysis shifts to a species-specific level and the scope of the assessment is refined to the current fishing environment. Applying more detailed assessment tools, Level 2 ERAs establish risk profiles for individual species using one of two methods: the semi-quantitative *Productivity & Susceptibility Analysis* (PSA) or the quantitative *Sustainability Assessment for Fishing Effects* (SAFE) (Department of Agriculture and Fisheries, 2018d; 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).

The completion of the Level 2 assessment for the RRF provides further depth to this fishery's ERA profile. With the focus shifting to individual species, the Level 2 ERA provides management with further avenues to explore the existence of both real and potential risks (Department of Agriculture and Fisheries, 2018d). Outputs from the Level 2 assessment will inform working group discussions and help identify fishery-specific risk management priorities. The Level 2 ERA builds on results contained in the whole-of-fishery (Level 1) assessment and strengthens linkages between the ERA process and the remaining areas of reform (Department of Agriculture and Fisheries, 2017b).

[1] *Fishery formally identified as the Rock Reef Fin Fish Fishery (RRFFF). Additional information on the management and configuration of the RRF is provided in the scoping study (Department of Agriculture and Fisheries, 2019a).*

2 Methods

2.1 The Fishery

As the PSA and SAFE are primarily used to assess risk in commercial fisheries, a large proportion of the Level 2 ERA will concentrate on commercial fishing activities conducted under the L1, L2 and L3 fishery symbols (Department of Agriculture and Fisheries, 2019a). In the RRF, the majority of the catch is reported from waters south of Baffle Creek (24.5°S) by commercial operators fishing under the L1 fishery symbol. However, fishers are permitted to harvest rocky reef species in the Great Barrier Reef Marine Park (GBRMP) providing they have the appropriate L2 or L3 endorsement (Department of Agriculture and Fisheries, 2018a; 2019a).

The management regime for the RRF consists of a mix of input and output controls. A number of these controls have either been reviewed, amended or introduced as part of a broader fisheries reform process (Department of Agriculture and Fisheries, 2017b). These include the introduction of a seasonal (spawning) closure and Total Allowable Commercial Catch (TACC) limits for snapper (*Chrysophrys auratus*) and pearl perch (*Glaucosoma scapulare*), boat limits (snapper), reduced possession limits (pearl perch), and increased minimum legal size limits (pearl perch) (Department of Agriculture and Fisheries, 2019h). These measures will continue to be built upon as part of the Strategy with the eventual objective being to establish and implement a comprehensive RRF-specific harvest strategy (Department of Agriculture and Fisheries, 2020a). As this harvest strategy is still in development, the Level 2 ERA only considered management arrangements that were in effect at the time of the assessment.

In addition to commercial fishing, the charter fishing sector will be a risk factor for a number of the rocky reef species. Similar to the commercial sector, charter operators must adhere to licencing and reporting requirements, but catch/effort is not restricted by quota. As with all fishing sectors, the charter sector must abide by spatial and seasonal closures, minimum and maximum size limits, and gear restrictions. In addition to the commercial fishery, the Level 2 ERA will take the charter sector into consideration when assessing fishing impacts to assessed rocky reef species.

Outside of the commercial and charter fisheries, several rocky reef species including snapper and pearl perch attract a significant level of attention from the recreational fishing sector. Recreational fishers harvest an estimated 85t of snapper each year (Fowler *et al.*, 2018) and this sector makes a notable contribution to the annual rate of fishing mortality. As both commercial and recreational fishers use similar apparatus, this sector will also interact with a similar range of species. Given these factors, the Level 2 ERA also considered the impact of the recreational sector on a number of the species assessed. As the recreational fishery does not have a designated area (excluding spatial closures), the Level 2 ERA will consider recreational data obtained from the entire Queensland east coast (Department of Agriculture and Fisheries, 2020b; Webley *et al.*, 2015).

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

2.2 Information Sources / Baseline References

Where possible, baseline information on the life history constraints and habitat preferences for each species was 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), *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 species was obtained through the *Atlas of Living Australia* (www.ala.org.au), *Species Profile and Threats Database* (Department of Environment and Energy, *www.environment.gov.au/cgi-bin/sprat/public/sprat.pl*) and resources associated with the management and regulation of marine national parks *e.g.* the *Great Barrier Reef Marine Park*, *Moreton Bay Marine Park* and *Great Sandy Marine Park.* Where possible, regional species distribution maps were sourced for direct comparison with effort distribution data (Whiteway, 2009).

Fisheries data used in the Level 2 ERA were obtained through the fisheries logbook program, a previous *Fisheries Observer Program* (FOP), the *Fishery Monitoring Program* (FMP)[2] and the *Statewide Recreational Fishing Survey* (Department of Agriculture and Fisheries, 2020b; 2021; Webley *et al.*, 2015).

2.3 Species Rationalisation Processes

The scope of the Level 2 (species-specific) ERA was determined by the outcomes of the whole-of-fishery (Level 1) assessment (Jacobsen *et al.*, 2019a). For the RRF, the Level 1 ERA recommended that the *Target & Byproduct Species* ecological component be progressed to a finer scale assessment (Table 1). Fishing related risks for a further two ecological components were progressed through the *Queensland Monitoring & Research Plan* (Table 1).

Table 1. *Summary of the outputs from the Level 1 (whole-of-fishery) Ecological Risk Assessment for the RRF. *Does not include Species of Conservation Concern or target & byproduct species returned for to the water due to regulations like minimum legal size limits or product quality.*

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

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

A preliminary list of target & byproduct species was compiled using catch data submitted through commercial logbooks from 2016–2018 (inclusive). Catch reported against each species or species complex was summed across years and ranked from highest to lowest. Cumulative catch comparisons were then used to identify the species 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).

While the Level 1 ERA assessed the shark ecological subcomponent as a low to intermediate risk (Table 1), the grey nurse shark (*Carcharias taurus*) was singled out as a higher risk species (Jacobsen *et al.*, 2019a). Grey nurse sharks have experienced historical population declines and the species has a distribution that overlaps with the RRF (Bansemer & Bennett, 2011; Department of the Environment, 2019). Evidence also suggests that the species will interact with line fishers on the Australian east coast (Bansemer & Bennett, 2010; Robbins *et al.*, 2013). As grey nurse sharks have conservative life history traits and small population sizes, risks to this species will be present at even low levels of fishing mortality. Grey nurse sharks are classified as *Critically Endangered* under the *EPBC Act 1999* and their incidental capture in commercial and recreational fisheries has been identified as a long-term threat for this species (Department of the Environment, 2019). For these reasons, grey nurse sharks were included in the RRF Level 2 ERA as a precautionary measure.

Where possible, the species rationalisation process was done in consultation with key stakeholders including Fisheries Working Groups[3] established under the *Queensland Sustainable Fisheries Strategy 2017–2027*. A full account of the species rationalisation process has been provided in Appendix A and Appendix B.

2.4 Ecological Risk Assessment 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 *Productivity & Susceptibility Analysis* (PSA) and the *Sustainability Assessment for Fishing Effects* (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 *i.e.* high-risk species being incorrectly assigned a lower risk rating. However, research has shown that the PSA tends to be more conservative and has a higher potential to produce false positives *i.e.* low-risk species that are assigned a higher risk rating due to the conservative nature of the method, data deficiencies *etc.* (Hobday *et al.*, 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

[3] The scope of the Level 2 ERA was discussed with the Rocky Reef Working Group at the 12–13 August 2019 meeting.

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 both the fishing intensity and the degree of overlap between a species' distribution and fishing effort (Hobday *et al.*, 2011; Zhou *et al.*, 2009). These parameters are used to determine the gear-affected area and the estimate of risk is sensitive to this quantity (Hobday *et al.*, 2011). The gear-affected area being 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). This can be difficult to calculate for species with poorly defined geographical distributions or with insufficient datasets. In the context of this ERA, this will be a factor for a number of the species included in this analysis.

In a line fishery, determining the gear-affected area can be difficult as it will depend on a range of factors including the number of lines/hooks, the way in which the hooks are used (*i.e.* number of hooks per line), the fishing method employed (trolling versus demersal), the distance between lines, the frequency with which the lines are retrieved, variations in fishing power and the use (if applicable) of ancillary equipment. In the RRF, commercial fishers are required to submit information on the number of tenders, crew numbers, line numbers, and fishing method (handline/reel or trolling). While operators are also required to identify a fishing location, this information only reflects the position of the greatest daily catch. As a consequence, locational data collected on line-fishing activities may not reflect the spatial extent of the fishery or the total area fished by the primary boat and any associated tenders.

From an ERA perspective, the above deficiencies are important as they introduce a degree of uncertainty surrounding the fine-scale distribution of fishing effort and the level of fishing intensity. This by extension has a bearing on the accuracy of estimates of the gear-affected area. Of significance, these deficiencies are being actively addressed as part of the Strategy and the mandated use of *Vessel Tracking* (Department of Agriculture and Fisheries, 2018f). However, other factors including the distance over which a species may be attracted to the bait may also impact the gear-affected area (Zhou *et al.*, 2019). This in itself may be difficult to determine without a clear estimate of the hook soak time and line retrieval frequency (*pers. comm*. Z. Zhou).

In addition to the gear-affected area, rocky reef species are targeted by recreational fishers and this sector will contribute to the overall level of risk. The SAFE method was principally developed for use in commercial fisheries and the method has yet to evolve to a point where it can accurately account for recreational fishing pressures. In Queensland, the majority of information from this sector is obtained through the voluntary localised collection of data (the boat ramp survey program, keen angler program and other initiative undertaken through the *Fishery Monitoring Program*) and a more expansive voluntary recreational fisher survey (Department of Agriculture and Fisheries, 2020b; Webley *et al.*, 2015). However, the level of data required to inform the SAFE method goes beyond what is collected by these programs, and inclusion of the recreational sector in the analysis will be difficult.

Given the importance of the gear-affected area and the methodology limitations with respect to assessing recreational fishing mortality, the PSA was adopted for the RRF Level 2 ERA. While the use of a PSA increases the potential for false positives, previous ERAs have successfully modified this method to account for recreational fishing (Furlong-Estrada *et al.*, 2017; Patrick *et al.*, 2010). To this

extent, it was considered to be the best method to assess the collective risk in this fishery. It is recommended that subsequent ERAs review the suitability and applicability of the SAFE method with the continued role out of initiatives being undertaken as part of the Strategy (Department of Agriculture and Fisheries, 2017b).

