Department of Agriculture and Fisheries

Sustainable Fisheries Strategy 2017–2027

Level 1 Ecological Risk Assessment
Mud & Blue Swimmer Crab (C1) Fishery

Queensland Government

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Executive Summary

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

The aim of the Level 1 ERA is to produce a broad risk profile for each fishery using a qualitative ERA method described by Astles *et. al*. (2006). The method considers a range of factors including the current fishing environment (*e.g.* current catch, effort and licensing trends), limitations of the current management arrangements (*e.g.* transfer of effort to already saturated markets, substantial increases in fishing mortality for key species, changing target species) and life-history constraints of the species being assessed. In the *Mud and Blue Swimmer Crab Fishery* (C1 Fishery) the Level 1 ERA assessed fishing related risks in 16 ecological components including target & byproduct species, bycatch, marine turtles, sea snakes, crocodiles, dugongs, cetaceans, protected teleosts, batoids (exc. sawfish), sawfish, sharks, syngnathids, seabirds, terrestrial mammals, marine habitats and ecosystem processes.

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

In the C1 Fishery, the preliminary ratings indicated that at least ten of the ecological components were at low risk of experiencing an undesirable event due to fishing activities. Five ecological components were classified as intermediate risk or higher and one as being at a negligible risk. The most notable risks related to target & byproduct (high risk), marine turtles (high risk), marine habitats (intermediate/high risk), bycatch (intermediate risk) and sawfish (intermediate risk). While the drivers of risk varied with each ecological component, limitations in the current management system, data limitations and the potential impacts of ghost pots influenced a number of risk profiles.

After the likelihood of the risk coming to fruition was considered, the risk profile for target & byproduct was downgraded from high to intermediate/high. This change recognised current management restrictions including a prohibition on the take of female crabs and undersized male crabs. The ability of this rating to be reduced further was limited by the absence of an overarching control on catch or effort, limited capacity to restrict or monitor regional fishing pressures and the extent of information on recreational fishing pressures. Overall risk ratings for all but one of remaining ecological components

(excluding seabirds) remained the same. Seabirds were downgraded from low to negligible due to the low probability of the group interacting with the apparatus.

Based on the outputs of the Level 1 ERA, the target & byproduct species ecological component and marine turtles will be progressed to a finer-scale Level 2 ERA. The Level 1 ERA identified key knowledge gaps in risk profiles for bycatch species, batoids (sawfish) and marine habitats. These information needs will be progressed to the *Fisheries Queensland Monitoring and Research Plan* for further consideration. The primary reason for this is that these outputs are considered to be more representative of the potential risk. Key information needs to refine the risk profiles include:

- Improving the level of understanding on compositions and release fates of non-target species in the commercial mud and blue swimmer crab fishery (bycatch, batoids–sawfish);
- Further assessment of regional catch and effort levels in the recreational fishing sector; particularly in south-east Queensland where populations may be more susceptible to cumulative fishing pressures (*i.e.* commercial and recreational fishing;
- Increasing the level of information on the prevalence and impact of ghost pots *e.g.* quantifying pot-loss rates in the commercial and recreational fishing sectors, evaluating their fishing potential and longevity/degradation rates (most ecological components including bycatch, batoids and marine habitats); and
- Validating species compositions and interaction rates (including release fates) for *threatened, endangered and protected* (TEP) species in both the recreational and commercial fishing sectors.

Summary of the outputs from the Level 1 (whole of fishery) Ecological Risk Assessment for the C1 (blue swimmer and mud crab) fishery.

Ecological Component	Level 1 Risk Rating	Progression
Target & Byproduct	Intermediate/High	Level 2 ERA
Bycatch	Intermediate	*Monitoring & Research Plan.*
Species of Conservation Concern (SOCC)		
Marine turtles	High	Level 2 ERA
Dugongs	Low	Not progressed further.
Cetaceans	Low	Not progressed further.
Sea Snakes	Low	Not progressed further.
Crocodiles	Low	Not progressed further.
Protected Teleosts	Low	Not progressed further.
Batoids (non-sawfish)	Low	Not progressed further.
Batoids (sawfish)	Intermediate	*Monitoring & Research Plan.*
Sharks	Low/Intermediate	Not progressed further.
Syngnathids	Negligible	Not progressed further.
Seabirds	Negligible/Low	Not progressed further.
Terrestrial mammals	Low	Not progressed further.
Marine habitats	Intermediate/High	*Monitoring & Research Plan.*
Ecosystem Processes	Low	Not progressed further.

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Definitions & Abbreviations

Active Licence	–	The definition of an active licence is the same as that used by DAF's data reporting system. An active licence is a licence that has reported catch and effort in the C1 Fishery through the logbook reporting system irrespective of the amount of catch and effort.
BRD	–	Bycatch Reduction Device.
Bycatch	–	The portion of the catch that is discarded/returned to sea. For the purpose of this ERA, the definition of bycatch does not include unwanted target and byproduct species.
Byproduct	–	The portion of catch retained for commercial sale that was not intentionally targeted.
C1 Fishery	–	Commercial blue swimmer and mud crab fishery. C1 refers to the commercial fishing symbol used by the fishery.
DAF	–	Queensland Department of Agriculture and Fisheries.
EC	–	Queensland's east coast.
ECIFFF	–	East Coast Inshore Fin Fish Fishery.
Ecological Component	–	Broader assessment categories that include *Target & Byproduct* (harvested) species, *Bycatch*, *Species of Conservation Concern*, *Marine Habitats* and *Ecosystem Processes.*
ECOTF	–	East Coast Otter Trawl Fishery.
ECTF	–	East Coast Trawl Fishery.
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 Assessments.
False positive'	–	The situation where a species at low risk is incorrectly assigned a higher risk rating due to the method being used, data limitation 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.
Fishing Licence	–	Effectively a fishing platform. A Fishing Licence can have multiple symbols attached including a net (N) and line (L) fishing symbol.

Fishery Symbol	–	The endorsement that permits a fishery to access a fishery and defines what gear can be used *i.e.* N = Net, L = line, T = trawl. The number of fishing symbols represents the maximum number of operators that could (theoretically) access the fishery at a single point in time.
GoC	–	Gulf of Carpentaria, including waters east of E 138°.
MLS	–	Minimum Legal Size limit.
MSY	–	Maximum Sustainable Yield.
MEY	–	Maximum Economic Yield.
Offshore waters	–	Tidal waters that are at least 2m deep at low water.
QBFP	–	Queensland Boating and Fisheries Patrol.
SAFS	–	Status of Australian Fish Stocks.
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.
Target	–	The primary species or species groups that have been selectively fished for and retained for commercial, recreational or traditional purposes.
WTO	–	Wildlife Trade Operation.

1 Overview

The *Queensland mud and blue swimmer crab* (C1 Fishery) is Queensland's third most valuable commercial fishery and one of the largest in terms of the prescribed fishing area. The two principal species, mud and blue swimmer crabs, are also popular target species for the recreational fishing sector. While the C1 fishery operates along the entire Queensland coast (excluding areas closed to fishing), it can be arbitrarily split into two regions 1) the Queensland east coast (EC) and 2) the Gulf of Carpentaria (GoC). The fishery is largely managed through input controls (*e.g.* gear restrictions, spatial closures); however a no-take policy on female crabs and a minimum legal size (MLS) limit for males is in place for fishing sectors *i.e.* commercial, recreational, and charter fishers. Output controls such as total allowable commercial catch (TACC) limits or Individual Transferrable Quotas (ITQs) do not apply to this fishery.[1]

The C1 Fishery has been subject to a number of sustainability and risk-based assessments; although the scope of these assessments vary. A stock assessment has been undertaken for blue swimmer crabs with the results indicating that the fishery was not overfished to the point where spawning biomass was significantly reduced (Sumpton *et al.*, 2015). However, Sumpton *et al.* (2015) found that population levels for legal crabs combined with the fishing effort levels (at that point in time) were not conducive to biomass increases and were unlikely to improve with respect to the economic outputs and/or transitioning to a point nearer to Maximum Economic Yield (MEY).[2] This finding is important as the *Queensland Sustainable Fisheries Strategy 2017–2027* contains key biomass targets including the establishment of catch limits based on achieving MEY by 2027 (Department of Agriculture and Fisheries, 2017). While a stock assessment is being developed for mud crabs, biomass estimates and reference points are not currently available for either the Queensland EC or for the GoC.

While a stock assessment has not been completed for mud crabs, both target species have been assessed as part of the Status of Australian Fish Stocks (SAFS). The status for both species vary slightly in that blue swimmer crabs are assessed at a whole of fishery level (all of Queensland), whereas mud crabs are assessed as two separate stocks (Queensland EC and GoC), In both instances, the stocks of each species were assessed as being sustainably fished (Grubert *et al.*, 2018; Johnston *et al.*, 2018). More detailed information on the SAFS assessments can be found at http://fish.gov.au/

More broadly, the blue swimmer crab (C1), mud crab (C1) and spanner crab (C2/C3) fisheries were the focus of a more detailed ecological risk assessment (ERA). Undertaken in 2009, this ERA utilised the *Scale, Intensity, Consequence, Analysis* (SICA) methodology to examine the risk posed by these fisheries on a number vulnerable target and non-target species (Hill & Garland, 2009). The results of this ERA informed discussions surrounding the management of the fishery including those relating to the issuing of approvals under the *Environment Protection and Biodiversity Protection Act 1999* (EPBC Act). The fishery has not been subject to further risk evaluations since the completion of this report.

In March 2018, Queensland released the *Ecological Risk Assessment Guideline* (the Guideline) (Department of Agriculture and Fisheries, 2018a) as part of the *Queensland Sustainable Fisheries Strategy 2017–2027* (Department of Agriculture and Fisheries, 2017). This Guideline provides an

[1] *Correct as of 7 March 2019.*
[2] *Further information on the key findings of the blue-swimmer crab stock assessment have been made available at:* https://www.daf.qld.gov.au/business-priorities/fisheries/monitoring-our-fisheries/data-reports/sustainability-reporting/stock-assessment-reports/assessment-of-the-blue-swimmer-crab-fishery

overview of the strategy being used to develop ERAs for Queensland's fisheries and includes a four-stage framework consisting of 1) a Scoping Study, 2) a Level 1, whole of fishery qualitative assessment, 3) a Level 2, species-specific semi-quantitative or low-data quantitative assessment, and 4) a Level 3 quantitative assessment (if applicable).

The following provides a broad, qualitative (Level 1) assessment of the risk posed by the C1 Fishery on a number of key ecological components. The Level 1 assessment follows-on from the completion of a scoping study that provides information on the current fishing environment, licencing trends and broad catch and effort analyses (Department of Agriculture and Fisheries, 2019b).

2 Focus/Intent

The risk profiles for Queensland's commercial fisheries vary and are highly dependent on the apparatus used. For example, the risk posed by line fishing activities will be lower when compared to a net or trawl fishery. Similarly, single-species fisheries like Spanish mackerel will present a lower risk when compared to multi-species or multi-apparatus fisheries. Every fishery will have elements that present a higher risk for one or more of the ecological components *i.e.* species groupings, marine habitats and ecosystem process that interact with the fishery. These risk elements will still be present in smaller fisheries including those where there is greater capacity to target individual species.

In recognition of the above point, the primary objective of the Level 1 assessments were to a) identify the key sources of risk within a particular fishery and b) the ecosystem components that are most likely to be affected by this risk. Used in this context, Level 1 ERAs produce outputs or risk assessments that are very fishery-specific. The inherent trade off with this approach is that risk ratings cannot be compared between fisheries as the scale, extent and impact of the risk are unlikely to be equal. They will however provide insight into the areas or fishing activities within the C1 Fishery that may contribute to an undesirable event for one or more of the ecological components.

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

3 Methods

The Level 1 assessment is used to assess risk at the whole of fishery level with the primary objective being to establish a broad risk profile for each fishery. Level 1 assessments will focus on a wide range of ecological components and will include detailed assessments for *Target & Byproduct* (harvested) species, *Bycatch*, *Species of Conservation Concern*, *Marine Habitats* and *Ecosystem Processes*.

For the purposes of this ERA, the term '*Species of Conservation Concern'* (SOCC) was used instead of '*Species of Conservation Interes*t' as the scope of the assessment will be broader. In Queensland, the term '*Species of Conservation Interest*' or SOCI refers specifically to a limited number of non-targeted species that are subject to mandatory commercial reporting requirements. The expansion of this list allows for the inclusion of non-SOCI species including those that are afforded additional legislative protections *e.g.* the listing of hammerheads as '*Conservation Dependent*' under the EPBC

Act. In the case of the SOCC, this ecological subgroup has been further divided into: marine turtles, sea snakes, crocodiles, dugongs, cetaceans, batoids, sharks, syngnathids, seabirds, protected teleosts and terrestrial mammals. The division of the SOCC ecological component recognises the variable life-history traits of this subgroup and the need to develop risk profiles for each complex.

Of the five ecological components, ecosystem processes represents the biggest challenge for management response as the viability of these processes will be influenced by factors outside of the control of fisheries management *e.g.* climate change, pollution, extractive use of the marine resources, and urban, port and agricultural development. From an ERA perspective, this makes it difficult to quantify the level of impact an individual fishery is having on these processes and by extension the accurate assignment of risk ratings. This problem is compounded by the fact that it is often difficult to identify measurable indicators of marine ecosystem processes (Pears *et al.*, 2012; Evans *et al.*, 2016). For example, what parameters need to be measured to determine if a) an ecosystem process is in decline, stable or improving and b) how much of this change can be attributed to fishing activities or lack thereof?

In order to refine the Level 1 ERA for ecosystem processes, a preliminary assessment was undertaken. The preliminary assessment examined the potential for a fishery to impact on 16 categories outlined in the *Great Barrier Reef Outlook Report 2014* (Great Barrier Reef Marine Park Authority, 2014). The specific processes examined in response to fisheries related impacts were *sedimentation*, *nutrient cycling / microbial processes*, *particle feeding*, *primary production*, *herbivory*, *predation*, *bioturbation*, *detritivory*, *scavenging*, *symbiosis*, *recruitment*, *reef building*, *competition*, *connectivity*, *outbreaks of disease* and *species introductions*. Not all processes are applicable to every fishery, but all processes were considered before being eliminated. A full definition of each ecosystem process has been provided in Appendix 1.

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

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

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

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

4. *Likelihood*–a secondary evaluation of the key factors underpinning the preliminary risk assessments, their relevance to the current fishing environment and the potential for the

fishery to contribute to this risk in the short to medium term. This step was included in recognition of the fact that preliminary scores (see *Risk Characterisation*) may overestimate the level of risk for some ecological components.