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 strategy* and *trophic level* (Table 2). *Productivity* attributes used in the Level 2 assessment were consistent with the ERAEF (Hobday *et al.*, 2011) and were applied across all ecological components subject to a PSA. Criteria used to assign each attribute a score of low (1), medium (2) or high (3) risk are outlined in Table 2.

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

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

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

For the *Susceptibility* component of the PSA, ERAEF attributes were used as the baseline of the assessment and included *availability*, *encounterability*, *selectivity* and *post-capture mortality* (Hobday *et al.*, 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 (2016, 2017 and 2018) and the highest value used as the basis of the *availability* assessment. Regional distribution maps were sourced from the *Atlas of Living Australia*, the *Species Profile and*

Threats Database (Department of Environment and Energy, www.environment.gov.au/cgi-bin/sprat/public/sprat.pl), the *CSIRO* and, where possible, refined using bathymetry and topographical data (Whiteway, 2009).

In instances where a species did not have a distribution map, *availability* scores were based on a broader geographic distribution assessment (global, southern hemisphere, Australian endemic) described in Hobday *et al.* (2007) (Table 3). A full summary of the overlap percentages used to assess *availability* has been provided in Appendix C.

- **Encounterability**—*Encounterability* considers the likelihood that a species will encounter the fishing gear when it is deployed within the known geographical range (Hobday *et al.*, 2007). The *encounterability* assessment is based on the behaviour of the species as an adult and takes into consideration information on the preferred habitats and bathymetric ranges. For the PSA, both parameters (*i.e.* adult habitat overlap and bathymetric range overlap) are assigned an individual risk score with the highest value used as the basis of the *encounterability* assessment.

- **Selectivity**—*Selectivity* is effectively a measure of the likelihood that a species will get caught in the apparatus. Factors that will influence *selectivity* include the fishing method, the apparatus used and the body size/morphology of the species in relation to the gear size (*e.g.* mesh size, trap opening). For the purpose of the RRF, *selectivity* scores were based on the likelihood that the animal will actively interact with the line (*e.g.* attraction to the bait) and become hooked.

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

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

In the Level 2 ERA, they will be used to further reduce the influence of false positives or risk overestimations for key species. As grey nurse sharks are protected in Queensland waters, the three additional attributes were not applied to this species. Summaries for the three additional attributes 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 the use of quotas based on biological reference points like Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY).

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 QLD Sustainable Fisheries targets.
Recreational desirability / other fisheries	<33% retention.	33–66% retention.	>66% retention.

- **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 scores. Conversely, species that are being fished above key biomass reference points (*e.g.* MSY), have been assigned a negative 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 (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 the impacts of this sector 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 the 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 theory being that 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 completion of the RRA.

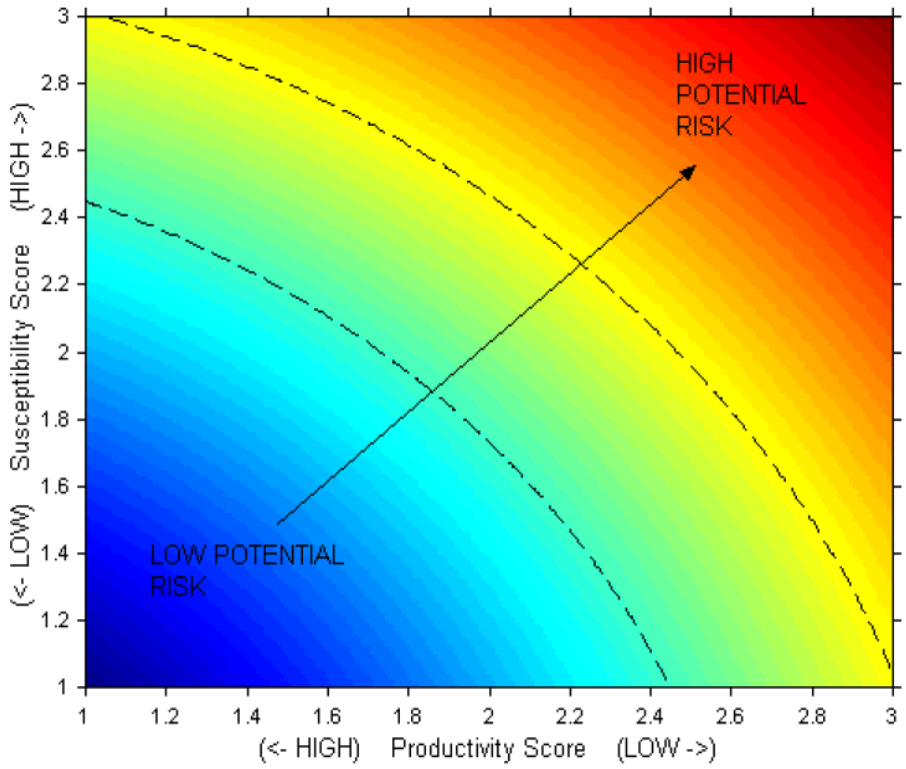

Figure 1. *PSA plot demonstrating the two-dimensional space which species units are plotted. PSA scores for species units represent the Euclidean distance or the distance between the origin and the productivity (x axis), susceptibility (y axis) intercept (excerpt from Hobday. et al., 2007).*

2.4.3 Uncertainty

A number of factors including imprecise or missing data and the use of averages or proxies can contribute to the level of uncertainty surrounding the PSA. Examples of which include the use of a default high score for attributes missing data and the use of values based at a higher taxon *i.e.* genera or family level (Hobday *et al.*, 2011). In the Level 2 ERA uncertainty is examined through a baseline assessment of each risk profile to determine the proportion of attributes assigned a precautionary high-risk rating due to data deficiencies.

As species with greater data deficiencies are more likely to attract the default high-risk rating, their profiles are more likely to fall on the conservative side of the spectrum. In these instances, it may be more appropriate to address these risks and data deficiencies through measures like the *Monitoring and Research Plan* (Department of Agriculture and Fisheries, 2018e).

2.4.4 Residual Risk

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

management with greater capacity to differentiate between potential and actual risks (Department of Agriculture and Fisheries, 2018d) 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, 2018). 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, 2018). 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 ERAs (Department of Agriculture and Fisheries, 2018d).

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 revised Australian Fisheries Management Authority (AFMA) Ecological Risk Assessment, Residual Risk Assessment Guidelines (Australian Fisheries Management Authority, 2018).*

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.
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.

Guidelines	Summary
***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 Target & Byproduct Species

The species rationalisation process produced a preliminary list of 13 target & byproduct species that were considered for inclusion in the Level 2 ERA (Appendix B). The majority of the catch (95%) was reported against eight species: snapper (*Chrysophrys auratus*), pearl perch (*Glaucosoma scapulare*), cobia (*Rachycentron canadum*), grass emperor (*Lethrinus laticaudis*), amberjack (*Seriola dumerili*), teraglin (*Atractoscion aequidens*), Australian bonito (*Sarda australis*), and leaping bonito (*Cybiosarda elegans*). These eight species formed the basis of the RRF Level 2 ERA.

Yellowtail kingfish (*Seriola lalandi*) and mahi mahi (*Coryphaena hippurus*) were included in the assessment due to their significance in other fishing sectors (both recreational and charter) and more recent commercial catch levels (approximately 2–6t per annum for each species, 2016–18) (Department of Agriculture and Fisheries, 2020b; Hughes *et al.*, 2018; Larcombe *et al.*, 2018). The remaining three species either had a low probability of interacting with the fishery or were low value species with limited retention rates (*annual catch* = <1t, 2016–18 period) (Department of Agriculture and Fisheries, 2019a; 2020b). Accordingly, frypan bream (*Argyrops bleekeri*), samsonfish (*Seriola hippos*) and sea sweep (*Scorpis aequipinnis*) were classified as secondary byproduct species and excluded from the analysis (Appendix B).

Based on the prescribed criteria (Table 2) all but one of the species had *productivity* scores lower than 2.00 (*average* = 1.67; *range* = 1.43–2.14). The exception being leaping bonito where data deficiencies contributed to the species registering a *productivity* score of 2.14 (Table 5). Of the attributes assessed, *trophic level* (*average* = 3.00) and *maximum age* (*average* = 1.90) registered the highest average scores. Conversely, all ten species were assessed as being at low (1) risk for the *fecundity* and *reproductive strategy* attributes (Table 5).

When compared to the *productivity* attributes, *susceptibility* assessments were more consistent. Four of the assessed attributes had an average score of 3.00 (high risk) with *availability* registering an average score of 2.90 (Table 5). Albeit marginal, *management strategy* had the lowest average score (2.60) which can be directly linked to management reforms introduced for snapper and pearl perch (Department of Agriculture and Fisheries, 2019h). Across the subgroup, *susceptibility* scores ranged from 2.43 to 3.00 (*average* = 2.86) (Table 5).

Based on the *productivity* and *susceptibility* scores, eight of the 10 species were assigned preliminary scores in the high-risk range (Fig 1; Table 5). The two exceptions being snapper and pearl perch which were assigned preliminary PSA scores equivalent to a medium-risk rating (Table 5).