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

The above framework differs slightly from Astles *et al.* (2006) in that it includes an additional step titled *Likelihood.* The inclusion of this additional step recognises the precautionary nature of qualitative assessments and the potential for risk levels to be overestimated in whole of fishery ERAs. This step in effect assesses the likelihood of the risk occurring in the current fishing environment and takes into consideration a) the key factors of influence and b) their relevance to the current fishing environment. In doing so, the *Likelihood* step helps to differentiate between **actual** and **potential** high risks. This aligns with the objectives of *Ecological Risk Assessment Guideline* (Department of Agriculture and Fisheries, 2018a) and helps limit the extent of 'false positives' or the misclassification of low risk elements as high risk.

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

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

4 Whole of Fishery Qualitative Assessments

4.1 Risk Context

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

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

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

The inclusion of 'potential' in the risk definition recognises the need to take into consideration both current and historic trends and the likelihood that a fishery will deviate from these trends in the short

to medium term. The reference to ‘structural elements of a fishery’ largely relates to the current fishing environment and the potential for it to change over the longer term *e.g.* the potential for effort to increase under the current management arrangements, effort displacements or the ability for effort to shift between regions.

In order to frame the scope of the assessment, a 20-year period was assigned to all Level 1 assessments. That is, the likelihood that the one or more of the ecological components will experience an undesirable and unacceptable change over the next 20 years due to fishing activities in the C1 Fishery. In order to do this, the Level 1 assessments assume that the management arrangements for the fishery will remain the same over this 20-year period. A 20-year timeframe has previously been used in ERAs involving the East Coast Trawl Fishery (ECTF) (Pears *et al.*, 2012; Jacobsen *et al.*, 2018) and is considered to be relatively precautionary.

At a whole of fishery level, the risk of the C1 Fishery contributing to or causing an undesirable event has declined over the last 20 years. This has been achieved through a range of management reform initiatives that have reduced both real and potential effort in the fishery. The most notable of these was the *2008-09 Latent Effort Review Process*. This process had a significant impact on the number of operators that could access the fishery (Department of Agriculture and Fisheries, 2019b) and was primarily responsible for the number of C1 symbols declining by more than 50% between 1999 (*n* = 923) and 2017 (*n* = 412). These reductions make a significant contribution to the risk minimisation process by helping to ensure that fishing effort, fishing mortality and catch does not expand significantly over a short period of time. This risk continues to be managed in the C1 Fishery through a limited licensing system which prevents new authorities being issued for the fishery (Department of Agriculture and Fisheries, 2019b). This is of particular relevance when attempting to understand and quantify the ‘Risk Context’ for this fishery.

Although the C1 Fishery is managed at a whole of state level, the commercial fishery can be divided into two broader regions: the Queensland EC and GoC. This contrasts with the majority of Queensland’s commercial fisheries that are limited to a single area or operation *e.g.* the Queensland EC or the GoC. From an ERA perspective, the EC accounts for over 80% (84 - 96.5%) of the total catch In the C1 Fishery and will therefore be the major factor of influence with respect to the final risk ratings (Department of Agriculture and Fisheries, 2019b).

Given the popularity of the species in Queensland, cumulative fishing pressures will shape the context of the final risk assessments. This will include the prevalence of the recreational fishing sectors and other commercial sectors which can retain mud and blue swimmer crabs as byproduct. At present the risk posed by the *East Coast Trawl Fishery* (ECTF) is managed by in-possession limits of 100 crabs per trip within Moreton Bay and 500 crabs per seven days outside of Moreton Bay. The ECTF is responsible for less than 12.1% of the total annual catch of blue swimmer crabs (since current possession limits were brought in in 2008) (Department of Agriculture and Fisheries, 2019a) and, with discard mortality rates estimated to be around 7% (Sumpton *et al.*, 2003), it will contribute to the cumulative fishing pressures for this fishery. Mud and blue swimmer crabs harvested in Queensland’s east coast net fisheries on the other hand will likely contribute little to cumulative fishing pressures due to the negligible amounts in which they are harvested (Department of Agriculture and Fisheries, 2019b).

4.2 Risk Identification

Fishing activities are frequently subdivided into categories that identify the sources of risk or potential hazards (Astles *et al.*, 2009; Hobday *et al.*, 2011; Pears *et al.*, 2012). What constitutes a hazard can vary between ERAs and is often dependent on the specificity and scale of the assessment. For larger scale assessments, some of the more commonly used fishing activities include: harvesting, discarding, contact without capture, loss of fishing gear, travel to and from fishing grounds, disturbance due to presence in the area and boat maintenance and emissions (Table 1). The fishing activities outlined in Table 1 will provide the foundation of the risk profiles and will be used to assign preliminary risk ratings to each ecological component (see *Risk Characterisation*).

In Queensland, 'cumulative fishing pressures' has also been identified as key source of risk (Table 1). Used as part of a Level 1 assessment, the term 'cumulative fishing pressures' will examine the risk posed by Queensland's other commercial fisheries and sectors outside of the commercial fishing industry. This parameter was included in the Level 1 assessment in recognition of the fact that a number of Queensland's fisheries have multiple fishing sectors (*e.g.* commercial, recreational, and charter). This means that the risk posed to some species may be higher than what is observed in the commercial fishing sector *e.g.* species that attract a high level of interest from the recreational fishing sector.

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

The inclusion of cumulative impacts in the Level 1 assessment provides further context on factors that may contribute to an undesirable event. In a fisheries-based ERA it can be difficult to account for these impacts in the final risk ratings. The main reason for this is that it can be difficult to define the extent of these impacts or quantify the level of contribution they make to an overall risk; particularly in a whole of fishery assessment (*e.g.* the impact of recreational fishing/boating activities on SOCC subgroups). Given this, final risk ratings will concentrate on commercial fishing activities with cumulative impacts (when and where appropriate) identified as an additional source of risk *e.g.* for species targeted and retained by commercial, charter and recreational fishers. In the event that one or more of the ecological components are progressed to a Level 2 assessment than the cumulative impacts (*e.g.* from other fisheries) will be given additional considerations.

Unlike the fishing activities, ratings assigned to 'cumulative risks' will not be used in the determination of preliminary risk scores (see *Risk Characterisation*). The main reason for this is that the preliminary risk scores relate specifically to commercial fishing activities.

The following provides an overview of the key fishing activities/sources of risk in the C1 Fishery and for each of the respective ecological components. When and where appropriate the contributor of risk (*i.e.* the fishing activity) is also identified in the text.

Table 1*. Summary of the key fishing activities and their relation to risk. Table 1 is based on an extract from Pears et al. (2012). * Cumulative risk scores are not considered when assigning preliminary risk ratings as these values relate specifically to the commercial fishing sector.*

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

4.2.1 Whole of Fishery

Harvesting and ***discarding*** are considered to be the greatest contributors of risk in the C1 Fishery, with ***loss of fishing gear*** viewed as a secondary factor of influence. While ***contact without capture*** is possible it was considered to be a lower risk for this fishery. This was primarily due to the passive nature of the fishing gear and the number of species that would be impacted by this type of fishing activity.

Travel to/from fishing grounds, ***disturbance due to presence in the area*** and ***boat maintenance and emissions*** are considered to be a lower risk in the C1 Fishery. Given the size of the fishery, the apparatus used and the species targeted, these impacts are likely to be localised, relatively short term and associated with the setting and retrieval of crab apparatus. There will however be some regional variance and the risks associated with the above activities may be elevated in high-use areas like south east Queensland. In these instances, the elevated risk will be due to the cumulative pressure exerted on an ecological component by all stakeholders, not just the C1 Fishery. For example, the impact of boat strike (and the associated risk) on regional marine turtle and dugong populations (Department of National Parks Sports and Racing, 2010).

4.2.2 Ecological Subcomponents

Target & Byproduct (harvested)

The ***harvesting*** of target species is the most significant source of risk for this ecological component with an average of 1054tof mud cab and 382tof blue swimmer crab retained for sale each year (2015–2017 average) (Department of Agriculture and Fisheries, 2019b). While the ***harvesting*** of crabs occurs along the entire coastline, there is a clear discrepancy between the size of the fishery on the Queensland EC and in the GoC. Almost 90% (2017) of the active C1 licences are based on the Queensland EC and the region is responsible for 91% of the total annual catch (Department of Agriculture and Fisheries, 2019b). As the fishery does not operate under regional management, this division is based largely on social (remote location), economic and operational considerations. Regional distribution of catch and effort is not expected to change significantly with the Queensland EC continuing to be the major contributor of risk in this fishery.

The absence of an overarching control mechanism means that effort levels can increase at both a whole of fishery (*e.g.* through the re-activation of underutilised licences) and regional level (*e.g.* the permanent or temporary transfer of licences). At a whole of fishery level, fisheries data suggests that the risk of effort increasing significantly over the short to medium term is relatively low. Management reforms have helped negate latency risks and the total number of fishing symbols and active licences has declined progressively since 2000 (Department of Agriculture and Fisheries, 2019b). At a regional level, the risk of effort increasing beyond an acceptable limit is considered to be higher. There is little capacity within the current management framework to address changing fishing patterns or restrict the amount of effort that is transferred towards other regions. Further, there are no legislative restrictions preventing an operator from transferring their licence from one region to the other on a permanent or temporary basis. This means that low-use C1 symbols from (*e.g.*) the GoC or far north Queensland can shift into regions with high-effort (*e.g.* south east Queensland) irrespective of the number of licences that are operating in the area (***harvesting|discarding***).

The transfer of licences from low effort regions to areas with high participation rates increases the risk that a region or population will experience an undesirable level of fishing mortality. This is of particular relevance to the C1 Fishery where management arrangements permit the use of more than 50 pots if a licence has more than one C1 fishery symbol attached.[3] Given these arrangements, it is conceivable that regional effort levels may increase through licence transfers (permanent or temporary) without there being a discernible increase in the number of operators accessing an area. The extent of this risk would be highly depend on the region and the extent of any increase in effort. These risks are compounded by a limited capacity to track and monitor total fishing mortality (commercial and recreational), an absence of biomass/sustainability reference points for mud crabs and biomass analyses indicating that the blue swimmer crab biomass was unlikely to increase under current (2015) fishing pressures.

On a species-specific level, the risk of ***harvesting*** resulting in one or both species experiencing an undesirable event is managed through minimum legal size limits and a long-term prohibition on the take of female crabs. These measures ensure that a high proportion of the blue swimmer and mud crab stocks are protected from ***harvesting*** (Hill & Garland, 2009). This proportion is likely to be higher

[3] *Regulations allow an operator to use a maximum of 50 pots, traps and dillies if the C1 fishery symbol is written on a licence once. If the C1 fishery symbol is written on a licence more than once, a maximum of 100 pots can be used.*

when the extensive array of spatial closures (green zones) on the Queensland EC are taken into consideration (Queensland Government, 2017). The inherent trade-off of having minimum legal size limits and no-take provisions for female crabs is that the C1 Fishery has a comparatively high discard rate. For example, Pillans *et al.* (2005) examined legal catch rates of mud crabs at four different locations in Moreton Bay and found that only 9–24% of catches could be retained (43–58%) and 27–43% of the total catch in waters open to fishing were females and undersized males respectively). While these results cannot be extrapolated to a whole of fishery level, they do highlight the degree to which ***discarding*** can and does occur in this fishery. While not universal, high discard percentages will increase the risk of injury and the potential for indirect fishing mortalities to occur *e.g.* predation.

While pot fishing is understood to have relatively low mortality rates (zero according to one study on *S. serrata*; Butcher *et al.*, 2012) compared to other fishing methods, crabs (***harvested*** and ***discarded***) can suffer physical damage or mortality during the apparatus deployment and capture phases. This can be due to a range of factors such as predation, direct entanglement, aggression between captured individuals (Sumpton *et al.*, 2003; pers. com. S. Barry) and during the crab removal process. Research conducted in the New South Wales mud crab fishery reported damage rates of 18% and included loss of limbs and carapace punctures from conspecifics. This study also found that the amount of damage strongly correlated with gender, trap type, soak time, water depth and moult stage (Butcher *et al.*, 2012). Injuries and damage to non-target animals (undersize males and all females) has implications for the management unit as it will reduce the fitness of ***discarded*** animals, increase the risk of predation and reduce post-release survival rates. There is a risk of crabs experiencing within pot mortality as a result of predation or territorial disputes with conspecifics or other species (pers. com. S. Barry). While crab pots can include designs and features (*e.g.* mesh size, escape vents) that allow for the escape of non-target species and undersized crabs (Jirapunpipat *et al.*, 2008; Johnson, 2010; Butcher *et al.*, 2012), they are not regulated/mandated for use in the C1 Fishery.

Byproduct in the C1 Fishery consists of all other crab species (excluding spanner crabs) and incorporates coral swimmer crabs (*Charybdis feriatus*), three-spot crabs (*Portunus sanguinolentus*) and hairyback crabs (*Charybdis natator*). Only moderate amounts of byproduct are retained in this fishery, with non-target species frequently making up less than 10tof the total annual catch (Department of Agriculture and Fisheries, 2019a; b). Unless availability of these species increase or market values change, the risk that one or more of the byproduct species will experience an undesirable event due to ***harvesting*** is expected to be low.

Loss of fishing gear in the C1 Fishery presents a risk to target and byproduct species due to the trapping nature of the apparatus. Even after baits are expired/consumed, target species and other animals can be attracted to lost pots for other reasons; to seek refuge, the residual scent of the bait, or prey animals becoming trapped or dying inside the pots (Sumpton *et al.*, 2003). Crab fishing apparatus may also be temporarily abandoned due to weather conditions or as competitive claim on a favourable fishing area (pers. com. S. Barry). Although not technically ***loss of fishing gear***, failing to check pots for several days also presents as a mortality risk to target and bycatch species similar to that of ghost pots (Sumpton *et al.*, 2003).

Information on pot loss rates is limited, however observational surveys in the Queensland blue swimmer crab fishery estimated that a single commercial fisher will lose an average 35 pots[4] per annum; half of which remain in the environment (Sumpton *et al.*, 2003). Sumpton *et al.* (2003) further estimated that a single ghost pot in the blue swimmer crab fishery will catch on average 22 crabs per annum. While this study focused specifically on the blue swimmer crab fishery it also demonstrated the potential for ghost pots to increase fishing mortality rates for mud crabs. The study also highlighted the need for additional information on the impact of ghost pots including on their origins (recreational *vs.* commercial), their longevity in the marine environment and their fishing potential. This information is considered to be of significant importance for subsequent ERAs as ghost pots have the potential to impact on both target and non-target species.

Additional information on the risk posed by the collective crab fishery including those pertaining to the recreational fishing sector, non-compliance, and black marketing has been provided in the *Cumulative Impacts* and *Issues Arising* sections of the Level 1 assessment.

Bycatch (non-SOCC)

The majority of bycatch in the C1 Fishery consists of inshore fin fish and smaller invertebrates accessing the bait placed in the trap. Bycatch from crab fishing has been known to include fin fish such as bream, catfish, gold spot grouper, Queensland groper, sleepy cod, mullet, sweetlip, grunter, and squire (Sumpton *et al.*, 2003; pers. com. S. Barry) with sharks, rays and eels caught with less frequency. While fishers are not permitted to retain product other than crabs as part of their C1 operation, anecdotal evidence suggests that a portion of the non-target catch is used to re-bait pots. The extent to which bycatch is used to re-bait pots is unknown but the quantities of bycatch taken from the fishery suggests that this represents more of a compliance risk than a sustainability risk.

Species of Conservation Concern

The C1 Fishery operates and interacts with a diverse range of species of conservation concern (SOCC). While reported interactions (SOCI logbook) are lower than in other fisheries, close to a quarter (23%) of the reports were recorded as dead discards (Department of Agriculture and Fisheries, 2019b). As none of the SOCC can be retained for sale in the C1 Fishery, ***discarding*** is considered to be the fishing activity posing the most risk to these species. The potential for ghost pots and unattended pots to become an attractant through self-baiting and or for the ropes to become a trap/entanglement hazard will also make ***loss of fishing gear*** a significant issue for some species. The risk of an interaction resulting in serious injury or death will be dependent on the part of the apparatus (*i.e.* float lines, pots, traps & dillies) and the species that was involved with the interaction.

Marine turtles

More than a third (34%) of the reported SOCI interactions from the C1 Fishery (2002–2017) involved marine turtles (Department of Agriculture and Fisheries, 2019b). This data revealed that of the marine turtles that interacted with the fishery, hawksbills had the highest interaction rates (45%) followed by green (24%), loggerhead (21%), and unspecified (9%) marine turtles. The vast majority of the reports from the SOCI logbooks indicate that the animal was released alive (97%), but the veracity of this data is unknown.

[4] A minor (4%) proportion of apparatuses in this study were inverted dillies, which have since become prohibited for use in Queensland waters (Sumpton et al., 2003).

As the SOCI logbooks evaluate the health of the animal at the time of its release (***discarding***), the data do not account for post-release mortalities. While a high proportion of the marine turtles are reported as being released alive, some of these animals may die as a result of injuries sustained from the gear or extended periods of submersion. This inference is partially supported by the *Marine Wildlife Stranding and Mortality Database* which attributes (directly and indirectly) between 14 and 55 turtle interactions per year (since 2000) to crab fishing activities (Table 2; Department of Environment and Heritage Protection, 2017b). Since the database categorised fishing related mortalities in the year 2000, at least 291 turtles have died as a result of crab pot or float line interactions [5] (Department of Environment and Heritage Protection, 2017b). As most of the C1 fishing effort is concentrated in south east Queensland (Department of Agriculture and Fisheries, 2019b), there is likely to be a higher proportion of deaths occurring in this region.

It is important to note that the *Marine Wildlife Stranding and Mortality Database* provides little insight into the origins of the apparatus, the legality of the pots, and does not attribute marine turtle deaths to a particular sector (commercial/recreational) or fishery (*e.g.* Spanner Crab Fishery, C1 Fishery, illegal operations). Even so, the causal effects of the marine turtle deaths suggest that it is a factor of influence when assessing the risk that the marine turtle subgroup will experience an undesirable event. The number of interactions reported in the *Marine Wildlife Stranding and Mortality Database* also suggests that the total number of interactions and mortalities (*in-situ* deaths plus post-release mortalities) may be higher than what is reported in the SOCI logbooks.

Table 2 *- Marine Wildlife Stranding and Mortality Database information on marine turtle interactions with fishing related activities including dead, rescued, and released alive individuals (excludes unconfirmed reports) (Department of Environment and Heritage Protection, 2017b).*

Year	Marine Turtles				
	Boat strike	Crab pot/float line	Ghost nets	Netting	Fishing line or rope
2000	78	14	0	0	10
2001	83	18	0	0	11
2002	65	29	0	0	23
2003	60	18	3	3	4
2004	75	25	21	5	7
2005	63	22	53	15	6
2006	67	26	6	4	11
2007	70	31	12	2	12
2008	92	47	22	4	16
2009	68	55	1	1	11
2010	63	44	15	0	14
2011[6]	126	37	5	32	24

[5] *This data includes reports from commercial fishers who are legally required to report turtle and dugong deaths to the Department of Environment and Heritage and through the SOCI logbook. This data will also include turtles that have interacted with recreational fishing sector and ghost pots.*

[6] *Data beyond 2011 is yet to be published and is not available to the public, hence why it is excluded from this assessment.*

From an ERA perspective, the risk of turtle mortalities are higher when the individual is caught in the actual pot *vs* entanglement in the associated float lines. This can be attributed to crab pots being submerged for several hours at a time and the need for turtles to access the surface to breathe. As the fished area of the blue swimmer crab fishery overlaps with habitats preferred by marine turtles (deeper, clear water environments), the risk to this subgroup may be higher in this sector of the C1 Fishery (Sumpton *et al.*, 2003). The omnivorous diet of some turtle species may also encourage them to target bait in traps or the crabs themselves (Department of Employment Economic Development and Innovation, 2011). This increases the likelihood of a turtle becoming trapped within the pot. If caught, the likelihood of the animal surviving is considered to be low without rapid intervention.

Modern crab fishing apparatus may involve turtle excluding devices and/or use of negative buoyancy rope which may reduce the occurrence of entanglement (SI - Oceanwatch Australia; Roosenburg & Green, 2000). Information on the effectiveness of these measures is limited and the full extent of their use in the C1 Fishery is unknown and currently not regulated in Queensland. These measures may be effective tools but will have limited value with respect to minimising marine turtle interactions with ghost pots (***loss of fishing gear***).

Given the above, there remains considerable potential for the C1 Fishery to contribute to the risk of an undesirable event occurring for marine turtles. The sheer number of pots in waterways from both the commercial and recreational sectors is the primary driver of the risk to marine turtles. Additionally, there is a moderate degree of overlap between the target species and environments where there is a higher potential for interactions. While only a small proportion of the reported interactions have resulted in the death of an animal, anecdotal evidence and post-mortem analyses suggest that total mortality (*in-situ* plus post release mortalities) will be higher in this fishery. Managing and aiming to minimise the risk to protected species complexes such as marine turtles is an integral goal for the *Queensland Sustainable Fisheries Strategy 2017-2027* (Department of Agriculture and Fisheries, 2017).

Dugongs

There are no reported interactions with dugongs in the SOCI logbook data. However, at least three interactions with a crab apparatus (including the associated floats) have been recorded in the *Wildlife Stranding and Mortality Database* (Greenland & Limpus, 2006; Meager, 2016b). In one of the three instances, the animal was released alive after intervention or was able to disentangle itself from the fishing apparatus.

Noting the potential for dugongs to interact with crab pots, the likelihood of this species interacting frequently with this fishery will be low. As the majority of commercial effort is targeted at mud crabs, fishers are less likely to operate in environments preferred by this species (clearer water) including their feeding grounds (Department of the Environment and Energy, 2018a). While there is greater potential of an interaction to occur in the blue swimmer crab fishery, this risk is still considered to be low. Accordingly, this sub-component has been assigned a low risk rating for the purposes of this ERA.

Cetaceans

Since 2002, around 8% (*n* = 8) of the SOCI interactions in the C1 Fishery were with whales; all of which were released alive (Department of Agriculture and Fisheries, 2019b). The *Wildlife Stranding*

and Mortality Database has a higher number of interactions with at least two deaths and 23 live releases attributed to crab fishing activities since 2006 (Table 3; Meager, 2016a).

In the C1 Fishery, cetacean interactions will most likely involve entanglement in the float lines of pots set in deeper water. Based on the dynamics of the fishery, these interactions are more likely to occur in the Blue Swimmer Crab Fishery. Due to the size of the animals involved, the consequences of the initial interaction are expected to be low with the animal releasing itself or swimming away after intervention (Department of Environment and Heritage Protection, 2017b). There may however be longer-term consequences for the animal; particularly if some of the fishing gear or float lines remain attached to the animal.

The degree of overlap between cetaceans' natural habitats and preferred crab fishing areas is moderately low, and reports from SOCI logbooks and ancillary reports suggests that these interactions are infrequent and largely non-lethal. While the C1 Fishery does pose a risk with respect to longer-term injuries, it represents a comparatively low range risk for this species complex overall.

Table 3 *- Marine Wildlife Stranding and Mortality Database information on cetacean interactions with fishing related activities including dead, rescued, and released alive individuals, but not including unconfirmed reports (Department of Environment and Heritage Protection, 2017b). *Prior to 2006, all fishing related strandings and mortalities were grouped as a single category.*

Year	Cetaceans			
	Vessel interactions	**Net fishing***	**Traps, ropes or floats***	**Line fishing gear***
2000	2	0		
2001	0	4		
2002	0	2		
2003	1	2		
2004	3	7		
2005	2	1		
2006	2	1	5	0
2007	3	2	7	1
2008	5	2	1	0
2009	1	4	1	0
2010	0	0	0	0
2011	2	4	1	0
2012	3	1	4	7
2013	1	1	4	6
2014	3	1	0	3
2015[7]	3	1	2	5

[7] *Data beyond 2015 is yet to be published.*

Batoids

Sawfish (*Family Pristidae*) are one of the few batoid families afforded full protection in Queensland waters. Sawfish distributions have contracted through time and populations on the Queensland east coast (for some species) may now be extirpated; particularly in central and southern Queensland (D'Anastasi *et al.*, 2013; Kyne *et al.*, 2013; Simpfendorfer, 2013). This in part would explain why there have been few interactions (*n* = 2) reported from this fishery through the SOCI logbooks (Department of Agriculture and Fisheries, 2019b). Some species including the green and narrow sawfish have been reported from other fisheries; namely the *East Coast Inshore Fin Fish Fishery* (ECIFFF). To this extent, the C1 Fishery has the potential to interact with these species on the east coast. In addition, the C1 Fishery operates in environments that are preferred by these species including estuarine and intertidal waters. Sawfish are particularly susceptible to capture in a wide range of fishing apparatus due to the morphology of their rostrum. This, combined with the fragmented nature of their distributions and a lack of information on how they interact with fisheries (in general) means that the sawfish subgroup will be at higher risk of experiencing an undesirable event.

Outside of sawfish, only the *Manta* genus and several species within the *Mobula* genus are listed as SOCI. The Estuary stingray *Hemitrygon fluviorum*[8] is listed as 'Near Threatened' under the *Nature Conservation* (*Wildlife) Regulation 2006*, but fishers are not required to record interactions with this species. When compared to sawfish, the risk posed to offshore pelagic batoids such as those in the *Manta* and *Mobula* genera will be lower. While the geographical distribution of these species will overlap with the fishery, interactions with the apparatus are unlikely.

There will be risks involved for smaller *H. fluviorum* and other batoids, which inhabit estuarine/inshore waters, as they have a benthic lifestyle and feed in grounds that overlap with the fishery (Last & Stevens, 2009). Interactions with other batoids including *H. fluviorum* would be infrequent and most likely be due to the animal trying to access the bait. These interactions will primarily involve smaller species or individuals who have managed to get into the pot through the opening. In the event that a batoid were to become trapped inside a pot, mortality rates are expected to lower when compared to other SOCC, as the apparatus remains stationary and submerged until the fisher retrieves the device and discards the animal. To this extent, the risk posed by the fishery to the majority of species in this subgroup is expected to be low.

Sharks

The majority of sharks, including benthic dwelling species, are considered to be at low risk of experiencing an undesirable event as a result of fishing activities in the C1 Fishery. While shark species will interact with and be caught in a crab pot, post release survival rates for most species will be high.

The Speartooth shark (*Glyphis glyphis*) lives in estuaries and inshore waters, and although information on the abundance and distribution of this species is limited, population numbers are expected to be low (Pogonoski & Pollard, 2003; Stevens *et al.*, 2005). Under Commonwealth legislation, *G. glyphis* is classed as critically endangered, and is a no-take species under *Fisheries Regulation 2008*. Due to its protection status, *G. glyphis* is also a SOCI, and interactions must be recorded.

[8] *Legislation and older publications refers to this species by the synonym Dasyatis fluviorum.*

Glyphis has not been recorded interacting with crab pots in the C1 Fishery or any other Queensland fishery, but recent research in the Gulf of Carpentaria has evidenced juveniles being caught in recreational crab fishing gear (Lyon *et al.*, 2017). Possible reasons for this complete absence of interactions in the SOCI data is the sheer rarity of the species, and/or identification discrepancies between *G. glyphis* and the more common and wide-spread, bull shark (*Carcharhinus leucas*). *Glyphis* and *C. leucas* share habitat ranges in north Queensland, and share very similar physical appearances, especially as juveniles (Last & Stevens, 2009; Department of Employment Economic Development and Innovation, 2011). While noting the potential for misidentifications, there is little evidence that *G. glyphis* interacts with crab pots and anecdotal evidence suggests that sharks are rarely caught as bycatch within the C1 Fishery.

Interactions between C1 fishers and the remaining shark species classified as SOCI are expected to be low to negligible. The fishery does not overlap with the preferred habitus of the grey nurse shark (*Carcharias taurus*), the sandtiger shark (*Odontaspis ferox*) and the white shark (*Carcharodon carcharias*) (Last & Stevens, 2009).

Given the above considerations and without further evidence, it is unlikely that activities in the C1 Fishery with have a significant, long-term (direct) impact on regional shark populations including those that are subject to additional reporting requirements.