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

Common name	Species name	Age at maturity	Maximum age	Fecundity	Maximum size	Size at maturity	Reproductive strategy	Trophic level	Productivity	Availability	Encounterability	Selectivity	Post-capture mortality	Management strategy	Sustainability assessments	Recreational desirability / other fisheries	Susceptibility	*PSA score*
Target & Byproduct																		
Snapper	*Chrysophrys auratus*	1	3	1	2	1	1	3	**1.71**	3	3	3	3	1	3	1	**2.43**	**2.97**
Pearl perch	*Glaucosoma scapulare*	1	2	1	1	1	1	3	**1.43**	3	3	3	3	1	3	2	**2.57**	**2.94**
Cobia	*Rachycentron canadum*	1	2	1	2	2	1	3	**1.71**	3	3	3	3	3	3*	2	**2.86**	**3.33**
Grass emperor	*Lethrinus laticaudis*	1	2	1	1	1	1	3	**1.43**	3	3	3	3	3	3*	2	**2.86**	**3.19**
Amberjack	*Seriola dumerili*	1	2	1	2	2	1	3	**1.71**	3	3	3	3	3	3*	3*	**3.00**	**3.46**
Teraglin	*Atractoscion aequidens*	2	2	1	2	2	1	3	**1.86**	3	3	3	3	3	3*	3*	**3.00**	**3.53**
Australian bonito	*Sarda australis*	1	1	1	1	2	1	3	**1.43**	3	3	3	3	3	3*	3*	**3.00**	**3.32**
Leaping bonito	*Cybiosarda elegans*	3*	3*	1	1	3*	1	3	**2.14**	3	3	3	3	3	3*	3*	**3.00**	**3.69**
Yellowtail kingfish	*Seriola lalandi*	2	1	1	2	2	1	3	**1.71**	3	3	3	3	3	3*	3*	**3.00**	**3.46**
Mahi	*Coryphaena hippurus*	1	1	1	2	2	1	3	**1.57**	2	3	3	3	3	3*	3*	**2.86**	**3.26**
Other																		
Grey nurse shark	*Carcharias taurus*	2	3	3	3	2	3	3	**2.71**	3	3	3	1	n/a	n/a	n/a	**2.50**	**3.69**

3.2 Grey Nurse Shark

The grey nurse shark recorded the highest *productivity* score of all species assessed (Table 5). This was to be expected given that shark species generally have *k*-selected life-history traits *e.g.* long-lived, delayed onset of sexual maturity and low *fecundity*.

As grey nurse sharks are no-take species, the *management strategy*, *sustainability assessments* and *recreational desirability / other fisheries* attributes were not included in the assessment for this species. Of the remaining *susceptibility* attributes, all but one received the highest risk rating (Table 5). *Post-capture mortality* was assigned a low-risk rating.

When the *productivity* and *susceptibility* attributes were taken into consideration, the grey nurse shark registered a preliminary score in the high-risk category (Table 5).

3.3 Uncertainty

Most *productivity* attributes were assigned risk ratings that were supported by data on the biology of the species and their potential to interact with the fishery. Published information for the leaping bonito was sparse and no estimates were available for *age and size at maturity* and longevity (*i.e. maximum age*). Accordingly, a precautionary high-risk score was assigned to these three biological attributes (Table 5).

In the *susceptibility* analysis, data deficiencies were confined to the *sustainability assessments* and *recreational desirability / other fisheries* attributes. Of the species assessed, only snapper and pearl perch have adequate *sustainability assessments* (Table 5). This resulted in the majority of the species receiving precautionary scores for this attribute. Outside of *sustainability assessments*, amberjack, teraglin, Australian bonito, leaping bonito, yellowtail kingfish and mahi mahi were all assigned precautionary high-risk scores for the *recreational desirability / other fisheries* attribute. Recreational retention rates were not available for these species, or if available, had a low level of confidence (Webley *et al.*, 2015).

3.4 Residual Risk Analysis

The following provides a brief overview of the key changes that were adopted as part of the RRA (Table 6) with a full overview of the key considerations provided in Appendix D.

3.4.1 Target & Byproduct Species

No changes were applied to the *productivity* scores for nine of the target & byproduct species. Leaping bonito's *productivity* score was lowered from 2.14 (Table 5) in the preliminary assessment to 1.43 in the RRA (Table 6). This change was due to amendments made in the RRA where precautionary high scores were replaced with proxy values from species with similar life histories (Appendix D).

The RRA for the *susceptibility* attributes resulted in amendments being made to six risk profiles (Table 6). Two species, snapper and pearl perch, had their *susceptibility* score increased from 2.43 and 2.57 respectively to 2.86 (Table 5; Table 6; Appendix D). *Susceptibility* scores for five other species, including amberjack, Australian bonito, leaping bonito, yellowtail kingfish and mahi mahi, were also adjusted due to changes associated with the *encounterability* and *recreational desirability / other fisheries* attributes (Table 6; Appendix D).

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

Common name	Species name	Age at maturity	Maximum age	Fecundity	Maximum size	Size at maturity	Reproductive strategy	Trophic level	Productivity	Availability	Encounterability	Selectivity	Post-capture mortality	Management strategy	Sustainability assessments	Recreational desirability / other fisheries	Susceptibility	*PSA score*
Target & Byproduct																		
Snapper	*Chrysophrys auratus*	1	3	1	2	1	1	3	**1.71**	3	3	3	3	2	3	3	**2.86**	**3.33**
Pearl perch	*Glaucosoma scapulare*	1	2	1	1	1	1	3	**1.43**	3	3	3	3	2	3	3	**2.86**	**3.19**
Cobia	*Rachycentron canadum*	1	2	1	2	2	1	3	**1.71**	3	3	3	3	3	3	2	**2.86**	**3.33**
Grass emperor	*Lethrinus laticaudis*	1	2	1	1	1	1	3	**1.43**	3	3	3	3	3	3	2	**2.86**	**3.19**
Amberjack	*Seriola dumerili*	1	2	1	2	2	1	3	**1.71**	3	3	3	3	3	3	1	**2.71**	**3.21**
Teraglin	*Atractoscion aequidens*	2	2	1	2	2	1	3	**1.86**	3	3	3	3	3	3	3	**3.00**	**3.53**
Australian bonito	*Sarda australis*	1	1	1	1	2	1	3	**1.43**	3	2	3	3	3	3	1	**2.57**	**2.94**
Leaping bonito	*Cybiosarda elegans*	1	1	1	1	2	1	3	**1.43**	3	2	3	3	3	3	1	**2.57**	**2.94**
Yellowtail kingfish	*Seriola lalandi*	2	1	1	2	2	1	3	**1.71**	3	3	3	3	3	3	2	**2.86**	**3.33**
Mahi mahi	*Coryphaena hippurus*	1	1	1	2	2	1	3	**1.57**	2	2	3	3	3	3	2	**2.57**	**3.01**
Other																		
Grey nurse shark	*Carcharias taurus*	2	3	3	3	2	3	3	**2.71**	3	2	3	1	n/a	n/a	n/a	**2.25**	**3.53**

As a result of the RRA, seven species had their overall risk scores amended: snapper, pearl perch, amberjack, teraglin, Australian bonito, leaping bonito and yellowtail kingfish. Three of the species (Australian bonito, leaping bonito, and mahi mahi) had their overall risk rating lowered (high to medium). Snapper and pearl perch however had their overall risk rating increased as part of the RRA (medium to high) (Table 6).

3.4.2 Grey Nurse Shark

The grey nurse shark was assigned a preliminary high-risk rating for the e*ncounterability* attribute. While noting the reasons behind this assignment, this was considered to be an overestimate for this species. In Queensland, grey nurse sharks are afforded significant protections from fishing activities including the use of spatial closures to protect known aggregating sites. These measures prohibit fishing in key habitat areas, in turn limiting the *encounterability* potential. These factors were taken into account as part of the RRA but did not alter the final risk rating (high) for this species (Table 6).

4 Risk Evaluation

There are three main demersal line fisheries operating on the Queensland east coast: the RRF, the Reef Line Fishery (RLF) and the East Coast Inshore Fishery (ECIF)[4] (Department of Agriculture and Fisheries, 2019a; d; f; g). A fourth line-fishery, the East Coast Spanish Mackerel Fishery (ECSMF), targets pelagic species managed under quota. Line fisheries are primarily differentiated by the species being retained; as opposed to fisheries-specific endorsements or separate areas of operation. If for example an operator retained snapper (*C. auratus*) and pearl perch (*G. scapulare*) during a single fishing event, then all of the catch and effort would be reported against the RRF. If however an operator retained a snapper and a shark during a single fishing event, they would technically be fishing in both the RRF and ECIF. In this instance, catch would be allocated to each of the respective fisheries with effort (days fished) reported in both the RRF and ECIF.

In the RRF, the above reporting requirements may over-emphasise the importance of some pelagic species. For example, the Australian bonito (*S. australis*), leaping bonito (*C. elegans*) and mahi mahi (*C. hippurus*) will be caught while targeting Spanish mackerel in the ECSMF (Department of Primary Industries and Fisheries, 2005; Ryan *et al.*, 2003). As the ECSMF is a single-species fishery (Department of Agriculture and Fisheries, 2019g); this portion of the catch is allocated to the RRF. [5] This means that total catch levels for some species may be higher than what is retained in the RRF and/or provide an inaccurate account of fisher intentions. While noting these caveats, these species were included in the Level 2 ERA and a baseline risk profile developed for each.

4.1 Target & Byproduct Species

As this aspect of the Level 2 ERA focuses specifically on target & byproduct species, it is unsurprising that the complex received risk ratings at the higher end of the spectrum (Table 7). These species are actively targeted by operators across their preferred habitats and in areas where they are more likely to be encountered. This was reflected in the risk profiles of each species; particularly in the scores

[4] The ECIF is primarily a mesh net fishery however operators are permitted to line fish for key species under an L1, L2 or L3 fishery symbol (Department of Agriculture and Fisheries, 2019d; Jacobsen et al., 2019b).

[5] More information on the dynamics of the RRF and the ECSMF are provided in the Scoping Study and whole-of-fishery (Level 1) ERA. Available at: https://www.daf.qld.gov.au/business-priorities/fisheries/monitoring-compliance/data/sustainability-reporting/ecological-risk-assessment

assigned to the *selectivity*, *availability* and *encounterability* attributes (Table 6). Evidently, these three attributes played a significant role in all ten species receiving higher risk ratings.

While all ten rocky reef species were found to be at higher risk, a number of the ratings were influenced by data deficiencies and/or involved species with comparatively low but consistent catch rates (Department of Agriculture and Fisheries, 2019a). This included amberjack (*S. dumerili*), Australian bonito (*S. australis*), leaping bonito (*C. elegans*), yellowtail kingfish (*S. lalandi*) and mahi mahi (*C. hippurus*). For these species, the outputs of the Level 2 ERA are more reflective of the potential risk *verse* an actual risk and the results are viewed as precautionary (Table 7). **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, 2017b), is viewed as less of a priority.** The decision to classify these assessments as precautionary was supported by an ad-hoc *Likelihood & Consequence Analysis* (Appendix E). With improved information, it is plausible that a number of these species could be excluded from future iterations of the RRF Level 2 ERA.