Protected teleosts

Interactions between the C1 Fishery and teleosts classified as SOCI are relatively low (Department of Agriculture and Fisheries, 2019b). Of the species classified as SOCI, internal information gathered by DAF indicate that crab fishers are more likely to interact with Queensland groper (*Epinephelus lanceolatus*), which occupy a range of habitats throughout their life-history, including estuaries and inshore waters (pers. com. S. Barry). However, records of Queensland groper caught in the C1 fishery have only recently (2016 and 2017) emerged through the SOCI logbooks. During this two year period, 22 *E. lanceolatus* were reported from commercial crab pots with records indicating all were released alive (Department of Agriculture and Fisheries, 2019b). Their carnivorous diet includes larger crustaceans and it is likely to be a contributing factor with respect to the species being caught within crab pots (Department of Primary Industries, 2006; pers. coms S. Barry). More broadly, anecdotal evidence and fishery observer research suggest that teleost bycatch fare well in crab pots and post release mortality is likely to be low (Sumpton *et al.*, 2003).

Sea snakes

Sea snakes interact infrequently with the C1 Fishery (n = 6, 2002 - 2017) with all but one of the SOCI interactions reported as a live discard (Department of Agriculture and Fisheries, 2019b). While the number of sea snakes that interact with crab pots may be higher, the ability of a sea snake to enter and escape a pot means that a high proportion of interactions are not reported (***contact without capture***). In the unlikely event that an individual cannot escape, mortality rates are expected to be high due to the need for sea snakes to access the surface. These mortalities (and associated risks) are unlikely to have significant or long-term implications for regional sea snake populations. Accordingly, it is recommended that this group is not progressed for further assessment.

Syngnathids

There is little evidence to suggest that syngnathids (seahorses, pipefish and seadragons) interact with the C1 Fishery. No interactions have been reported in the SOCI logbook and there are no reports of

the species turning up in the bycatch of mud and blue swimmer crab fisheries (Ryan *et al.*, 2003; Sumpton *et al.*, 2003). In the event that a syngnathid interacted with a crab fishing apparatus, their small, elongated body structure would allow them to past through the mesh and/or extract themselves with relative ease. The potential for this type of interaction to occur is further reduced by the fact that syngnathids tend to have smaller home ranges and live a relatively sedentary lifestyle.

Due to the low level of risk posed to syngnathids, it is recommended that this group is not progressed for further assessment.

Crocodiles

There have been intermittent reports (*n* = 15) of crocodile interactions in the C1 Fishery since the introduction of the SOCI logbook, with the majority of individuals dying during the fishing event (Department of Agriculture and Fisheries, 2019b). These interactions occur in the crocodile's natural range (central and northern Queensland) and are more likely to occur when operators are targeting mud crabs in riverine, estuarine and inshore waters. While there is limited information on the size of these animals, it is anticipated that mortality rates would be higher in smaller animals with the risk decreasing significantly as the animal increases in size and strength. Outside of the SOCI logbook there is limited information on the extent of interactions between crocodiles and commercial fisheries on the Queensland coast, as crocodiles are not included in the *Wildlife Stranding and Mortality Database*.

There is some potential for crocodile interactions to be underreported in the C1 Fishery; particularly in more remote areas or in instances where an animal has interacted with fishing gear (pots & float lines) without capture. Even so, the risk of these species experiencing an undesirable event due to C1 Fishery activities is considered to be low. This finding is primarily due to a) to the northern Australia distribution of crocodiles and b) the concentration of fishing effort south east Queensland (Read *et al.*, 2004; Department of Agriculture and Fisheries, 2019b).

Seabirds

Recorded SOCI data for the C1 Fishery included two cormorants, and a single darter and pelican caught between 2002 and 2017, suggesting interactions with this subgroup are uncommon (Department of Agriculture and Fisheries, 2019b). This inference is supported by observer research data from the blue swimmer crab fishery (Sumpton *et al.*, 2003) and previous sustainability assessments (Department of the Environment and Water Resources, 2007). Due to the low level of risk posed to sea birds by the C1 Fishery, it is recommended that this group is not progressed for further assessment.

Terrestrial mammals

The false water rat (*Xeromys myoides*) is a small native mammal that is nocturnal and has a semi-aquatic lifestyle. False water rats feed on small crabs and mud lobsters, shellfish, and snails found in coastal mangrove forests, and hunt on mud flats on an outgoing tide (Department of Employment Economic Development and Innovation, 2011). Although an exact species range is not available, the false water rat is likely to inhabit the coasts of central to south-east Queensland, an area of the state where mud crab fishing is concentrated (Department of the Environment and Energy, 2018b). Both Commonwealth and State assessments list this species as vulnerable, contributing to its classification as a SOCI. There are conservation concerns with this species because of habitat loss and degradation, urban development, and predation from feral animals.

The false water rat is listed as a SOCI, but logbooks use the broad term ‘water rats’ and do not specify a particular species to assist commercial fishers. Given this, there is potential for this species to be misidentified with rakali (*Hydromys chrysogaster*); another water rat species that is distributed across Queensland. Unlike *X. myoides*, *H. chrysogaster* it is not listed under Commonwealth or State protection legislation. Given the broad definition used in the SOCI logbooks, there is a degree of ambiguity surrounding the water rat data as it may include *X. myoides*, *H. chrysogaster*, and even terrestrial rats. This in itself could present a problem when assessing the risk level assigned to a particular species.

While noting the above concerns regarding species identifications, SOCI data suggests that interactions between water rats and the crab fishery are low (n = 6 between 2002 and 2017) (Department of Agriculture and Fisheries, 2019b). These interactions are likely to occur when an animal gains access to a crab pot that has been exposed at low tide. The biggest risk being that the animal is unable to escape the trap before the water levels rise during the incoming tide. The biggest risk being that the animal is unable to escape the trap before the water levels rise during the incoming tide. This risk however is expected to be at the lower end of the spectrum when compared with other SOCC subgroups.

Marine Habitats

The majority of effort in the C1 Fishery is targeted at mud crabs in inshore waters, estuaries and mangrove forests. These areas are critically important habitats for a diverse array of marine life, including other economically important species (Laegdsgaard & Johnson, 1995; Department of Environment and Heritage Protection, 2017a). These habitats also experience a high degree of natural disturbance (*e.g.* tidal fluctuations and storm events) and are frequently impacted on by anthropogenic activities (*e.g.* urban development, boat wash). In this context, the direct impacts of the mud crab fishery are expected to be smaller and largely confined to the pot setting and retrieval process. These will include sediment resuspension, damage to marine plants (*e.g*. mangroves) and the addition temporary structures that could alter the way biota use the environment (Laegdsgaard & Johnson, 2001).

The risk profile for the Blue Swimmer Crab Fishery will be similar to the Mud Crab Fishery with respect to the scale, type and intensity of the impacts. As this sector operates in clearer waters, it has the potential to interact with habitats and vegetation that are less abundant in the Mud Crab Fishery *e.g.* seagrass beds. The extent of these impacts will be highly dependent on where the pots are being set but are expected to be localised, relatively short term, and low-risk in nature. Information on small-scale or regional habitat disturbance due to fishing activities though is limited.

Inferences regarding the impact of the C1 Fishery on marine habitats are based on the understanding that the majority of the commercial pots are deployed by boat. However, it is noted that crab fishing apparatus can also be deployed from the shore; particularly within the recreational fishing sector. To deploy and retrieve pots this way, fishers must walk through mangrove forests, across mudflats, seagrass beds, and other low-tide areas, and this can have implications for macrofaunal assemblages and microhabitats. Mangrove pneumatophores, macroalgae and gastropods are known to be negatively affected by trampling activity in the short and long term (Ross, 2006). From an ERA perspective, these impacts are associated more with the recreational fishing sector as land-based deployment of crab fishing apparatus is not viable for commercial fishermen who have larger operations.

When compared to actual fishing, the loss of crab pots (***loss of fishing gear***) arguably presents more of a long-term risk for marine habitats. Sumpton *et. al.*, (2003) estimated that each commercial fisher can lose up to 35 pots per year This study found that the design features (*i.e.* mesh size, entrance size) of apparatus lost in the environment had significant influence on its trapping abilities, and that the thickness and quality of frame rods were the main determinant of how long a pot will last (Sumpton *et al.*, 2003). More recently, Queensland Boating and Fisheries Patrol (QBFP) have been conducting systematic patrols to locate and collect unmarked and derelict crab pots from waterways across the state, and number of ghost pots are expected to have remained high.[9] Pots may last in the environment for up to four years (Sumpton *et al.*, 2003), but the hazard may be shorter lived if sediment were to build up over it (Hill & Garland, 2009).

More broadly, ghost posts introduce non-degradable pollutants into the marine environment such as nylon mesh and ropes, plastic floats, and metal frames, and have the potential to become sediment traps or an environmental hazard. Further, ghost float ropes may exist on the surface, in the water column, or attached to the benthos, and are likely to be a hazard for marine megafauna, which are highly susceptible to entanglement (Gregory, 2009).

Ecosystem Processes

The C1 Fishery is unique in that there are only two target species, both of which are protected by minimum size limits and a no-take policy on females. The protection of females alone will help mitigate against over-harvesting as it maintains the supply of eggs for recruitment processes (Sumpton *et al.*, 2003). Similarly, the minimum size limit (Department of Agriculture and Fisheries, 2019b) for *S. serrata* and *P. armatus* exceed the size ranges for reproductive maturity for both species (Brown, 1993; Robertson & Kruger, 1994; Sumpton *et al.*, 2003), meaning that both reproductive males and females are able to live and reproduce in Queensland waters whilst protected from harvest. In terms of ecological processes, harvesting mud and blue swimmer crabs with these protection measures in place means there is likely to be a low risk to sub-components involving crabs such as predation, nutrient cycling / microbial processes, scavenging, recruitment, competition and connectivity (Appendix 1).

Although there is a significant amount of ***discarding*** of target species in the C1 Fishery, the majority of discarded individuals are released alive and post-release mortality is expected to be low. There is a low risk that ***discarding*** crabs which have sustained injuries or become stressed as a result of capture and release may be susceptible to higher rates of predation, scavenging, and outbreaks of disease (Appendix 1). Information on post-release mortalities is difficult to obtain and the extent of this occurring cannot be quantified.

Of all fishing activities, ***loss of fishing gear*** in the C1 Fishery likely has the highest impact on ecological processes. Loss of crab pots and gear is understood to be quite high in this fishery and ghost posts will have negative implications for both target and non-target species (see section *4.2.2 Ecological components; Target & byproduct*) (Sumpton *et al.*, 2003). More broadly, ghost pots and the associated float lines or ropes may affect natural sedimentation processes by trapping particles and creating a build-up of deposition. They also have the potential to smother primary producers such as

[9] *Example from 29 January 2019 (http://statements.qld.gov.au/Statement/2019/1/29/crab-pots-seized-body-cameras-worn-by-sunshine-coast-fisheries-officers).*

seagrass or mangrove pneumatophores (Appendix 1). These impacts though are likely to be localised and would more than likely present a low range risk.

As ghost pots maintain their ability to trap animals when abandoned (Sumpton *et al.*, 2003), there is further potential for the collective fishery (*i.e.* commercial and recreational) to interfere with the natural predation, scavenging and competition processes. Recruitment could also be affected if reproductive females are becoming trapped and dying inside lost crab gear. It is relatively unlikely that these impacts will lead to an undesirable event and ***loss of fishing gear*** presents a low risk to these ecological components within the C1 Fishery (Appendix 1).

The setting and retrieval of pots may have a minor impact on natural sedimentation processes, resulting from ***disturbance due to presence in the area***. Boat noise is also known to impact natural predation patterns of some fish species (McCormick *et al.*, 2018). Due to the small vessel sizes and minimal pot interaction within the C1 Fishery, disturbance due to presence in the area is likely to present a low risk to these ecosystem sub-components.

Other fisheries largely relates to the recreational fishing sector, because of the significant contribution to the total annual harvest of crabs (see section *4.3.1 Fisheries Related Impacts; Other fisheries*). Having such a significant presence, the recreational sector will have similar impacts to the commercial on ecological subcomponents, generating a low range risk score for sedimentation, primary production, predation, scavenging, recruitment, competition, connectivity and outbreaks of disease.

4.3 Cumulative Impacts

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

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

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

External Risks are addressed in Queensland through a wide variety of forums and by various departments. Given the wide-ranging nature of these risks, these risks will not be addressed directly within Queensland's ERA framework. They have however been included in the Level 1 assessment

as they have the potential to either impact on fishery (*i.e.* pose a risk to the fishery) or are a factor that the fishery contributes to (*i.e.* risks posed by the fishery). When and where appropriate, the Queensland Government will contribute to these discussions including (among others) participating in the *Reef Plan 2050* process, broader management reform initiatives, national plans of action and recovery strategies. In these instances, DAF will continue to participate and represent the fishing interests of the State.

4.3.1 Fisheries Related Impacts

Other Fisheries

The recreational and charter sectors are subject to the same output controls as the commercial sector but are further restricted by tighter gear constraints (four pots per person) and an in-possession limit of ten crabs per person (mud crabs only). As Queensland does not have a recreational fishing licence the majority of information on participation rates, catch rates and species compositions is gathered through voluntary fisher surveys and a fisheries monitoring program. The *2013-14 Statewide Recreational Fishing Survey* estimated that catch of mud crabs is proportionately large and is only exceeded by whiting (Department of Agriculture and Fisheries, 2019a) (***harvesting***). Catch data from this survey also revealed that only 20% of mud crabs and 41% of blue swimmer crabs were retained (with high confidence estimates), suggesting that the sector has a similarly high rate of discards. The high rate of ***discarding*** in the recreational sector mean that damages linked to commercial crab fishing activities (see section *4.2.2 Ecological Subcomponents; Target & Byproduct (harvested)* above) will apply to the recreational sector as well.

The popularity of crab species in the recreational fishing sector is reflected in the quantity of the catch being recorded from the sector. From a risk perspective, the recreational fishing sector makes a substantial contribution to level of fishing mortality experienced by both species and by extension the cumulative pressure exerted on these stocks. These impacts are likely to extend beyond direct fishing pressures with the recreational sector also expected to significantly contribute to the number of ghost pots (***loss of fishing gear***) through poorly marked pots, loss of markers during poor weather or high river flows, and (on occasion) third parties accessing the pots illegally. With new recreational crab pots retailing for less than $20, this issue may be compounded by the fact that lost pots can be replaced relatively cheaply. Risks associated with ghost pots originating from the recreational sector also extend to a number of the SOCC including marine turtles.