For snapper and pearl perch, the high-risk rating is consistent with what is known about the status of their stocks on the Queensland east coast (Department of Agriculture and Fisheries, 2019h; Fowler *et al.*, 2018; Roelofs & Stewart, 2018; Sumpton *et al.*, 2017; Wortmann *et al.*, 2018). It also reflects a higher need to manage the risk at a species level. The situation surrounding cobia (*R. canadum*), grass emperor (*L. laticaudis*), and teraglin (*A. aequidens*) is less certain and the outputs of the Level 2 ERA may still overestimate the risk posed to these species. However, all three species have experienced historical catch and effort increases and further investigations are required into the suitability of management arrangements involving these species. Due to these considerations, cobia, grass emperor and teraglin were given the same classification as snapper and pearl perch *i.e.* were not assigned precautionary risk ratings (Table 7).

Table 7. *Overview of the final risk ratings for the rocky reef species including those where the introduction of species-specific initiatives are viewed as less of a priority (i.e. precautionary risks).*

Common name	Species name	Productivity	Susceptibility	Risk rating
Snapper	*Chrysophrys auratus*	1.71	2.86	**High**
Pearl perch	*Glaucosoma scapulare*	1.43	2.86	**High**
Cobia	*Rachycentron canadum*	1.71	2.86	**High**
Grass emperor	*Lethrinus laticaudis*	1.43	2.86	**High**
Amberjack	*Seriola dumerili*	1.71	2.71	**Precautionary High**
Teraglin	*Atractoscion aequidens*	1.86	3.00	**High**
Australian bonito	*Sarda australis*	1.43	2.57	**Precautionary Medium**
Leaping bonito	*Cybiosarda elegans*	1.43	2.57	**Precautionary Medium**
Yellowtail kingfish	*Seriola lalandi*	1.71	2.86	**Precautionary High**
Mahi mahi	*Coryphaena hippurus*	1.57	2.57	**Precautionary Medium**

As expected, the biology of the ten target & byproduct species displayed traits commonly associated with teleost life-histories *e.g.* faster rates of growth, higher levels of *fecundity*, and an earlier onset of sexual maturity (Adams, 1980). While these factors produced lower *productivity* scores, it was not enough to offset some of the more prominent fishing related risks. This was primarily due to the *trophic level* attribute being assigned the highest score across all ten species (Table 7) (Hobday *et al.*, 2007). The inclusion of this attribute would have contributed to the production of more conservative risk assessments which could be negated by a move towards a quantitative ecological risk assessment.[6]

In the whole-of-fishery (Level 1) ERA, the absence of an effective control on catch and effort was found to be one of the more significant risks for this fishery (Jacobsen *et al.*, 2019a). Since the release of the Level 1 ERA (Jacobsen *et al.*, 2019a), some notable steps have been undertaken to address this risk for two of the key species; snapper and pearl perch. These measures include the introduction of total allowable commercial catch (TACC) limits, a prohibition on the take of snapper using nets, and the introduction of a seasonal closure from 15 July to 15 August (Appendix E; Department of Agriculture and Fisheries, 2019h). These reforms are substantial and will help mitigate a number of the key risks posed by this fishery (Jacobsen *et al.*, 2019a).

The above reforms have yet to be reviewed in terms of their effectiveness at managing catch and effort. For these reasons, the Level 2 ERA employed a positive but precautionary approach to their use in the RRF. This included assigning a medium (2) risk score to the *management strategy* attribute instead of a low risk (Table 6; Appendix D). If, over time, the above reforms prove to be effective at managing catch and effort across sectors (commercial, charter and recreational) and are conducive to stock recovery, then score reductions for *management strategy* and *recreational desirability / other fisheries* should be considered. From an ERA perspective, a score reduction in just one of these attributes (*e.g.* medium [2] to low [1] for *management strategy*) would move pearl perch into the medium-risk category. A score reduction in both attributes would see snapper and pearl perch re-classified as medium risk (Fig. 1; Table 6).

Outside of snapper and pearl perch, the management regime for the remaining RRF species is less developed. While the fishery has size and possession limits for most species (Appendix F), there is limited capacity within the current management regime to control catch and effort at a whole-of-fishery or species level. In the PSA, this was reflected in the *management strategy* attribute where the majority of the species were assigned the highest risk rating (Table 6). Going forward, this is one area where the management regime can be improved to minimise the risk to secondary target species. While this may include the further use of TACC limits, it is recognised that species-specific output controls like those used for snapper and pearl perch may be less suited to other rocky reef species given their retention rates in the fishery. With that said, their inclusion in a formal harvest strategy would likely result in a score reduction in the *management strategy* attribute.

In addition to the *management strategy* attribute, *sustainability assessments* was identified a key driver or risk for rocky reef species (Table 6). For snapper and pearl perch, the risks were more

[6] *The Monte Carlo resampling technique was used to provide further insight into the influence of this attribute on the final risk ratings (Hobday et al., 2007). Monte Carlo resampling produces a range of productivity scores by removing one of the attributes at a time until all attribute combinations are used. For three of the species, pearl perch, cobia and grass emperor, resampling produced a range of risk scores in the medium and high-risk ratings. These results were not considered to be sufficient to amend the final risk ratings or facilitate the assignment of a precautionary risk rating.*

obvious as both have negative *sustainability assessments* and/or negative biomass trends (Department of Agriculture and Fisheries, 2019a; Fowler *et al.*, 2018; Roelofs & Stewart, 2018; Sumpton *et al.*, 2017; Wortmann *et al.*, 2018). None of the remaining eight species have been the subject of a detailed stock assessment and risk scores attributed to these species were all precautionary. Efforts have been made to determine the stock status of cobia, grass emperor, mahi mahi and yellowtail kingfish (Department of Agriculture and Fisheries, 2018g; Hughes *et al.*, 2018; Larcombe *et al.*, 2018), but these species have been classified as *undefined* (Department of Agriculture and Fisheries, 2018g). The remaining four species have not been the subject of any stock status assessment process to date.

With the ten species having negative, undefined, or no stock status assessments, there was limited scope in the Level 2 ERA to assign scores lower than a 3 (high risk) to the *sustainability assessments* attribute (Table 6). For some of these species, this is likely to be an overestimate given that a high proportion of the catch and effort (commercial, recreational and charter) involves snapper, pearl perch, cobia and grass emperor (Department of Agriculture and Fisheries, 2019a; 2020b).[7] With the continued roll-out of initiatives instigated under the Strategy, it is anticipated that this aspect of the Level 2 ERA will be further refined and a number of the species will be re-classified as a lower risk element. Mechanisms that will assist in this process include the development of a dedicated RRF harvest strategy (Department of Agriculture and Fisheries, 2020a), improved catch monitoring and data validation techniques (Department of Agriculture and Fisheries, 2018c), targeted research (Department of Agriculture and Fisheries, 2018e), and finer scale evaluations of effort usage patterns (Department of Agriculture and Fisheries, 2018f).

Recreational desirability / other fisheries was the only attribute where a species had their preliminary score increased as part of the RRA. In the preliminary assessment, scores assigned to this attribute were based on retention rates in the recreational fishing sectors (Webley *et al.*, 2015). Based on the best available data, snapper, pearl perch, cobia and grass emperor were all assigned low to moderate scores (Table 5). While these scores aligned with the prescribed criteria (Table 3), low or medium-risk ratings were considered an underestimate for both snapper and pearl perch. This in part is due to the popularity of the species in non-commercial fisheries (*e.g.* cumulative fishing pressures), the presence of negative stock status assessments, and the limited capacity for management to monitor recreational catch within and between years.

Of significance, a number of measures have now been implemented in the fishery to address the cumulative fishing risk for snapper and pearl perch. On 1 September 2019, more stringent possession and size limits were introduced for pearl perch along with new boat limits for snapper. These measures were complimented by the introduction of a seasonal closure which restricts the take of both species from 15 July to 15 August. The main objectives of this closure being a) to reduce fishing pressure on both species (*i.e.* reduce cumulative fishing pressures) and b) protect snapper stock during its spawning season when they are more vulnerable to capture (Department of Agriculture and Fisheries, 2019b; h). Unfortunately, there has been limited opportunities to evaluate their effectiveness and the capacity of these measures to improve the status of both stocks (Fowler *et al.*, 2018; Roelofs & Stewart, 2018; Sumpton *et al.*, 2017; Wortmann *et al.*, 2018). In the context of this ERA, this ongoing uncertainty resulted in the assignment of more conservative risk scores.

[7] *Additional information on RRF catch and effort available through Qfish* (https://qfish.fisheries.qld.gov.au/query/7fef25bc-c09b-4237-a48a-2cf2a79cc4e4/table?customise=True)

While the Level 2 ERA identifies the life-history constraints and fishing activities that increase risk, there are a number of confounding factors that cannot easily be accounted for in a PSA. One of these factors is the condition and preservation of key habitats for both adults and juveniles. The *encounterability* attribute examines fishing effort overlap with species' habitat and depth range but does not consider the health and condition of these habitats. Future assessments would benefit considerably from more information on the habitats used by rocky reef species across all life stages and the degree to which it influences recruitment and fishery production (Parsons *et al.*, 2014; Rogers *et al.*, 2014; zu Ermgassen *et al.*, 2015).

Another factor that is difficult to incorporate into a PSA is cryptic mortalities or unreported catch including those relating to shark depredation (Jacobsen *et al.*, 2019a), illegal fishing activities, non-compliance with recreational bag limits and black marketing. These factors will contribute to the total rate of fishing mortality of all of the species assessed. Where possible, these mortalities were addressed as part of the *post-capture mortality* attribute. *Post-capture mortalities* though are difficult to assess in the marine environment as they are often not observed and are less likely to be reported. These issues are compounded by an absence of data on the number of discards including those that have been preyed on / damaged during the capture and retrieval process. Future ERAs would benefit from additional data on the composition and number of discards in the RRF and other sources of mortality *e.g.* the extent and prevalence of shark depredation, discard mortalities in the recreational fishing sector.

Going forward, rocky reef species may derive some benefit from additional assessment using the *Sustainable Assessment of Fishing Effects* or SAFE approach. Comparisons have shown that SAFE method produces fewer false positives and may provide greater differentiation in terms of the risk posed to each species. As the method compares fishing mortality against reference points based on natural mortality rate and growth rates (Zhou & Griffiths, 2008), it may provide a more informative account of how a species will respond to fishing pressures. Given the available data, base SAFE (bSAFE) is viewed as the most viable option for this fishery. Information thresholds for the bSAFE are lower than the enhanced version (eSAFE) and are comparable to the PSA. The ability to assess these species using bSAFE though will still be predicated on management's ability to quantify gear-affected area across the fishery.