A risk that pertains to only blue swimmer crabs is one influenced by the much larger ECTF, which has the potential to interact with significantly more crabs than pot fisheries. Trawl nets are largely indiscriminate, capturing far more small and soft shelled individuals than crab pots and therefore resulting in higher discard rates for this species (Sumpton *et al.*, 2003). More significantly, direct damage from trawl gear and post-release mortality of blue swimmer crabs is greater in trawl fisheries compared to pot fishing activities (Sumpton *et al.*, 2003). Queensland's trawl fisheries currently harvest relatively low numbers of blue swimmer crabs, estimated at 6-12% of the total annual harvest for this species since 2008 (when trawl possession limits were introduced) (Department of Agriculture and Fisheries, 2019a; Fisheries Regulation 2008). High discard and additional mortalities (90% and 7% respectively; Sumpton *et al.*, 2003) within trawl fisheries increase the likelihood that this species would experience an undesirable event if operators were to increase effort and fully utilise their blue swimmer crab possession limits.

Aboriginal peoples and Torres Strait Islander peoples exercising their traditional fishing rights are permitted to harvest female and undersized crabs using recreational gear or traditional methods, provided it is not for commercial purposes (*Native Title Act 1993; Fisheries Act 1994*). Annual harvest of mud and blue swimmer crabs by Aboriginal peoples and Torres Strait Islander peoples is estimated to be low at around 13t(Department of Agriculture and Fisheries, 2019b). This sector is not likely to be a significant factor for the overall risk of the C1 Fishery, but a lack of accurate and up to date information regarding the catch and effort, in addition to relaxed input and output controls for this sector, has the potential to contribute to the risk of overfishing.

Non-compliance remains an ongoing issue for this fishery; particularly with mud crabs. Common offences include possession of no-take crabs (females & undersized), exceeding in possession limits (recreational sector), black market trade (***harvesting***), interference with apparatus, the use of non-compliant gear and keeping inaccurate logbook records (DAF unpublished data). As Queensland is the only jurisdiction with a complete ban on the taking of female crabs, the risk of non-compliance through the translocation of product is a considered to be a significant risk in this fishery (Barry, S. pers. com.).

Although the QBFP aim to patrol the entire Queensland coast, the size of the State creates challenges for monitoring and enforcement activities. This is especially relevant to the GoC, where QBFP facilities and resources are limited. The difficulty with the black marketing of crabs (***harvesting***) is that the activity is not isolated to a particular sector or region. Further, crab fishing is a relatively inexpensive exercise both with respect to capture and retention of crabs.

4.3.2 External Risks

Urban Development & Changes in Land Use

Mud and blue swimmer crabs, among a multitude of other species, are reliant on inshore estuary and mangrove habitats for at least one stage of their life cycles (Clarke *et al.*, 2004; Webley *et al.*, 2009). The impacts of urban development and changes in land use on these types of habitats originate from a diverse range of sources, and vary in their level of effect.

Clearing natural habitats (*i.e.* vegetation removal, dredging *etc.*) to build marine infrastructure (*i.e.* marinas, seawalls, and ports) has the potential modify local and regional biodiversity, cause habitat fragmentation, and modify natural patterns for dispersal species such as mud and blue swimmer crabs (Bulleri & Chapman, 2010). Alteration of natural hydrology can be the result of the construction of artificial systems, and can impact on marine life by changing flow rates, salinity, and sedimentation levels in tidal waters (Ball *et al.*, 2006; Queensland Government, 2016). Examples of this type of development include the construction of dams, flood mitigation gates, culverts, concrete drains and gutters, and infilling of wetlands for urban development (Queensland Government, 2016).

Excavation of land is a problem for catchments and marine habitats because of the extensive presence of acid sulphate soils along the Queensland coastline. Sulphuric acid and heavy metal run-off from disturbed soils are known to have detrimental impacts on plants such as mangrove forests, in addition to mass fish and invertebrate die-offs (Queensland Government, 2016). Anthropogenic pollution such as herbicides, pesticides, and oil, are known to have adverse effects on the physiology of marine organisms and biodiversity of species assemblages (Reylea, 2005; Rhind, 2009; National Oceanic and Atmospheric Administration, 2018).

Other sources of urban development within the state include sand mining, aquaculture infrastructure, energy infrastructure (gas, electricity, water pipelines/dams), and increased recreational activities (Department of Environment Water Heritage and the Arts, 2009). It is difficult to quantify to the impact urban development and changes in land use has on the C1 Fishery as the source and severity will vary between regions.

Marine Debris & Pollutants

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

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

The C1 Fishery is likely to represent a comparatively small, but consistent source of marine pollution. However, these risks are very difficult to quantify and almost impossible to assign to a particular sector or activity, due to the multifaceted sources of this risk. For example, marine pollutants can be sourced from land based runoff and boat emissions, from not only fishers but also recreational boat users and commercial shipping as well. Marine pollutants and emissions present a somewhat unique situation in that they are a risk to the fishery whilst risk is simultaneously increased by fishing activity.

Boat Strike

The effects of vessel use are generally similar regardless of whether they are used for commercial or recreational fishing, or some other form of recreational use. Therefore, despite the direct impacts being relatively low for the C1 Fishery, these impacts, when analysed in context of all vessel activity, may be a higher risk than initially perceived.

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

The greatest risk for humpback whales occurs in offshore areas around major ports and the offshore area between the Whitsundays and Shoalwater Bay (Department of the Environment and Energy, 2017).

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

Climate Change

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

Changes in temperature and oceanic chemistry have been seen to affect physiology, growth and reproduction of fisheries species as well as the primary production that many of these species depend on (Sumaila *et al.*, 2011). This can lead to widespread shifts in fish and ecosystem productivity and stock distributions. There is also evidence of increased ocean acidity. Increased carbon dioxide in the atmosphere decreases the pH of seawater (*i.e.* increased acidity), leading to ocean acidification and dissolution of calcium based reef-building corals, molluscs and crustaceans (Hoegh-Guldberg *et al.*, 2007). Within this context, sustainably managed fisheries will be in a better position to respond to the effects of climate change. Fisheries already under significant stress due to, for example, overfishing, pollutants, and habitat degradation, may not have the resilience to deal with such a largescale threat (Sumaila *et al.*, 2011).

While DAF is currently unable to manage for the effects of climate change, due to the largely unquantifiable nature of largescale climatic effects on the C1 Fishery, these issues are important to consider when identifying risks and future management decisions for the fishery. The Queensland Government will continue to address these issues through a range of forums, and try to align these changes with the objectives of the *Queensland Sustainable Fisheries Strategy 2017-2027*.

4.4 Risk Characterisation

Used as part of the Level 1 assessment, the primary purpose of the *Risk Characterisation* stage is to assign a qualitative value to each fishing activity that represents the potential (low, Intermediate or high) for it to contribute to an undesirable event for each of the ecological components and SOCC subcomponents (Table 4). In doing so, the *Risk Characterisation* stage aims to identify the key sources of risk from each fishery in order to inform finer scale assessments. If, for example, an ecological subcomponent is identified as ‘high risk’ in the Level 2 *Productivity, Susceptibility, Analysis*

(PSA) or a *Sustainability Assessment for Fishing Effects* (SAFE), the results of the Level 1 assessment will identify the activities within the fishery that are contributing to this risk.

The scores assigned to each ecological component (excluding Ecosystem Processes) and SOCC subcomponent are based on the issues raised during the *Risk Identification* process (refer section 4.3). To this extent, they take into consideration the current fishing trends (*e.g.* current catch, effort and licensing), limitations of the current management regime (*e.g.* the ability for effort to be transferred to already saturated markets, substantial increases in fishing mortality for key species, changing target species) and the consequences of the interaction. While the majority of SOCC are classified as bycatch they have been assessed as separate entities in recognition of their complex life histories. Risk scores assigned to ecosystem processes are based on the preliminary assessment (Appendix 1) and represent the maximum score assigned to that particular fishing activity.

As the boundary of the C1 Fishery includes both the Queensland EC and the GoC the risk characterisation table (Table 4) is based at the whole of fishery level. As the dynamics of the C1 Fishery on the Queensland EC and the GoC are vastly different, this complicates the situation surrounding the preliminary risk assessments. For example, preliminary risk ratings based at a whole of fishery level will mask inter-regional differences including the likelihood that fishing activities in the GoC will present a lower risk for a number of the ecological components. To account for this variance, two regional *Risk Characterisation* tables have been provided in Appendix 2. These provide a more detailed view on the risks posed by the fishery in each region and the likelihood that one or more of the fishing activities will contribute to an undesirable event under the current management framework.

Similarly, target species in the C1 Fishery have different profiles including the areas of operation. These differences were accounted for in the *Risk Identification* stage where the majority of risk attributed to the mud crab fishery. It is important to note though that the risk ratings assigned in Table 4 take into consideration a range of factors including the ability of operators to target one or both species, mechanisms to control catch or effort and ancillary factors such as the appeal of the species to other sectors. In the case of blue swimmer crabs, the risk ratings contained in Table 4 could be considered precautionary in nature. In the event that the species is classified as high-risk in subsequent (Level 2) assessments, this Level 1 assessment will provide insight into the mechanisms or activities contributing to this risk.

Outputs of the *Risk Categorisation* stage, excluding *cumulative impacts*, were used to assign each ecological component with a preliminary risk rating based on the highest risk score in the profile (Table 4). If for example an ecological component received a ‘high risk’ for one or more of the fishing activities, it would be reflected in the preliminary risk ratings (Appendix 3). These preliminary risk ratings are conservative in nature and provide the first opportunity to remove low risk elements from the assessment process. Scores assigned to the cumulative risks were not considered as the preliminary risk scores are only applicable to the commercial fishery. The cumulative impacts scores though provide insight into the potential for ancillary risks to impact each of the respective ecological components.

***Table 4**. Summary of risk scores for the C1 Fishery for the whole of fishery, including the impact of the main fishing activities on key ecological components.*

Ecological Component	Crab potting–Risk Profiles							Preliminary Risk Rating	Cumulative fishing impacts
	Harvesting	Discarding	Contact without capture	Loss of fishing gear*	Travel to/from grounds	Disturbance due to presence in area	Boat maintenance & emissions		
Target & Byproduct	H	I	L	I/H	L	L	L	H	I/H
Bycatch (Non-SOCC)	-	L/I	L	I	L	L	L	I	L
SOCC									
Marine turtles	-	H	I	H	L	L	L	H	H
Sea snakes	-	L	L	L	L	L	L	L	L
Crocodiles	-	L	L	L	L	L	L	L	L
Dugongs	-	L	L	L	L	L	L	L	L
Cetaceans	-	L	L	L	L	L	L	L	L
Protected teleosts	-	L	L	L	L	L	L	L	L
Batoids	-	L/I	L/I	I	L	L	L	I	I
Sharks	-	L/I	L	L/I	L	L	L	L/I	L
Syngnathids	-	-	-	-	-	-	-	-	-
Sea birds	-	L	L	L	L	L	L	L	L
Ter. mammals	-	L	L	L	L	L	L	L	L
Marine Habitats	-	-	-	I/H	L	L	L	I/H	I/H
Ecosystem Processes	L	L	-	L/I	L	L	-	L/I	L

** Gear may be recreational*

In line with above approach, preliminary assessments for the C1 Fishery indicated that fishing activities presented a negligible or low risk to at least 10 of the ecological components or subcomponents (sea snakes, crocodiles, dugongs, cetaceans, batoids excl. sawfish, protected teleosts, syngnathids, seabirds, terrestrial mammals and ecosystem processes). Sharks had a preliminary risk rating of low-intermediate with bycatch (non-SOCC) and sawfish assessed as being at an intermediate risk. Only three of the ecological components had preliminary risk assessments greater than intermediate–Target & Byproduct (high), marine turtles (high) and marine habitats (intermediate/high) (Appendix 3).

A full account of the preliminary risk ratings, key considerations and risk factors have been provided in Appendix 3. However, the following provides a general overview of the key findings of the *Risk Characterisation* stage:

- Target and byproduct species received higher risk ratings due to a) the absence of an overarching control on catch or effort, b) the potential for licences and effort to be readily transferred across the state and c) the cumulative fishing pressures.
- Loss of fishing gear was considered to be a significant risk for a number of the ecological components including marine habitats.
- Marine turtles were determined to be the SOCC subgroup most at risk of from crab fishing activities across a number of the fishing sectors.

4.5 Likelihood

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

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

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

When mitigation measures and risk likelihood are given further consideration in the C1 Fishery, the risk ratings of two ecological components were reduced. The most notable of these were the downgrading of the risk rating for target & byproduct (high to intermediate/high) and seabirds (low to negligible) (Appendix 3). The downgrading of target & byproduct was due to the longstanding

prohibition of the take of female and undersized male crabs, which theoretically protects at least half of the population from harvesting. As the retention of females is not permitted in the fishery and males are subject to a minimum legal size limit, this amended risk rating may still represent an overestimate. The ability of this risk rating to be reduced further though was limited by the absence of an overarching control on catch or effort, an absence of information on finer scale fishing pressures, the potential for the species to be overfished at a regional level *i.e.* in south east Queensland and the extent of information on recreational fishing pressures.

Of the remaining ecological components, the only other amendment was made to the preliminary risk rating for seabirds. In this instance, the risk rating was downgraded from low to negligible to reflect the limited capacity with which the subgroup is able to interact with the fishery.

A summary of the key findings of the Level 1 ERA have been provided in Table 5. Additional information on the Level 1 risk ratings including key considerations of both the preliminary risks and mitigation measures has been provided in Appendix 3.

***Table 5**. Level 1 risk ratings for the ecological components and subcomponents interacting with the Mud and Blue Swimmer Crab (C1) Fishery taking into consideration the likelihood of the risk coming to fruition in the short to medium term.*

Ecological Component	Level 1 Risk Rating	Considerations/Justifications	Level 2 Required?
Target & Byproduct	Intermediate/High	• Fishery does not currently have an effective control of catch and effort at a whole of fishery, regional or species level. • Although the mud crab and blue swimmer crab fisheries have been classed as sustainable, there is evidence from industry that under current effort levels the fishery is not economically viable *e.g.* the fishery is being fished at MSY *vs.* MEY. • There is also evidence there has been effort shift from the inshore net fisheries into C1 given the increase in the value of mud crab (operators are permitted to fish simultaneously on the C1 and an N or L fishery symbol). • The two main species in the C1 Fishery are mud crab and blue swimmer crab. There is evidence that as commercial fishers stop fishing for mud crab they shift to blue swimmer crab, particularly in Moreton Bay. • There is evidence that byproduct species are encountered whilst fishing for the target species (either mud crab or blue swimmer	Yes

Ecological Component	Level 1 Risk Rating	Considerations/Justifications	Level 2 Required?
		crab) and commercial fishers with a C1 are able to retain both species. • There is strong evidence that suggests black marketing of mud crab is a major issue in the mud crab fishery. Mud crab is a priority black market species for management intervention in Queensland. • Given the social significance of the target two species, the cumulative impacts (*e.g.* recreational based fishing mortality) would be substantial for this subgroup. • The fishery has in place a number of long-term and well established risk mitigation measures including a prohibition on the take of female crabs and a minimum legal size limit for males. • These measures (*exc.* risks associated with illegal fishing) afford protection to (theoretically) at least half of the standing population and contributed to the subgroup receiving a lower risk rating. • Additional measures addressing these risks are being considered by the crab working group but have not (to date) been implemented.	
Bycatch (non-SOCC)	Intermediate	• Crab pots will catch non SOCC bycatch species such as common fish species. Retention of all species other than crab species is prohibited. • However, there is little information on bycatch in the C1 Fishery and it is an issue that may require additional monitoring or attention. • From an operational perspective, the more an apparatus is worked the less impact to bycatch species *e.g.* the bycatch species can be returned to the water alive before being predated upon by crabs.	No

Ecological Component	Level 1 Risk Rating	Considerations/Justifications	Level 2 Required?
		• The biggest issue regarding interactions with bycatch species is from lost pots and ghost pots that continue to fish (self-bait). This impact is very difficult to quantify as this catch cannot be monitored. • The impact of the C1 Fishery on the bycatch ecological component may be an avenue requiring further exploration to determine interaction rates, quantities and species compositions. • Bycatch mitigation measures are being considered by the crab working group but are yet to be implemented. • Cumulative risks including the impact of recreational fishers and ghost pots will be a broader risk factor for this subgroup.	
Species of Conservation Concern (SOCC)			
Turtles	High	• Risk is relevant to this fishery as marine turtles can become entangled with crab pot float lines and in the entrances of certain crab pots. • Risk is not limited or restricted to the commercial fishery with recreational fishing and ghost pots viewed as significant contributors of risk. • Limited capacity to validate interaction rates and/or the extent of (potential) underreporting. • Total number of interactions (commercial and recreational) and total mortality (in-situ, post-release) is potentially higher than what is recorded. • Risk will not be equal across the C1 Fishery and may be more applicable to areas where turtle populations are higher *e.g.* south east Queensland including Moreton Bay.	Yes

Ecological Component	Level 1 Risk Rating	Considerations/Justifications	Level 2 Required?
		• No real mechanisms in place to obtain information or quantify pot loss rates in either the commercial or recreational fishing sectors,	
Sea snakes	Low	• Low interaction rates and subgroup expected to have high post release survival rates.	No
Crocodiles	Low	• Interactions do occur in this fishery but with reduced frequency • Some fishers in the gulf use PVC bait tubes and this significantly reduces interactions with crocodiles. • Limited spatial overlap between higher effort fishing grounds (SEQ) and preferred habitats (possibly in FNQ).	No
Dugongs	Low	• Interactions with this fishery are unlikely, and if applicable will be infrequent and very low numbers. • Entanglement (*e.g.* in float lines) more likely than entrapment. • Limited spatial overlap between key fishing grounds and preferred habitats. • Indirect impacts (contact without capture, loss of fishing gear, boat strike) considered to be a higher risk than direct impacts (capture, discarding).	No
Cetaceans	Low	• Interactions with this fishery are unlikely, and if applicable will be infrequent and very low numbers. • Interactions with this fishery will be more likely in the Blue Swimmer Crab Fishery. • Entanglement (*e.g.* in float lines) more likely than entrapment. • Limited spatial overlap between key fishing grounds and preferred habitats. • Indirect impacts (contact without capture, loss of fishing gear, boat strike) considered to be a	No

Ecological Component	Level 1 Risk Rating	Considerations/Justifications	Level 2 Required?
		higher risk than direct impacts (capture, discarding).	
Teleosts (protected/SOCI only)	Low	• Low interactions and subgroup is expected to survive interactions with active fishing pots *i.e.* those being checked. • Cumulative risks including the impact of recreational fishers and ghost pots will be a broader risk factor for this subgroup.	No
Batoids	Batoids (exc. sawfish) - Low	• There is evidence that crab pots interact with batoid species, albeit low. If handled correctly, post-release survival rates for this subgroup expected to be high. • Risk is considered to be higher for sawfish due to their contracted range, the potential for these species to interact with the Mud Crab Fishery across their range and the increased risk of entanglement and injury.	No
	Sawfish - Intermediate	• The impact of the C1 Fishery on the bycatch ecological component may be an avenue requiring further exploration to determine interaction rates, quantities and species compositions. • Cumulative risks including the impact of recreational fishers and ghost pots will be a broader risk factor for this subgroup.	No
Sharks	Low/Intermediate	• There is evidence that shark species can interact with crab pots and get trapped (partially or wholly) within the apparatus. • Risk to most species considered to be low. Risk overall is elevated due to the potential for the fishery to interact with river sharks (*Glyphis* spp.) across there range. • Total number of interactions may be masked due to misidentifications and an absence of information on bycatch from the recreational fishing sector.	No

Ecological Component	Level 1 Risk Rating	Considerations/Justifications	Level 2 Required?
Syngnathids	Negligible	• N/A as interaction rates (if applicable) are unlikely to have long term implications for regional populations.	No
Seabirds	Negligible/Low	• Low number of interactions and fishery is unlikely to have long term implications for regional populations.	No
Terrestrial Mammal	*Low*	• Some potential for species to interact with this subgroup; particularly if set above the low water mark. • Majority of interactions are expected to be with more common species with false water rat (*Xeromys myoides*) interacting infrequently with the fishery. • Degree of uncertainty regarding final risk rating due to increased potential for misidentifications to occur *i.e.* may be negligible or higher. • Clarification required on what species are interacting with the C1 Fishery and their conservation status.	No
Marine Habitats	Intermediate/High	• There is evidence that he act of potting has direct impact to the marine ecosystem *e.g.* interaction with seagrass in shallow environments and damage to mangroves setting and retrieving pots. • Regional impacts of ghost pots evident in clean up patrols undertaken by QBFP. • Impacts are likely to be regionalised and more prominent in areas where ghost pots are more likely to accumulate. • Risks difficult to assess at a whole of fishery level and extent of risk assessments limited by data deficiencies.	

Ecological Component	Level 1 Risk Rating	Considerations/Justifications	Level 2 Required?
Ecosystem processes**	Low	• Unknown but expected to be low given the species being targeted and the nature of the fishing apparatus.	

4.6 Issues Arising

Increased Effort on Underutilised Licences

This issue extends from the lack of finer spatial management arrangements and the need to balance fisher flexibility and their access to the resource. In the C1 Fishery, this is considered to be a notable issue as fishers can transfer a C1 Fishery symbol from low effort areas like the GoC or far north Queensland to (*e.g.*) south east Queensland which already has a well-established fishery or vice versa. This has the potential to become a concern because of a) the absence of an effective control of catch or effort, b) the ability of operators to switch between species and c) the absence of a stock assessment for the primary target species (mud crabs). This issue will be most applicable to the target and byproduct species ecological component which will be progressed to a Level 2 assessment.

Transfer of Effort

While the fishery as a whole may not experience a significant increase in effort, there is considerable potential for effort to increase at a regional level and for individual species. This is largely due to the absence of regional management arrangements and an effective control of catch and effort. In the C1 Fishery, this risk will be of particular relevance to areas that already experience higher levels of effort. In this context, the transfer of licences (and effort) has the potential to increase fishing mortality rates and by extension the potential for an undesirable event to occur. The extent of licence and effort transfer in this fishery though remains largely unknown.

Of significance there are a number of initiatives being undertaken as part of the *Queensland Sustainable Fisheries Strategy 2017–2027* that will assist in the monitoring and mitigation of this risk. The most notable of these is the expansion of the current Vessel Monitoring System (VMS)to include all commercial fishing boats by the end of 2020 (Department of Agriculture and Fisheries, 2018c). This system will help to improve the accuracy and validity of spatial data for the Level 2 assessments, and help to quantify the level of risk associated with the movement of effort within a fishery. It will however take time to both implement this policy and obtain the level of data needed to inform the ERA process. In the interim, future ERAs will benefit from a) a more immediate evaluation of shifting catch compositions and effort patterns through time and b) the reasons behind any shifts including increased marketability, licence transfers and increased regulations.

Loss of Gear

Previous research indicates that loss of gear in this fishery is a significant issue (Sumpton *et al.*, 2003). A considerable amount of time has passed since a survey of commercial pot loss in the Blue Swimmer Crab Fishery was carried out in south east Queensland (Sumpton *et al.*, 2003), but current information on the loss of pots is limited, especially within the commercial mud crab fishery and

recreational sector. Level 2 assessments would strongly benefit from updated information, as it is likely to be a prominent factor of risk within the C1 Fishery.

From an ERA perspective, this is an issue that has the potential to impact on a range of ecological components including target & byproduct species, bycatch and key SOCC subgroups *i.e.* marine turtles.

Use of Bycatch Reduction Devices

Bycatch reduction devices (BRD) for crab pots are available and have shown to improve gear selectivity in mud crab fisheries (Grubert & Lee, 2013) and reduce bycatch within other crab fisheries (Roosenburg & Green, 2000; Department of Agriculture and Fisheries, 2019b). Limited information exists about the effectiveness of BRDs that are available for crab pots, and the extent of their use in the C1 Fishery or the recreational sector, but research into this area and subsequent management reforms regarding the use of escape vents or excluder devices has the potential to refine Level 2 assessments; namely for the marine turtle subgroup (Table 5).

Under-reporting of SOCI Interactions

Species of Conservation Interest or SOCI is a group of species that are afforded additional protections in Queensland waters. Often no-take species, this group includes marine turtles, whales, dolphins, crocodiles, seabirds, sawfish plus a small number of sharks, rays, teleosts and syngnathids. This group formed the basis of the broader *Species of Conservation Concern* (SOCC) ecological component that was assessed as part of this Level 1 ERA. In Queensland, all commercial operators are required to report interactions with these species in a dedicated SOCI logbook.

While difficult to quantify, the number of SOCI interactions are likely to be underreported in this fishery. At the very least, information contained in the *Marine Wildlife Stranding and Mortality Database* suggests that interaction rates are higher than what is reported in the SOCI logbooks. This differential may be due to the prevalence of ghost posts and or mortalities resulting from non-commercial sectors of the fishery. Despite this ambiguity, the *Marine Wildlife Stranding and Mortality Database* does report interactions with commercial crab fishing apparatus that were not reported in the SOCI logbooks; several examples exist for the Spanner Crab Fishery, but it is equally plausible that similar cases occur within the C1 Fishery,

Interactions with SOCC feature heavily in discussions surrounding the broader sustainability of a fishery. The relevance of these interactions are also reflected in third party assessments including approvals issued under the *Environment Protection and Biodiversity Conservation Act 1999*. This focus means that the commercial fishing sector already has the mechanisms in place to improve the level of information on SOCI interactions. In terms of the conditions imposed on the EPBC approvals and third-party assessments of the fishery's sustainability, there is arguably a greater impetus for this sector of the fishery to improve the quality of the SOCI logbook data. The potential for the recreational sector to interact with SOCI and contribute to ghost pots though highlights the need to collect further information from this sector.

Obtaining accurate information on SOCC (*i.e.* SOCI plus batoids and sharks) interactions will assist in the refinement of risk profiles for key species including batoids, sawfish and marine turtles. For marine turtles, this information will also help to improve the accuracy of the Level 2 (species-specific) ERAs where attributes with limited data are assigned more conservative risk scores.

SOCI Identifications

There is a small possibility that fishers could misidentify SOCI species in the field or misinterpret the SOCI logbook (only a common name is provided in logbooks) and consequently inaccurately record or not record interactions. This is most applicable to what is listed as the *false water rat* in SOCI logbooks (*Xeromys myoides*), which could be confused with other species of rat, or rakali (*Hydromys chrysogaster*). As the conservation status of rat species varies widely, further clarification is required as to which terrestrial species actually interact with this fishery and the extent of these interactions.

Non-Commercial Fishing Data

The historical data for the Queensland recreational fishing sector is poor with state wide surveys only commencing in 1997. This lack of historical catch, effort and distribution data contributes to significant difficulties in managing risk within the fishery, particularly as fishing effort is not directly regulated in the recreational sector. However, management measures do include in possession limits, gear restrictions, size limits and spatial closures.

The majority of information on the recreational take of mud and blue swimmer crabs is obtained through voluntary localised monitoring programs (*e.g.* the boat ramp survey program) and more expansive voluntary recreational fisher surveys (Department of Agriculture and Fisheries, 2015). Recreational harvest estimates are derived from the state wide recreational fishing surveys and are generally only useful at the stock level for common target species. The main reasons for this are that the surveys do not produce useable estimates for rare or infrequently caught species and a lack of sampling power can result in the data having poor species resolution. For example, recreational data for mud and blue swimmer crabs is reported as part of a broader catch category titled ‘crabs’ (Department of Agriculture and Fisheries, 2015). Given these factors, the extent of fishing mortality resulting from the recreational fishing requires further investigation. This is considered to be of particular relevance to south east Queensland where there is a higher concentration of commercial effort.

Catch harvested by Aboriginal peoples and Torres Strait Islander peoples remains the least understood component of the collective crab fishery. This sector is likely to have lower levels of catch and effort; although the dynamics of the fishery are poorly understood. At a whole of fishery level, this fishing sector is unlikely to make a significant contribution to overall risk levels. This sector may have more of a role to play with respect to regional fishing pressures. Accordingly, further information on the distribution and extent of this fishery would be useful for future ecological risk assessments.

Non-compliance

Non-compliance and the black marketing of product (particularly mud crabs) is an issue in this fishery and continues to remain a risk. This risk continues to be managed through the QBFP and in 2018 the Queensland Government proposed legislative amendments to further strengthen laws aimed at sea food black marketing. This is being done as part of the *Queensland Sustainable Fisheries Strategy 2017–2027*.

5 Summary & Recommendations

When the outcomes of the preliminary risk assessment and the secondary evaluation of likelihood (Table 5. Appendix 3) are taken into consideration, only three of the ecological components were assigned a risk rating above intermediate–target & byproduct, marine turtles and marine habitats

(Table 5). Of these three, target & byproduct (intermediate/high risk) and marine turtles (high risk) will be progressed to a Level 2 ERA. While the marine habitats ecological component was assigned an intermediate/high risk rating, this ecological component was not progressed to a Level 2 ERA due to a) the influence of ghost pots on the final risk rating, b) the regional nature of these impacts and c) an inability to define the extent of the fishing-related impacts across the entire C1 Fishery.