Recommendations

1. *Identify avenues/mechanisms that can be used to a) improve catch monitoring in the RRF (preferably in near or real-near time), b) minimise the risk of non-compliance (e.g. black marketing), and c) validate information obtained through the logbook program (commercial and charter fishing).*

2. *Improve the level of information on the biology, stock structure, and status of species other than snapper and pearl perch to better monitor catch against biological reference points and fishing pressures against target reference points.*

3. *Review the suitability, applicability and value of data submitted through the logbook program on the dynamics of the fishery. As part of this process, it is recommended that the logbook reporting requirements be extended to include information on what fishing symbol is being used.*

4. *Reassess species with high-risk ratings once a harvest strategy has been fully implemented in the fishery, prioritising both snapper and pearl perch.*
5. *Evaluate options for the extended use of output controls for secondary target & byproduct species noting that TACC limits are already applied to snapper and pearl perch.*
6. *Implement measures to improve the level of information on fine-scale effort movements, with particular emphasis on increasing our understanding of regional fishing pressures / cumulative fishing risks e.g. the suitability, applicability, or necessity of having additional protections for key species in high-effort / high-catch areas.*
7. *Quantify the cumulative fishing pressures exerted on key species and, when and where appropriate, review the suitability/applicability of possession limits for rocky reef species, explore avenues to improve monitoring across sectors, and collect more information on recreational catch rates, discards, post-capture mortality, and non-compliance.*
8. *Improve the level of information on discards, post-release survival rates, and the extent of cryptic/unreported mortalities including shark depredation.*
9. *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 Grey Nurse Sharks

Common name	Species name	Productivity	Susceptibility	Risk rating
Grey nurse shark	*Carcharias taurus*	2.71	1.75	**Precautionary High**

The grey nurse shark (*C. taurus*) was included in the Level 2 ERA as a precautionary measure and reflects the conservation status of the species on the Queensland east coast. The species has experienced historical population declines and is highly susceptible to overfishing. Research shows that grey nurse sharks will interact with line fishers and evidence suggests that post-interaction mortalities are a risk for this species. As grey nurse sharks migrate between New South Wales and Queensland, these impacts will be compounded by cross-jurisdictional fishing activities including those used for bather protection (Bansemer & Bennett, 2011; Department of Agriculture and Fisheries, 2018b; Department of Primary Industries (NSW), Undated).

Grey nurse sharks recorded the highest *productivity* score of the assessment and their biological traits were identified as a key driver of risk (Table 6). If for example, all of the *susceptibility* attributes were assigned the lowest value possible (1), this species would still register a medium-risk rating. These biological constraints limit the ability of the species to absorb incidental fishing mortalities and restricts the speed at which regional populations can recover from declines (Department of the Environment, 2014; 2019; Last & Stevens, 2009). As grey nurse sharks are already protected, these biological risks will be difficult to address through a fisheries reform agenda.

At a whole-of-fishery level, the *susceptibility* risk posed by line fishing will not be uniform. Grey nurse sharks are known to form aggregations in south east Queensland including at Cherub's Cave (Moreton Island), Flat Rock (North Stradbroke Island), Henderson Rock (Moreton Island) and Wolf

Rock (Rainbow Beach) (Department of Environment and Science, 2018). These four sites are situated within the *Moreton Bay* and *Great Sandy Marine Parks* and are afforded full protection from fishing activities (Department of National Parks Sport and Racing, 2015a; b). These restrictions apply to the commercial, charter, and recreational line fishing sectors, and reduce the interaction potential in key areas. Analogous aggregation sites have been reported from New South Wales and the species undertakes annual migrations between the two (Bansemer & Bennett, 2011; Department of Primary Industries (NSW), Undated). These factors were taken into consideration as part of the RRA and resulted in the species receiving a lower risk score for the *encounterability* attribute (Table 6; Appendix D).

While noting the above protections, grey nurse sharks will move beyond the confines of the spatial closures and into areas where the risk of an interaction occurring is higher. Examples of which include when individuals move outside of a spatial closure to feed and during key migration periods (Bennett & Bansemer, 2004). Grey nurse sharks are also found in waters north of the *Great Sandy Marine Mark* where species-specific protection measures are less developed. This in part is due to an absence of information on population numbers, movements, and aggregating behaviours in central and northern Queensland (*pers. comm.* D. Bowden). In these northern areas, regional risk levels may be more difficult to quantify as the species could occur in lower numbers/densities but have a higher overlap with areas with elevated line effort (commercial and non-commercial).

With improved information on the distribution of grey nurse sharks in central and northern Queensland, the risk profile for this species could be further refined. Most descriptions of the grey nurse shark distribution include the entire Queensland and New South Wales coastline (Atlas of Living Australia, 2020; Last & Stevens, 2009; Pollard & Smith, 2009). These broader distribution maps were used in the PSA and resulted in the species having a high *availability* score (Table 6). While noting the above evaluation, evidence suggests that the majority of the stock occurs from mid-Queensland to southern New South Wales (Bansemer & Bennett, 2011; Department of Environment and Science, 2018; Department of the Environment, 2019). With improved information on grey nurse shark distributions and interaction locations, scores assigned to this attribute could be reduced.

At a whole-of-fishery level, there is little information on grey nurse shark interactions in the RRF. No commercial interactions have been reported through the *Species of Conservation Interest* (SOCI) logbooks or a previous *Fisheries Observer Program* (Department of Agriculture and Fisheries, 2019a). An absence of interactions can be partly attributed to the current management arrangements that limit commercial fishing in areas where grey nurse sharks are found in greater abundance. With that said, there is limited capacity within the current management regime to validate data from the SOCI logbook program, monitor catch in real or near-real time and determine (if applicable) the extent of any underreporting (Department of Agriculture and Fisheries, 2019a). This issue is compounded by an absence of data on grey nurse interactions in the recreational sector and contact without capture events (*e.g.* line breakages).

Research has shown that grey nurse sharks will interact with a line apparatus when targeting demersal-set baits and hooked fish (Bansemer & Bennett, 2010; Robbins *et al.*, 2013). If handled correctly, there is a high probability that a shark brought to the surface will survive the initial interaction. However, these types of interactions can have longer-term implications, particularly with respect to hook wounds, internal injuries, and infections (Bansemer & Bennett, 2010; Department of the Environment, 2019; Pollard & Smith, 2009; Robbins *et al.*, 2013). These risks are considered to

be of particular relevance to the recreational sector where the use of lighter gear makes contact without capture events more likely *e.g.* line breakages (Bansemer & Bennett, 2010). In the most severe cases, gear-related infections can lead to significant injuries, reduced feeding capacity, and mortalities. While not universal, these types of injuries and impediments are more likely to occur in sharks that have been hooked multiple times.

While noting the outputs of the Level 2 ERA, it is recognised that the risk profile for grey nurse sharks is more complicated. Line fishing is viewed as a risk for this species and is a fishing activity that has the potential to impact on the long-term health of individuals *e.g.* multiple hooking incidents leading to increased difficulties feeding, disease *etc*. (Bansemer & Bennett, 2010; Department of the Environment, 2014; Robbins *et al.*, 2013). These risks though will extend beyond the RRF to other sectors (*e.g.* recreational fishing) and jurisdictions. The challenge being how best to assess and quantify the extent of this impact, the extent of contact without capture events, and the likelihood of the interaction ending in mortality due to (*e.g.*) secondary infections and wounds. It is also noted that ancillary initiatives like the *Shark Control Program* pose a more immediate risk to this species and it is viewed as a more direct source of fishing mortality within Queensland waters; n = 29 reported mortalities since 2001 (Queensland Government, 2019).

Due to the above reasons, the RRF is considered to be a contributor of risk for this species *verse* the main driver of risk. The inherent challenge of this assessment is that the extent of this risk contribution cannot be verified due to data deficiencies and uncertainty surrounding interaction rates, release fates, and gear retention levels across the commercial and non-commercial line sectors. When compared to other line fisheries, these issues are considered to be more pressing in the RRF as operators target fish in areas where grey nurse sharks are more likely to be encountered.

Recommendations

1. *Provide a synthesis of regional distribution data, critical habitats, and movement patterns of grey nurse sharks for comparison with the distribution of commercial line effort along the Queensland east coast, including in areas adjacent to and north of known aggregation sites.*
2. *Identify mechanisms to improve the level of information on the extent and nature of grey nurse shark interactions with the recreational and charter fishing sectors, and the cumulative risks posed to this species by line fishing.*

5 Summary

The results of the Level 2 ERA suggest that all of the assessed target & byproduct species and the grey nurse shark are at an elevated risk from fishing activities in the RRF. This was to be expected given that the harvested species are actively targeted by operators in their preferred habitats. It is recognised that the dynamics of a fishery will change through time with catch and effort fluctuating at a whole-of-fishery, regional and species level. The results of the Level 2 ERA though provide a sound baseline of assessments that can be reviewed and amended (where appropriate) to accommodate additional data or management reforms.

While the outputs of the Level 2 ERA indicate that the RRF poses a higher risk to the species assessed, this risk is not expected to be uniform. For a number of species, the final risk ratings are viewed as precautionary and have a high probability of being reduced with additional information. If

for example data sets improved to a point where the scores assigned to one attribute could be reduced by one category (*e.g.* from high to medium), the risk rating of at least four target & byproduct species could be downgraded from high to medium. If this was replicated in a second attribute, all ten harvested species would fall into the medium-risk category. In this context, the listed recommendations for both harvested species and the grey nurse shark will assist with mitigating, managing and understanding risk in the RRF.

Of significance, a number of these risks are already being actively addressed as part of the broader *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017b; 2019c). These include mandating the use of *Vessel Tracking*, the development of a dedicated RRF harvest strategy (Department of Agriculture and Fisheries, 2020a) and improved catch monitoring and validation techniques (Department of Agriculture and Fisheries, 2018c). These initiatives have the potential to reduce the risk posed to rocky reef species and mitigate some of the longer-term risks identified (Jacobsen *et al.*, 2019a). These measures though will take time to develop, implement and evaluate for effectiveness.

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7 Appendix

Appendix A – Species rationalisation process.

Appendix B – Species rationalisation process: justifications and considerations.

Appendix C – *Availability* overlap percentages.

Appendix D – *Residual Risk Analysis* justifications.