Outside of these ecological components, the Level 1 ERA identified a number of information gaps which a) contributed to the level of uncertainty and b) produced more conservative/precautionary risk evaluations. To address these issues and help refine a number of the risk profiles, the following avenues should be progressed to the *Fisheries Queensland Monitoring and Research Plan* (Department of Agriculture and Fisheries, 2018b). Specifically:

1. Improving the level of understanding on compositions and release fates of non-target species in the commercial mud and blue swimmer crab fishery (bycatch, batoids–sawfish);

2. Further assessment of regional catch and effort levels in the recreational fishing sector; particularly in south east Queensland where commercial fishing is more prevalent;

3. Increases the level of information on the prevalence and impact of ghost pots *e.g.* quantifying pot-loss rates in the commercial and recreational fishing sectors, evaluating their fishing potential and longevity/degradation rates (most ecological components including bycatch, batoids and marine habitats); and

4. Validating species compositions and interaction rates (including release fates) for *threatened, endangered and protected* (TEP) species in both the recreational and commercial fishing sectors.

6 References

Arias-Ortiz, A., Serrano, O., Masqué, P., Lavery, P. S., Mueller, U., Kendrick, G. A., Rozaimi, M., Esteban, A., Fourqurean, J. W., Marbà, N., Mateo, M. A., Murray, K., Rule, M. J. & Duarte, C. M. (2018). A marine heatwave drives massive losses from the world's largest seagrass carbon stocks. *Nature climate change*.

Astles, K. L., Gibbs, P. J., Steffe, A. S. & Green, M. (2009). A qualitative risk-based assessment of impacts on marine habitats and harvested species for a data deficient wild capture fishery. *Biological Conservation* **142**, 2759-2773.

Astles, K. L., Holloway, M. G., Steffe, A., Green, M., Ganassin, C. & Gibbs, P. J. (2006). An ecological method for qualitative risk assessment and its use in the management of fisheries in New South Wales, Australia. *Fisheries Research* **82**, 290-303.

Ball, D., Wake, J. & McKillup, S. (2006). *Point discharge of storm water runoff into a landward mangrove community: initial investigations indicate a negative effect on keystone species (mangrove crabs, Family: Grapsidae)*. Wellington, New Zealand.

Bergmann, M., Gutow, L. & Klages, M. (2015). *Marine anthropogenic litter*: Springer.

Brown, I. W. (1993). Mangrove Crabs. In *Nearshore Marine Resources of the South Pacific* (Wright, A. & Hill, L., eds.), p. 710. Suva: Institute of Pacific Studies.

Bulleri, F. & Chapman, M. G. (2010). The introduction of coastal infrastructure as a driver of change in marine environments. *Journal of Applied Ecology* **47**, 26-35.

Burgin, S. & Hardiman, N. (2011). The direct physical, chemical and biotic impacts on Australian coastal waters due to recreational boating. *Biodiversity and Conservation* **20**, 683-701.

Butcher, P. A., Leland, J. C., Broadhurst, M. K., Paterson, B. D. & Mayer, D. G. (2012). Giant mud crab (Scylla serrata): relative efficiencies of common baited traps and impacts on discards. *ICES Journal of Marine Science* **69**, 1511–1522.

Byrnes, T., Buckley, R., Howes, M. & Arthur, J. M. (2016). Environmental management of boating related impacts by commercial fishing, sailing and diving tour boat operators in Australia. *Journal of Cleaner Production* **111**, 383-398.

Clarke, K., Ryan, S., Gaddes, S., Doohan, M., Bullock, C., Williams, L., Frost, N., Higgs, J., Dunning, M. & Sumpton, W. (2004). *Ecological Assessment of the Queensland Blue Swimmer Crab Pot Fishery*. Department of Primary Industries and Fisheries, Queensland Government. Brisbane, Queensland.

D'Anastasi, B., Simpfendorfer, C. & van Herwerden, L. (2013). *Anoxypristis cuspidata*. Available at http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T39389A18620409.en (Accessed 11 May 2018)

Department of Agriculture and Fisheries (2015). Statewide Recreational Fishing Survey 2013-14. *Queensland Government*. Available at https://www.daf.qld.gov.au/business-priorities/fisheries/monitoring-compliance/monitoring-reporting/recreational-fishing/statewide-recreational-fishing-surveys (Accessed 11 April 2019)

Department of Agriculture and Fisheries (2017). Queensland Sustainable Fisheries Strategy 2017 - 2027. Available at https://www.daf.qld.gov.au/business-priorities/fisheries/sustainable/sustainable-fisheries-strategy (Accessed 11 April 2019)

Department of Agriculture and Fisheries (2018a). Ecological Risk Assessment Guidelines. Available at https://www.daf.qld.gov.au/business-priorities/fisheries/sustainable/sustainable-fisheries-strategy (Accessed 11 April 2019)

Department of Agriculture and Fisheries (2018b). Queensland Sustainable Fisheries Strategy: Fisheries Queensland Monitoring and Research Plan. Available at https://www.daf.qld.gov.au/business-priorities/fisheries/sustainable/sustainable-fisheries-strategy (Accessed 11 April 2019)

Department of Agriculture and Fisheries (2018c). Sustainable Fisheries Strategy: Vessel Tracking. Available at https://www.daf.qld.gov.au/business-priorities/fisheries/sustainable-fisheries-strategy/vessel-tracking (Accessed 7 June 2018)

Department of Agriculture and Fisheries (2019a). QFish. Available at http://qfish.fisheries.qld.gov.au/ (Accessed 7 May 2019)

Department of Agriculture and Fisheries (2019b). *Scoping Study - Mud & Blue Swimmer Crab (C1) Fishery*. Department of Agriculture and Fisheries, Queensland Government. Brisbane, Australia.

Department of Employment Economic Development and Innovation (2011). *Looking after protected species in Queensland; A comprehensive guide for commercial fishers*. State of Queensland,. Department of Employment, Economic Development and Innovation, Queensland Government. Brisbane, Australia.

Department of Environment and Heritage Protection (2017a). Estuarine and marine ecosystems. *State of Queensland*. Available at https://www.ehp.qld.gov.au/state-of-the-environment/subtheme/?id=estuarine-marine-ecosystems (Accessed 5 March 2018)

Department of Environment and Heritage Protection (2017b). Marine wildlife strandings annual reports. *State of Queensland*. Available at https://www.ehp.qld.gov.au/wildlife/caring-for-wildlife/strandnet-reports.html (Accessed 8 May 2018)

Department of Environment Water Heritage and the Arts (2009). Significant impact guidelines for the vulnerable water mouse (*Xeromys myoides*) Nationally threatened species and ecological communities Background paper to EPBC Act policy statement 3.20. *Australian Government, Department of Environment, Water, Heritage and the Arts*. Available at https://www.environment.gov.au/system/files/resources/e7abd03f-e5fc-4e42-b971-995e2d4841ac/files/xeromys-myoides-background.pdf (Accessed 20 March 2018)

Department of National Parks Sports and Racing (2010). *Boat strike impact on turtle and dugong in Moreton Bay*. Department of National Parks Sports and Racing, Queensland Government. Brisbane, Queensland. https://www.npsr.qld.gov.au/parks/moreton-bay/boat-strikes/

Department of Primary Industries (2006). Giant Queensland grouper, Epinephelus lanceolatus. *New South Wales Government*. Available at https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/636275/Giant-Queensland-groper-Primefact-169-final.pdf (Accessed 8 May 2018)

Department of the Environment and Energy (2017). *National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna*. Department of the Environment and Energy, Australian Government. Canberra, ACT.

Department of the Environment and Energy (2018a). *Dugong dugon* in Species Profile and Threats Database. Department of the Environment and Energy, Australian Government. Available at http://www.environment.gov.au/sprat (Accessed 19 June 2018)

Department of the Environment and Energy (2018b). *Xeromys myoides* — Water Mouse, False Water Rat, Yirrkoo. *Australian Government*. Available at http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=66 (Accessed 28 May 2018)

Department of the Environment and Water Resources (2007). Assessment of the Queensland Blue Swimmer Crab Pot Fishery. *State of Queensland*. Available at http://www.environment.gov.au/system/files/pages/14653b5c-0fd7-4398-b594-a39d48ee0dfd/files/report07.pdf (Accessed 9 May 2018)

Duke, N. C., Kovacs, J. M., Griffiths, A. D., Preece, L., Hill, D. J. E., van Oosterzee, P., Mackenzie, J., Morning, H. S. & Burrows, D. (2017). Large-scale dieback of mangroves in Australia's Gulf of Carpentaria: a severe ecosystem response, coincidental with an unusually extreme weather event. *Marine and Freshwater Research* **68**, 1816-1829.

Evans, K., Bax, N. J. & Smith, D. C. (2016). *Australia State of the Environment 2016: marine environment*. Department of the Environment and Energy, Australian Government. Canberra, ACT.

Great Barrier Reef Marine Park Authority (2014). *Great Barrier Reef Outlook Report 2014*. Great Barrier Reef Marine Park Authority, Australian Government. Townsville, Queensland.

Greenland, J. A. & Limpus, C. J. (2006). *Marine wildlife stranding and mortality database annual report 1. Dugong*. State of Queensland, Environmental Protection Agency.

Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society B: Biological Sciences* **364**, 2013-2025.

Grubert, M. A., Johnson, D., Johnston, D. & Helmke, S. (2018). Status of Australian Fish Stocks: Mud Crabs (2018). *Fisheries Research and Development Cooperation*. Available at http://fish.gov.au/report/155-MUD-CRABS-2018 (Accessed 7 March 2019)

Grubert, M. A. & Lee, H. S. (2013). *Improving gear selectivity in Australian mud crab fisheries*. Northern Territory Government, Department of Primary Industries and Fisheries.

Hill, F. & Garland, A. (2009). *Ecological Risk Assessment of Queensland's Blue Swimmer, Spanner and Mud Crab Fisheries*. Department of Primary Industries, Queensland Government. Brisbane, Queensland.

Hobday, A. J., Smith, A. D. M., Stobutzki, I. C., Bulman, C., Daley, R., Dambacher, J. M., Deng, R. A., Dowdney, J., Fuller, M., Furlani, D., Griffiths, S. P., Johnson, D., Kenyon, R., Knuckey, I. A., Ling, S. D., Pitcher, R., Sainsbury, K. J., Sporcic, M., Smith, T., Turnbull, C., Walker, T. I., Wayte, S. E., Webb, H., Williams, A., Wise, B. S. & Zhou, S. (2011). Ecological risk assessment for the effects of fishing. *Fisheries Research* **108**, 372-384.

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell, C. D., Sale, P. F., Edwards, A. J., Caldeira, K., Knowlton, N., Eakin, C. M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R. H., Dubi, A. & Hatziolos, M. E. (2007). Coral Reefs Under Rapid Climate Change and Ocean Acidification. *Science* **318**, 1737-1742.

Holbrook, N. J. & Johnson, J. E. (2014). Climate change impacts and adaptation of commercial marine fisheries in Australia: a review of the science. *Climatic Change* **124**, 703-715.

Jacobsen, I., Zeller, B., Dunning, M., Garland, A., Courtney, T. & Jebreen, E. (2018). *An Ecological Risk Assessment of the Southern Queensland East Coast Otter Trawl Fishery and the River & Inshore Beam Trawl Fishery*. Department of Agriculture and Fisheries, Queensland Government. Brisbane, Queensland.

Jirapunpipat, K., Phomikong, P., Yokota, M. & Watanabe, S. (2008). The effect of escape vents in collapsible pots on catch and size of the mud crab *Scylla olivacea*. *Fisheries Research* **94**, 73-78.

Johnson, A. E. (2010). Reducing bycatch in coral reef trap fisheries: escape gaps as a step towards sustainability. *Marine Ecology Progress Series* **415**, 201-209.

Johnston, D., Chandrapaven, A., Garland, A., Beckmann, C. & Johnson, D. (2018). Status of Australian Fish Stocks: Blue Swimmer Crab (2018). Available at http://fish.gov.au/report/179-Blue-Swimmer-Crab-2018 (Accessed 7 March 2019)

Kyne, P. M., Carlson, J. & Smith, K. (2013). *Pristis pristis*. The IUCN Red List of Threatened Species 2013. Available at https://www.iucnredlist.org/species/18584848/18620395 (Accessed 11 December 2018)

Laegdsgaard, P. & Johnson, C. (2001). Why do juvenile fish utilise mangrove habitats? *Journal of Experimental Marine Biology and Ecology* **257**, 229-253.

Laegdsgaard, P. & Johnson, C. R. (1995). Mangrove habitats as nurseries: unique assemblages of juvenile fish in subtropical mangroves in eastern Australia. *Marine Ecology Progress Series*, 67-81.

Last, P. R. & Stevens, J. D. (2009). Sharks and rays of Australia. 645.

Lyon, B., Dwyer, R., Pillans, R., Campbell, H. & Franklin, C. (2017). Distribution, seasonal movements and habitat utilisation of an endangered shark, *Glyphis glyphis*, from northern Australia. *Marine Ecology Progress Series* **573**, 203-213.

McCormick, M. I., Allan, B. J. M., Harding, H. & Simpson, S. D. (2018). Boat noise impacts risk assessment in a coral reef fish but effects depend on engine type. *Scientific Reports* **8**, 3847.

Meager, J. J. (2016a). *Marine wildlife stranding and mortality database annual report 2013-2015. Cetacean and Pinniped*. Conservation Technical and Data Report. Department of Environment and Heritage Protection, Queensland Government. Brisbane.

Meager, J. J. (2016b). *Marine wildlife stranding and mortality database annual report 2013-2015. Dugong*. Conservation Technical and Data Report 2016. Department of Environment and Heritage Protection, Queensland Government. Brisbane.

Meager, J. J. & Limpus, C. J. (2012). *Marine wildlife stranding and mortality database annual report 2011. III. Marine Turtle*. Conservation Technical and Data Report 2012. Department of Environment and Heritage Protection, Queensland Government. Brisbane.

National Oceanic and Atmospheric Administration (2018). How does oil impact marine life? *National Ocean Service, U.S. Department of Commerce*. Available at https://oceanservice.noaa.gov/facts/oilimpacts.html (Accessed 13 Nov 2018)

Pears, R. J., Morison, A. K., Jebreen, E. J., Dunning, M. C., Pitcher, C. R., Courtney, A. J., Houlden, B. & Jacobsen, I. P. (2012). Ecological Risk Assessment of the East Coast Otter Trawl Fishery in the Great Barrier Reef Marine Park: Technical Report.