Appendix E – *Likelihood & Consequence Analysis*.

Appendix F – Summary of management arrangements for rocky reef species.

Appendix A—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 were considered over a three year period (2016–2018 inclusive) with the final species list refined using the following steps.

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

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

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

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

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

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

    c. Catch categories that could not be refined to species level such as *Fish—unspecified* were excluded from the analysis.

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

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

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

Appendix B—Species rationalisation process: justifications and considerations.

Ecological component	Common name	Species name	CAAB*	Level 2 ERA	Justifications & Comments
Target & Byproduct	Snapper	*Chrysophrys auratus*	37353001	Assessed	• A primary target species in the commercial sector of the RRF and is a high-value species for both the charter and recreational fishing sectors. • Included in the list of species comprising 95% of the reported catch.
	Pearl perch	*Glaucosoma scapulare*	37320003	Assessed	• A primary target species in the commercial sector of the RRF and is a high-value species for both the charter and recreational fishing sectors. • Included in the list of species comprising 95% of the reported catch.
	Cobia	*Rachycentron canadum*	37335001	Assessed	• Included in the list of species comprising 95% of the reported catch. • Data suggests that total catch has increased for this species through time (Department of Agriculture and Fisheries, 2019a). • No objections from the Fisheries Working Group for the inclusion of this species in the Level 2 ERA.
	Grass emperor	*Lethrinus laticaudis*	37351006	Assessed	• Included in the list of species comprising 95% of the reported catch.

Ecological component	Common name	Species name	CAAB*	Level 2 ERA	Justifications & Comments
					• Data suggests that total catch has increased for this species through time (Department of Agriculture and Fisheries, 2019a). • No objections from the Fisheries Working Group for the inclusion of this species in the Level 2 ERA.
	Amberjack	*Seriola dumerili*	37337025	Assessed	• While not viewed as one of the primary species, non-standardised CPUE for this species tends to be higher (Department of Agriculture and Fisheries, 2019a). • Included in the list of species comprising 95% of the reported catch. • No objections from the Fisheries Working Group for the inclusion of this species in the Level 2 ERA.
	Teraglin	*Atractoscion aequidens*	37354020	Assessed	• While not viewed as one of the primary species, non-standardised CPUE for this species tends to be higher (Department of Agriculture and Fisheries, 2019a). • Included in the list of species comprising 95% of the reported catch. • No objections from the Fisheries Working Group for the inclusion of this species in the Level 2 ERA.
	Australian bonito	*Sarda australis*	37441020	Assessed	• Included in the list of species comprising 95% of the reported catch.

Ecological component	Common name	Species name	CAAB*	Level 2 ERA	Justifications & Comments
					• Generally caught and retained in smaller quantities by operators in the RRF. • No objections from the Fisheries Working Group for the inclusion of this species in the Level 2 ERA.
	Leaping bonito	*Cybiosarda elegans*	37441008	Assessed	• Included in the list of species comprising 95% of the reported catch. • Generally caught and retained in smaller quantities by operators in the RRF. • No objections from the Fisheries Working Group for the inclusion of this species in the Level 2 ERA.
	Yellowtail kingfish	*Seriola lalandi*	37337006	Assessed	• Included based on regular annual retention in the commercial sector including recent years (2–6t; 2016–2018) (Department of Agriculture and Fisheries, 2020b). • Attracts interest from recreational and charter fishing sectors (Department of Agriculture and Fisheries, 2020b; Hughes *et al.*, 2018). • No objections from the Fisheries Working Group for the inclusion of this species in the Level 2 ERA.
	Mahi mahi	*Coryphaena hippurus*	37338001	Assessed	• Included based on regular annual retention in the commercial sector including recent years (2–6t; 2016–2018) (Department of Agriculture and Fisheries, 2020b).

Ecological component	Common name	Species name	CAAB*	Level 2 ERA	Justifications & Comments
					• Attracts interest from recreational and charter fishing sectors (Department of Agriculture and Fisheries, 2020b; Larcombe *et al.*, 2018). • No objections from the Fisheries Working Group for the inclusion of this species in the Level 2 ERA.
	Frypan bream	*Argyrops bleekeri*	37353006	Not assessed	• Catch data for the species from 2016–2018 (inclusive) was <1t (Department of Agriculture and Fisheries, 2020b). • No objections raised by the Fisheries Working Group.
	Samsonfish	*Seriola hippos*	37337007	Not assessed	• Catch data for the species from 2016–2018 (inclusive) was <1t (Department of Agriculture and Fisheries, 2020b). • No objections raised by the Fisheries Working Group.
	Sea sweep	*Scorpis aequipinnis*	37361004	Not assessed	• Catch data for the species from 2016–2018 (inclusive) was <1t (Department of Agriculture and Fisheries, 2020b). • No objections raised by the Fisheries Working Group.

Appendix C—*Availability* overlap percentages used as part of the PSA.

Common name	Species	% overlap			Highest overlap	Availability score
		2016	2017	2018		
Snapper	*Chrysophrys auratus*	46.8	39.9	36.6	**46.8**	**3**
Pearl perch	*Glaucosoma scapulare*	63.6	61.2	56.5	**63.6**	**3**
Cobia	*Rachycentron canadum*	25.7	21.7	19.4	**25.7**	**2**
Grass emperor	*Lethrinus laticaudis*	39.0	30.1	30.3	**39.0**	**3**
Amberjack	*Seriola dumerili*	87.1	80.8	60.7	**87.1**	**3**
Teraglin	*Atractoscion aequidens*	80.6	81.1	67.2	**81.1**	**3**
Australian bonito	*Sarda australis*	92.7	89.9	68.6	**92.7**	**3**
Leaping bonito	*Cybiosarda elegans*	25.7	21.7	19.4	**25.7**	**2**
Yellowtail kingfish	*Seriola lalandi*	59.9	55.1	52.1	**59.9**	**3**
Mahi mahi	*Coryphaena hippurus*	9.2	7.1	6.1	**9.2**	**1**

Appendix D—*Residual Risk Analysis* justifications.

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
Target & Byproduct Leaping bonito (*C. elegans*)	*Age at maturity (Productivity)*	3	1	Based on the PSA methodology, any unknown *productivity* or *susceptibility* attributes are automatically scored a precautionary high score (3). Given the little information available for leaping bonito (*C. elegans*), three biological attributes were scored high (3) in the preliminary assessment. As a part of the residual risk assessment, a proxy species, Australian bonito (*Sarda australis*), was used to assign more accurate *productivity* scores. Australian bonito is closely related (phylogenetically) to the leaping bonito, and both species have natural distributions that overlap in Queensland waters (Block *et al.*, 2001; Bray & Schultz, 2019; Schultz, 2019). Based on their biology and known distribution, it is unlikely that the life history of the leaping bonito would differ markedly from the Australian bonito. The decision to use *S. australis* as a proxy is not expected to lead to a false-negative result. ***Key changes to the PSA scores*** Default high-risk scores assigned to *age at maturity*, *maximum age,* and *size at maturity* attributes were reduced to match the Australian bonito's attribute scores. These changes were done in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of data information* and *Guideline 2: Additional scientific assessment & consultation*.
	Maximum age (Productivity)	3	1	
	Size at maturity (Productivity)	3	2	
Target & Byproduct Australian bonito (*S. australis*) Leaping bonito (*C. elegans*)	*Encounterability (Susceptibility)*	3	2	The Australian bonito (*S. australis*), leaping bonito (*C. elegans*) and mahi mahi (*C. hippurus*) are fast moving species often associated with epipelagic environments (Bray, 2020; Bray & Schultz, 2019; Schultz, 2019). To this extent, they are less inclined to be targeted or caught on demersal-set baits and more likely to interact with trolling operations. This is of particular relevance to mahi mahi which is generally viewed as a pelagic predator that targets fish closer to the surface of the water (Bray, 2020; Collette *et al.*, 2015; Nunes *et al.*, 2015). These behaviours suggest that the

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
Mahi mahi (*C. hippurus*)				*encounterability* potential for these three species would be less when compared to a number of other rocky reef species. This inference is supported by catch data form the fishery which shows that bonito and mahi mahi are retained in smaller quantities (Department of Agriculture and Fisheries, 2019a) *Note*—Species like bonito may be caught and retained by operators fishing in the East Coast Spanish Mackerel Fishery (ECSMF). As the ECSMF is considered to be a single species fishery (Department of Agriculture and Fisheries, 2019g), this portion of the catch will automatically be allocated to the RRF. At present, there is limited information on what percentage of the total bonito and mahi mahi catch comes from fishers targeting Spanish mackerel and what percentage comes from fishers operating within the RRF. ***Key changes to the PSA scores*** Preliminary scores assigned in the PSA were considered to be an overestimate and were reduced from high (3) to medium (2). Given their feeding patterns and behaviours, these scores may still be an overestimate; particularly for mahi mahi. These scores could potentially be reduced further with additional information or clarity on the origin of the catch *i.e.* from fishers targeting Spanish mackerel or fishers targeting rocky reef species. In addition to the two bonitos and mahi mahi, some consideration was given to reducing the *encounterability* scores of yellowtail kingfish (*S. lalandi*), amberjack (*S. dumerili*) and cobia (*R. canadum*). The situation surrounding these three species though were less certain and therefore the original PSA scores were retained as a precautionary measure. The decision to amend the *encounterability* scores was done in accordance with *Guideline 2: Additional scientific assessment & consultation* with key input provided by members of the *Rocky Reef Fishery Working Group* (6 May 2020).

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
Target & Byproduct Snapper (*C. auratus*)	*Recreational desirability / other fisheries (Susceptibility)*	1	3	In the PSA, snapper (*C. auratus*) was assigned a low (1) risk rating for the *recreational desirability* attribute based on retention rates reported from the *Statewide Recreational Fishing Survey 2013–14* (27% of snapper retained) (Webley *et al.*, 2015). While noting this assessment, snapper is a primary target of the recreational fishing sector (*pers. comm.* T. Martin, J. Webley), with survey data indicating historical catches ranging from 82 to 552 tonnes (Wortmann *et al.*, 2018). It is also noted that a) discard rates in this sector will be influenced by size/bag limits and b) retention rates for legal sized snapper will be higher than what is reported for the entire sector (*pers. comm.* C. Lunow). While the majority of recreationally caught snapper are released (Department of Agriculture and Fisheries, 2020b), mortality rates for released fish remain poorly understood. Snapper can suffer barotrauma and hook-related injuries that can lead to post-release mortalities (Butcher *et al.*, 2012; Mclennan *et al.*, 2014; Stewart, 2008). Illegal fishing is also viewed as a risk factor for this species, with snapper identified as one of nine priority species for black marketing (Department of Agriculture and Fisheries, 2019h). This was taken into consideration as part of the RRA and was identified as a factor of influence when assessing the suitability of the PSA score assigned to the *recreational desirability / other fisheries* attribute. Snapper's angling popularity is also reflected in the charter sector. In recent years (2016–18) Queensland's charter sector harvested approximately 19t to 27t of snapper per year and discarded close to 27,000 fish over the three year time period (Department of Agriculture and Fisheries, 2020b). The charter sector will therefore contribute to the total rate of fishing mortality for this species. It is recognised that a number of measures have been implemented in the fishery to address the cumulative fishing risk for this species. On 1 September 2019, new boat limits for snapper were introduced as a black-marketing deterrent, and they were reclassified as a line-only species. These measures were complimented by the introduction of a new seasonal closure which restricted the

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				take of snapper between 15 July and 15 August (inclusive). The main objectives of this closure being a) to reduce fishing pressure on the species (*i.e.* reduce cumulative fishing pressures) and b) protect snapper stocks during the spawning season when they are most vulnerable to being caught (Department of Agriculture and Fisheries, 2019b; h). As these reforms are relatively recent, there has been limited evaluation of their effectiveness and the capacity of these measures to improve the status of snapper stocks (Fowler *et al.*, 2018; Roelofs & Stewart, 2018; Sumpton *et al.*, 2017; Wortmann *et al.*, 2018). In the context of this ERA, this ongoing uncertainty resulted in the assignment of more conservative risk scores. ***Key changes to the PSA scores*** The low-risk score assigned to *recreational desirability / other fisheries* for snapper was increased to a 3 based on the species having high recreational appeal, cumulative fishing pressures (*e.g.* commercial, charter and recreational), and uncertainty surrounding the total catch from this sector. The decision to increase this rating is precautionary and minimises the risk of the PSA producing a false-negative result. The decision to increase this risk score for this attribute is precautionary and should be reviewed once the efficacy of the current management arrangements are reviewed. The decision to amend the score assigned to the *recreational desirability / other fisheries* attribute was done in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of data information* (*i.e.* absence of consistent monitoring, reporting of the recreational catch, black marketing *etc.*) and *Guideline 2: Additional scientific assessment & consultation*.
Target & Byproduct Pearl perch (*G. scapulare*)	*Recreational desirability / other*	2	3	Pearl perch (*G. scapulare*) was scored medium (2) for the *recreational desirability* attribute based on moderate retention rates reported from the *Statewide Recreational Fishing Survey 2013–14* (49% of pearl perch retained) (Department of Agriculture and Fisheries, 2020b). However, there are

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
	fisheries (Susceptibility)			more factors than retention rates to be considered when assessing risk to a species. Pearl perch is a recreationally desirable species in Queensland, with annual catch estimates ranging from 11 to 148 tonnes over the last few decades (Sumpton *et al.*, 2017). While over half of the pearl perch catch was released according to the most recent recreational fishing survey (Department of Agriculture and Fisheries, 2020b), post-release mortality rates driven by hook related injuries and barotrauma are understood to be high (Campbell *et al.*, 2014; McKay, 1997). Even when pearl perch are caught while targeting other species, legal sized catches will almost always be retained by recreational fishers given the high table quality of the fish (*pers. comm.* T. Martin, J. Webley). Pearl perch's angling popularity is also reflected in the charter sector. In recent years (2016–18), Queensland's charter sector harvested approximately 12t to 13t of pearl perch per year and discarded over 15,000 fish over the three year time period (Department of Agriculture and Fisheries, 2020b). The charter sector will therefore contribute to the total fishing mortality to the species. It is recognised that a number of measures have been implemented in the fishery to address the cumulative fishing risk for this species. On 1 September 2019, more stringent possession and size limits were introduced for pearl perch along with new boat limits for snapper. These measures were complimented by the introduction of a new seasonal closure which restricted the take of both species from 15 July to 15 August. The main objectives of this closure being a) to reduce fishing pressure on both species (*i.e.* reduce cumulative fishing pressures) and b) protect snapper stock during its spawning season when they are most vulnerable to being caught (Department of Agriculture and Fisheries, 2019b; h). As these are relatively recent developments, there has been limited evaluation of their effectiveness and the capacity of these measures to improve the status of both stocks (Fowler *et*

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				al., 2018; Roelofs & Stewart, 2018; Sumpton *et al.*, 2017; Wortmann *et al.*, 2018). In the context of this ERA, this ongoing uncertainty resulted in the assignment of more conservative risk scores. ***Key changes to the PSA scores*** The intermediate risk score assigned to *recreational desirability / other fisheries* for pearl perch was increased to a 3 based on the recreational popularity of the species and mortalities associated with angling. The decision to increase this risk score for this attribute is precautionary and should be reviewed once the efficacy of the current management arrangements are reviewed. The decision to amend the score assigned to the *recreational desirability / other fisheries* attribute was done in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of data information* (*i.e.* absence of consistent monitoring, reporting of the recreational catch, black marketing *etc.*) and *Guideline 2: Additional scientific assessment & consultation*.
Target & Byproduct Amberjack (*S. dumerili*) Australian bonito (*S. australis*) Leaping bonito (*C. elegans)*	*Recreational desirability / other fisheries (Susceptibility)*	3	1	Amberjack (*S. dumerili*), Australian bonito (*S. australis*) and leaping bonito (*C. elegans*) were all assigned precautionary high-risk scores (3) for the *recreational desirability / other fisheries* attribute due to an absence of species-specific data. While the three species were included in the *Statewide Recreational Fishing Survey 2013–14*, amberjack and trevally were assessed as a single category (36% retention, moderate confidence) as were the two bonito species (low confidence estimates) (Webley *et al.*, 2015). As part of the RRA, further information was sought from the scientific community on recreational fishing retention rates for these species. This feedback indicated that *recreational desirability* was less of a risk factor for these species. These species are often only caught when targeting other pelagic species, and are frequently returned to the water or used for secondary purposes *e.g.* bait (*pers. comm.* T. Martin, J. Webley). While high confidence catch and harvest information for these species is unavailable, they are likely to be at lower risk from cumulative fishing pressures.

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				Key changes to the PSA scores Default high-risk scores assigned to the *recreational desirability / other fisheries* attribute for amberjack, Australian bonito and leaping bonito were reduced to low (1) based on recommendations made during expert consultation. These changes were done in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of data information* and *Guideline 2: Additional scientific assessment & consultation*.
Target & Byproduct Teraglin (*A. aequidens*)	*Recreational desirability / other fisheries (Susceptibility)*	3	3	Teraglin (*A. aequidens*) was assigned a precautionary high-risk score (3) for the *recreational desirability / other fisheries* attribute because recreational retention rates within the *Statewide Recreational Fishing Survey 2013–14* were of low confidence. As a part of the RRA, further information was sort on the *recreational desirability* of this species and the suitability of the preliminary risk rating. Lowering risk scores for teraglin was considered given that they are caught and harvested in lower numbers in and are infrequently targeted by recreational fishers (*pers. comm.* T. Martin, J. Webley). However, extensive historical harvesting of this species from multiple fishing sectors and within adjacent jurisdictions (New South Wales) suggest that stock levels have declined (Bray, 2017; New South Wales Government, 2010). While it is true that Queensland recreational fishers infrequently target teraglin, the good table quality of the fish means that they are almost always retained when caught (*pers. comm.* J. Webley, J. McGilvray). Cumulative fishing pressures have historically, and are still likely to, play a significant role in contributing to the risk for teraglin. ***No changes to the PSA scores*** While no changes were made to the PSA scores, *recreational desirability* of this species and the potential for this sector to impact on stock levels within Queensland requires further investigation.

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
Target & Byproduct Yellowtail kingfish (*S. lalandi*) Mahi mahi (*C. hippurus*)	*Recreational desirability / other fisheries (Susceptibility)*	3	2	Yellowtail kingfish (*S. lalandi*) and mahi mahi (*C.* hippurus) assigned precautionary high-risk scores (3) for the *recreational desirability / other fisheries* attribute because recreational retention rates within the *Statewide Recreational Fishing Survey 2013–14* were of low confidence (Webley *et al.*, 2015). As part of the RRA, further information was sought from the scientific community on recreational fishing retention rates for these species. This feedback indicated that *recreational desirability* was less of a risk factor for these species. Yellowtail kingfish are commonly targeted by recreational fishers but catch is often released (*i.e.* sport fishing) (*pers. comm.* T. Martin, J. Webley). Mahi mahi have historically been targeted less by the recreational fishing sector (mostly due to inaccessibility), but since the introduction of Fish Aggregation Devices (FADs) they are increasing in popularity. Legal sized mahi mahi are frequently retained as they are a quality table fish, but undersized fish (<50cm) can still make up a larger proportion of catch (*pers. comm.* T. Martin, J. Webley). While high confidence catch and harvest information for yellowtail kingfish and mahi mahi are unavailable, they are likely to be at moderate risk from cumulative fishing pressures. ***Key changes to the PSA scores*** Default high-risk scores assigned to the *recreational desirability / other fisheries* attribute for yellowtail kingfish and mahi mahi were reduced to medium (2) based on recommendations made during expert consultation. These changes were done in accordance with *Guideline 1: Risk rating due to missing, incorrect or out of data information* and *Guideline 2: Additional scientific assessment & consultation*.
Target & Byproduct Grass emperor (*L. laticaudis*)	*Recreational desirability / other*	2	2	As part of the RRA, consideration was given to reducing the *recreational desirability / other fisheries* scores for a grass emperor and cobia. However, further information is required on the targeting of these species in the recreational and charter fishing sectors, retention rates, and discards. Based on the available data, a combined 11–18t are retained in the charter fishery each

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
Cobia (*R. canadum*)	*fisheries (Susceptibility)*			year (2016–2018 inclusive) with between ~1700 and 2350 fish discarded each year (Qfish data). Data from the recreational fishing sector is less certain due to an absence of mandatory reporting requirements. ***Key changes to the PSA scores*** No changes were made to scores assigned as part of the RRA. These considerations though were highlighted as part of the RRA as it is an avenue where the risk profile of both species can be improved and refined.
Target & Byproduct Snapper (*C. auratus*) Pearl perch (*G. scapulare*)	*Management strategy (Susceptibility)*	1	2	On 1 September 2019, new management arrangements came into effect for two of the more prominent commercial and recreational species: snapper (*C. auratus*) and pearl perch (*G. scapulare*) (Department of Agriculture and Fisheries, 2019h). These measures included, among others: *1.* An increase in the minimal legal size limit for pearl perch (35cm to 38cm); *2.* New seasonal closure for snapper and pearl perch from 15 July to 15 August each year; *3.* Boat limits for snapper which is classified as a high priority black market species, and reduced possession limits for pearl perch; *4.* The introduction of TACC limits for snapper (42t) and pearl perch (15t) On the back of these changes, the *management strategy* attribute was assigned a preliminary risk score of 1 (low risk) as part of the PSA. Measures introduced on 1 September 2019 represent a marked improvement with respect to the management of the risk posed to these species across the commercial, charter, and recreational fishing sectors. These measures though have only come into effect recently and, as a consequence, there is little information on how effective they are in terms of managing catch and effort and/or the need to make further amendments going into the future. This problem is

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				compounded by the fact that both species have negative *sustainability assessments* (Fowler *et al.*, 2018; Roelofs & Stewart, 2018; Sumpton *et al.*, 2017; Wortmann *et al.*, 2018). ***Key changes to the PSA scores*** Given the above considerations, scores assigned to the *management strategy* attribute were increased from low (1) to medium (2) for snapper and pearl perch. This decision is precautionary and consideration should be given to reviewing these scores once management arrangements can be reviewed to determine a) their effectiveness and b) the responsiveness of the stocks. These changes were done in accordance with *Guideline 4: Effort and catch management arrangements for target & byproduct species.*
SOCC Grey nurse shark (*C. taurus*)	*Encounterability (Susceptibility)*	3	2	While grey nurse sharks are found along the Queensland coastline and in habitats fished by operators in the RRF, their aggregative and migratory behaviours need to be taken into consideration. Both of these factors will have a bearing on the species' *encounterability* potential but are not easily accounted for in the PSA. Most distribution maps for the grey nurse shark include the entire Queensland and New South Wales coastlines. However, grey nurse sharks form aggregations, particularly in south east Queensland and New South Wales. In Queensland, grey nurse sharks are known to form aggregations at Cherub's Cave (Moreton Island), Flat Rock (North Stradbroke Island), Henderson Rock (Moreton Island) and Wolf Rock (Rainbow Beach) (*pers. comm.* D. Bowden; Department of Environment and Science, 2018). These four sites are situated within the *Moreton Bay* and *Great Sandy Marine Parks* and are afforded full protection from fishing activities (Department of National Parks Sport and Racing, 2015a; b). While animals will move outside of these closures, they reduce the interaction potential in areas where grey nurse sharks aggregate at higher densities.

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				In addition to aggregating behaviours, grey nurse sharks are known to undertake annual migrations between aggregation sites in Queensland and New South Wales. Research suggests that these migrations are related to the species' age and reproductive cycle. As a condensed summary, Bansemer & Bennett (2011) found that females and mature males moved northward, mating in late spring to early summer in waters off of the coast of northern NSW and southern Queensland. Pregnant *C. taurus* aggregated at Wolf Rock in southern Queensland, at the most northerly aggregation site from late summer to early winter before migrating south to pup in central and southern waters of their range in late winter to late spring. This research also showed that immature sharks of both sexes moved less than mature sharks, showed no synchronised migration patterns, and were mostly restricted to central and southern waters. It is unclear if all grey nurse sharks undertake similar migrations, and evidence suggest that individuals can be found north of Wolf Rock (*pers. comm.* D. Bowden). However, a high proportion of the east coast *C. taurus* population is found in waters from New South Wales to mid-Queensland. These are the individuals more likely to undertake migrations and, in doing so, will spend periods of time outside of Queensland managed waters. From an ERA perspective, this reduces the *encounterability* potential with RRF fishers. ***Key changes to the PSA score*** Scores assigned to the *encounterability* attribute were decreased from high (3) to medium (2). This decision was primarily based on the following: *1.* Key aggregation sites in Queensland are already afforded protection from fishing activities; *2.* A proportion of the stock migrates outside of Queensland for a period of time *i.e.* cannot be caught or interact with the RRF during this period;

Species	Attribute	PSA Score	RRA Score	Justifications and Considerations
				3. While the distribution of grey nurse sharks cover the entire coastline, the majority of the stock is located from mid-Queensland to New South Wales. These changes were done in accordance with *Guideline 2: Additional scientific assessment & consultation* with further consideration given to *Guideline 6: Management arrangements to mitigate against the level of bycatch.*

Appendix E—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, 2019e) and whole-of-fishery (Level 1) assessment (Jacobsen *et al.*, 2019c), 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 indicative scores of the likelihood that fishing activities in the Rocky Reef Fishery (RRF) 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 E2**. 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 or 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 or population to an acceptable level.

***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

The LCA for RRF target & byproduct species and the grey nurse shark produced risk ratings from low to high. Snapper (*Chrysophrys auratus*) and pearl perch (*Glaucosoma scapulare*) received the highest risk scores. Teraglin (*Atractoscion aequidens*) also received a high-risk rating, and grass emperor and cobia received moderate ratings. Based on the LCA criteria, the remaining target & byproduct species were assessed as low risk. The one non-target species included in the analysis, the grey nurse shark (*Carcharias taurus*), was found to be at moderate risk (Table E4).

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

Common name	Species name	Likelihood	Consequence	Matrix score	Risk category
Snapper	*Chrysophrys auratus*	3	4	**12**	**High**
Pearl perch	*Glaucosoma scapulare*	3	4	**12**	**High**
Cobia	*Rachycentron canadum*	2	3	**6**	**Medium**
Grass emperor	*Lethrinus laticaudis*	2	3	**6**	**Medium**
Amberjack	*Seriola dumerili*	1	3	**3**	**Low**
Teraglin	*Atractoscion aequidens*	3	3	**9**	**High**
Australian bonito	*Sarda australis*	1	2	**2**	**Low**
Leaping bonito	*Cybiosarda elegans*	1	2	**2**	**Low**
Yellowtail kingfish	*Seriola lalandi*	1	3	**3**	**Low**
Mahi mahi	*Coryphaena hippurus*	1	2	**2**	**Low**
Grey nurse shark	*Carcharias taurus*	2	3	**6**	**Medium**

4. Considerations

Outputs of the LCA support maintaining a high-risk rating for snapper, pearl perch and teraglin. In the context of the broader Level 2 ERA, these results provide further weight to the notion that the outputs of the PSA (refer Table 7) are more representative of a real or actual risk *verse* the potential risk.

At the other end of the spectrum, the LCA for amberjack, Australian bonito, leaping bonito, yellowtail kingfish and mahi mahi indicate that the likelihood of the risk coming to fruition over the short to medium term is lower than what was presented by the PSA (refer to Table 7). When these results were taken into consideration as part of a weight of evidence approach (*e.g.* catch & effort trends, scoping study, whole-of-fishery [Level 1] ERA, species-specific [Level 2] ERA), they support the assignment of a precautionary risk rating.

Of note, the LCA assigned a medium-risk rating to grass emperor and cobia which was lower than the outputs of the PSA (Table 7). While noting this differential, grass emperor and cobia are key species within the RRF and effort levels for both have increased through time (Department of Agriculture and Fisheries, 2019a). Cumulative fishing pressures are also expected to be higher for these two species (Table 7). Given these factors, risks relating to the capture and harvest of these species require further consideration and may require further management reforms. Therefore, the outputs of the Level 2 ERA were considered to be more representative of a real or actual risk, and a high-risk rating was retained.

The LCA for grey nurse sharks produced a risk rating that was lower than the PSA. In the PSA, the final risk rating for grey nurse sharks was heavily influenced by the *productivity* assessment with biological constraints identified as a key driver of risk. While the species will interact with line fishers (commercial, recreational and charter), this risk is partly mitigated through fisheries protections that restrict line fishing around known aggregation sites. Annual migrations also see a portion of the population move outside of Queensland managed waters; albeit into NSW where cumulative fishing pressures will become a factor. While the risk differential was smaller for this species (*i.e.* medium *vs.* high), the LCA and a weight-of-evidence approach supports the assignment of a precautionary risk rating for this species.

Appendix F—Summary of management arrangements for rocky reef species.

List is not exhaustive and further information on the restrictions applied to each species and across the Rocky Reef Fishery is available through the Department of Agriculture and Fisheries website (https://www.daf.qld.gov.au/) and within the fisheries legislation (https://www.daf.qld.gov.au/business-priorities/fisheries/sustainable/legislation).

Common name	Scientific name	Size restrictions	Recreational possession limit	Quota restrictions	Species-specific seasonal closures
Snapper	*Chrysophrys auratus*	35cm (min)	4 with no more than 1 over 70cm plus boat restrictions.	42t TACC limit	15 July to 15 August
Pearl perch	*Glaucosoma scapulare*	38cm (min)	4	15t TACC limit	15 July to 15 August
Cobia	*Rachycentron canadum*	75cm (min)	2	n/a	n/a
Grass emperor	*Lethrinus laticaudis*	30cm (min)	10	n/a	n/a
Amberjack	*Seriola dumerili*	50cm (min)	Combined limit of 2 (total) for both Amberjack and Samsonfish	n/a	n/a
Teraglin	*Atractoscion aequidens*	38cm (min)	5	n/a	n/a
Australian bonito	*Sarda australis*	n/a	General possession limit of 20	n/a	n/a
Leaping bonito	*Cybiosarda elegans*	n/a	General possession limit of 20	n/a	n/a
Yellowtail kingfish	*Seriola lalandi*	60cm (min)	2	n/a	n/a
Mahi mahi	*Coryphaena hippurus*	50cm (min)	5	n/a	n/a
Frypan bream	*Argyrops bleekeri*	n/a	General possession limit of 20	n/a	n/a
Samsonfish	*Seriola hippos*	50cm (min)	Combine limit of 2 (total) for both Amberjack and Samsonfish	n/a	n/a
Sea sweep	*Scorpis aequipinnis*	n/a	General possession limit of 20	n/a	n/a