Pillans, S., Pillans, R. D., Johnstone, R. W., Kraft, P. G., Haywood, M. D. E. & Possingham, H. P. (2005). Effects of marine reserve protection on the mud crab *Scylla serrata* in a sex-biased fishery in subtropical Australia. *Marine Ecology Progress Series* **295**, 201-213.

Pogonoski, J. J. & Pollard, D. A. (2003). Northern river shark. In *The Conservation Status of Australian Chondrichthyans: Report to the IUCN Shark Specialist Group Australia and Oceania Regional Red List Workshop* (Cavanagh, R. D., Kyne, P. M., Fowler, S. L., Musick, J. A. & Bennett, M. B., eds.), p. 170. Brisbane, Australia.

Queensland Government (2016). Acid Sulphate Soils. *Queensland Government*. Available at https://www.qld.gov.au/environment/land/soil/acid-sulfate (Accessed 21 March 2018)

Queensland Government (2017). Marine Parks; Zoning and designated Areas. *State of Queensland*. Available at https://www.qld.gov.au/environment/coasts-waterways/marine-parks/zoning (Accessed 13 June 2018)

Read, M., D. Miller, J., P. Bell, I. & Felton, A. (2004). *The distribution and abundance of the estuarine crocodile, Crocodylus porosus, in Queensland*.

Reylea, R. A. (2005). The impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities. *Ecological Applications* **15**, 618-627.

Rhind, S. M. (2009). Anthropogenic pollutants: a threat to ecosystem sustainability? *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences* **364**, 3391–3401.

Robertson, W. D. & Kruger, A. (1994). Size at Maturity, Mating and Spawning in the Portunid Crab *Scylla serrata* (Forskål) in Natal, South Africa. *Estuarine, Coastal and Shelf Science* **39**, 185-200.

Roosenburg, W. M. & Green, J. P. (2000). Impact of a bycatch reduction device on diamondback terrapin and blue crab capture in crab pots. *Ecological Applications* **10**, 882-889.

Ross, P. M. (2006). Macrofaunal loss and microhabitat destruction: the impact of trampling in a temperate mangrove forest, NSW Australia. *Wetlands Ecology and Management* **14**, 167-184.

Ryan, S., Doohan, M., Dunning, M., Helmke, S., Bullock, C., Jebreen, E. J., Zeller, B., Williams, L., Higgs, J., Clarke, K., Brown, I., Gribble, N., Sumpton, W., Bailey, S. & Peverell, S. (2003). *Ecological Assessment of the Queensland Mud Crab*. Queensland Department of Primary Industries.

Simpfendorfer, C. A. (2013). Pristis zijsron. The IUCN Red List of Threatened Species 2013. Available at https://www.iucnredlist.org/species/39393/18620401 (Accessed 11 December 2018)

Steffen, W., Hughes, L., Alexander, D. & Rice, M. (2017). *Cranking Up The Intensity: Climate Change and Extreme Weather Events*. Climate Council of Australia.

Stevens, J. D., Pillans, R. D. & Salini, J. P. (2005). *Conservation Assessment of Glyphis sp. A (Speartooth Shark), Glyphis sp. C (Northern River Shark), Pristis microdon (Freshwater Sawfish) and Pristis zijsron (Green Sawfish)*. CSIRO Marine Research. Hobart, Tasmania.

Sumaila, U. R., Cheung, W. W. L., Lam, V. W. Y., Pauly, D. & Herrick, S. (2011). Climate change impacts on the biophysics and economics of world fisheries. *Nature climate change* **1**, 449.

Sumpton, W., Campbell, M., O'Neill, M., McLennan, M., Campbell, A. & Leigh, G. M. (2015). *Assessment of the blue swimmer crab fishery*. Department of Agriculture and Fisheries, Queensland Government. Brisbane, Queensland.

Sumpton, W., Gaddes, S., McLennan, M., Campbell, M., Tonks, M., Good, N., Hagedoorn, W. & Skilleter, G. (2003). Fisheries biology and assessment of the blue swimmer crab (*Portunus pelagicus*) in Queensland. *Report to the Fisheries Research and Development Corporation, Project* **98**, 17.

United Nations Environment Program (2014). *Single Species Action Plan for the Loggerhead Turtle (Caretta caretta) in the South Pacific Ocean*. https://www.cms.int/en/document/single-species-action-plan-loggerhead-turtle-south-pacific-ocean

Webley, J. A. C., Connolly, R. M. & Young, R. A. (2009). Habitat selectivity of megalopae and juvenile mud crabs (*Scylla serrata*): implications for recruitment mechanism. *Marine Biology* **156**, 891.

Appendix 1–Ecological Processes Preliminary Assessment

Ecological Processes Categories

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

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

Ecosystem Processes Preliminary Assessment

Due to the difficulty of assessing the impacts of a fishery on ecosystem processes, a precautionary approach was adopted for the Level 1 assessment. In line with this approach, an initial or preliminary assessment was undertaken for 16 ecosystem processes that may be influenced by fishing activities. As with risk scores for the whole of fishery assessment (Table 5) each category was assigned a risk rating of Low (L), Intermediate (I), High (H), or negligible (-). This risk score describes the potential for each the fishing activity to impact negatively on the ecosystem process category.

For the Level 1 ERA, each fishing activity was assigned a final risk score that corresponded with the maximum risk rating assigned in the preliminary assessment. If for example 'Predation' received an 'H', than the final risk score for harvesting will be an 'H'. To this extent, the final risk scores assigned to each fishing activity present the highest potential risk and therefore may not be applicable to all of the ecosystem processes categories. Used in this context, the Level 1 assessment for ecosystem processes should be considered as both precautionary and preliminary in nature. The following presents a summary of the preliminary risk scores assigned to the main fishing activities in the C1 Fishery.

Ecological Component	**Fishing–Main activities of the Fishery**							
	Harvesting	**Discarding**	**Contact without capture**	**Loss of fishing gear***	**Travel to/from grounds**	**Disturbance due to presence in area**	**Boat maintenance & emissions**	**Other fisheries**
Sedimentation	-	-	-	L/I	-	L	-	L/I
Nutrient cycling / Microbial activity	L	-	-	-	-	-	-	-
Particle feeding	-	-	-	-	-	-	-	-
Primary production	-	-	-	L	-	-	-	L
Herbivory	-	-	-	-	-	-	-	-
Predation	L	L	-	L/I	L	L	-	L/I
Bioturbation	-	-	-	-	-	-	-	-
Detritivory	-	-	-	-	-	-	-	-
Scavenging	L	L	-	L/I	-	-	-	L/I
Symbiosis	-	-	-	-	-	-	-	-
Recruitment	L	-	-	L/I	-	-	-	L/I
Reef building	-	-	-	-	-	-	-	-
Competition	L	-	-	L	-	-	-	L
Connectivity	L	-	-	-	-	-	-	L
Outbreaks of disease	-	L	-	-	-	-	-	L
Species introductions	-	-	-	-	-	-	-	-
ECOSYSTEM PROCESSES (overall)	L	L	-	L/I	L	L	-	L

Appendix 2–Regional Risk Characterisation Profiles

The following provides an overview of the *Risk Characterisation* assessment for C1 fishing operations on the Queensland east coast (Table A2) and in the Gulf of Carpentaria (Table A3). As the majority of catch and effort in the C1 Fishery occurs on the Queensland EC, the *Risk Characterisation* profile for this region mirrors the broader fishery (Table 4). While not universal, risk scores assigned to ecological components impacted by the fishery in the GoC tended to be lower.

***Table A1**. Summary of preliminary risk scores for the C1 Fishery for Queensland's east coast, including the impact of the main fishing activities on key ecological components.*

	Crab potting–Main activities of the fishery							**Cumulative impacts Other Fisheries**
Ecological Component	**Harvesting**	**Discarding**	**Contact without capture**	**Loss of fishing gear***	**Travel to/from grounds**	**Disturbance due to presence in area**	**Boat maintenance & emissions**	
Target & Byproduct	I/H	I	L	I/H	L	L	L	I/H
Bycatch species (Non-SOCC)	-	L/I	L	I	L	L	L	L
Species of Conservation Concern								
1. Marine turtles	-	H	I	H	L	L	L	H
2. Sea snakes	-	L	L	L	L	L	L	L
3. Crocodiles	-	L	L	L	L	L	L	L
4. Dugongs	-	L	L	L	L	L	L	L
5. Cetaceans	-	L	L	L	L	L	L	L
6. Protected teleosts		L	L	L	L	L	L	L
7. Batoids	-	L/I	L/I	I	L	L	L	I
8. Sharks	-	L	L	L	L	L	L	L
9. Syngnathids	-	-	-	-	-	-	-	-
10. Sea birds	-	L	L	L	L	L	L	L
11. Ter. mammals	-	L	L	L	L	L	L	L
Marine Habitats	-	-	-	I/H	L	L	L	I/H
Ecosystem Processes	L	L	-	L/I	L	L	-	L

** Gear may be recreational*

Table A2. *Summary of preliminary risk scores for fishing in the C1 Fishery for the Queensland Gulf of Carpentaria coast, including the impact of the main fishing activities on key ecological components.*

	Crab potting–Main activities of the fishery							
Ecological Component	**Harvesting**	**Discarding**	**Contact without capture**	**Loss of fishing gear***	**Travel to/from grounds**	**Disturbance due to presence in area**	**Boat maintenance & emissions**	**Cumulative impacts Other Fisheries**
Target & Byproduct	I	I	L	I	L	L	L	L
Bycatch species (Non-SOCC)	-	L	L	I	L	L	L	L
Species of Conservation Concern								
1. Marine turtles	-	L	L	I	L	L	L	L
2. Sea snakes	-	L	L	L	L	L	L	L
3. Crocodiles	-	L	L	I	L	L	L	L
4. Dugongs	-	L	L	L	L	L	L	L
5. Cetaceans	-	L	L	L	L	L	L	L
6. Protected teleosts	-	L	L	L	L	L	L	L
7. Batoids	-	L/I	L/I	I	L	L	L	I
8. Sharks	-	L	L	L	L	L	L	L
9. Syngnathids	-	-	-	-	-	-	-	-
10. Sea birds	-	L	L	L	L	L	L	L
11. Ter. mammals	-	L	L	L	L	L	L	L
Marine Habitats	-	-	-	I	L	L	L	L
Ecosystem Processes	L	L	-	L/I	L	L	-	L

** Gear may be recreational*

Appendix 3–Risk Ratings and Outputs.

The primary objective of the Level 1 assessments were to a) identify the key sources of risk within a particular fishery and b) the ecosystem components that are most likely to be effected by this risk. Preliminary risk ratings developed as part of the *Risk Characterisation* stage take into consideration the current fishing environment (*e.g.* current catch, effort and licensing trends) and risk factors associated with the current management regime (*e.g.* transfer of effort to already saturated markets, substantial increases in fishing mortality for key species, changing target species). Depending on the fishery, broader risk factors may also contribute to an ecological component receiving a more conservative risk rating. These preliminary rates are precautionary or more conservative in nature and provide a more holistic account of a) risks posed by the fishery and b) provide the Level 1 ERA with greater capacity to address the (potential) long-term consequences of a risk. The trade-off with this approach is that the preliminary risk may overestimate the level of risk posed to an ecological component or be a reflection of the 'potential risk'. Otherwise known as a 'false positive', these values effectively overestimate the risk posed to an ecological component or subcomponent.

The potential for large-scale qualitative ERAs to produce 'false positives' places added importance on examining the likelihood of the risk coming to fruition in the short to medium term. The following provides an overview of the preliminary risk ratings and an assessment of the likelihood of it occurring in the Mud and Blue Swimmer Crab (C1) Fishery. Depending on the species and the current fishing pressures, preliminary risk ratings may be amended to reflect the current fishing environment.

Ecological Component	**Key Issues / Sources of Risk**	**Risk Characterisation (Preliminary rating)**	**Considerations of Likelihood**	**Level 1 Risk Rating**
Target & Byproduct	• Absence of an effective control of catch and effort at a whole of fishery, regional and species level. • The fishery has a large footprint that incorporates both the Gulf of Carpentaria and the Queensland east coast • High potential for effort to be transferred between regions and species. • Restricted information on regional effort distributions.	High	*Likelihood* • Although the mud crab and blue swimmer crab fisheries have been classed as sustainable, there is evidence from industry that under current effort levels the fishery is not economically viable *e.g.* the fishery is being fished at MSY *vs.* MEY. • There is also evidence there has been effort shift from the inshore net fisheries into C1 given the increase in the value of mud crab (operators are permitted to fish simultaneously on the C1 and an N or L fishery symbol).	Intermediate / High

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Target & Byproduct	• Absence of updated stock assessments and biomass estimates. • Some prominent mitigation measures in place (*e.g.* MLS, and no-take on females). • Mitigation measures may be undermined by black marketing which has been identified as a key issue for this fishery–particularly mud crabs.		• The two main species in the C1 Fishery are mud crab and blue swimmer crab. There is evidence that as commercial fishers stop fishing for mud crab they shift to blue swimmer crab, particularly in Moreton Bay. • There is evidence that byproduct species are encountered whilst fishing for the target species (either mud crab or blue swimmer crab) and commercial fishers with a C1 are able to retain both species. • There is strong evidence that suggests black marketing of mud crab is a major issue in the mud crab fishery. Mud Crab is a priority black market species for management intervention in Queensland. • Given the social significance of the target two species, the cumulative impacts (*e.g.* recreational based fishing mortality) would be substantial for this subgroup. *Mitigation Measures / FWG Discussions* • The fishery has in place a number of long-term and well established risk mitigation measures including a prohibition on the take of female crabs and a minimum legal size limit for males. These measures (*exc.* risks associated with illegal fishing) afford protection to (theoretically) at least half of the standing population.	

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Target & Byproduct			• Significantly, a number of the risks are being actively addressed by the C1 Fisheries Working Group (FWG). Options being considered include: - Improving regional management *e.g.* dividing the C1 Fishery into three management units (Blue swimmer crab, all Queensland waters; Mud crab, Gulf of Carpentaria; Mud crab, East coast). - Setting a total allowable commercial catch (TACC) for each management unit above and exploring the potential use of Individual Transferable Quota (ITQ) units. - Introduce traceability tags for commercially caught mud crab to verify quota and reduce black marketing. - The introduction of an in possession recreational limit for blue swimmer crabs and mud crabs to address additional issues relating to the black marketing of key species. - Developing harvest strategy that will contain decision rules for further effort reductions if required e.g. commercial TAC reduction for declines in catch, or recreational possession limits decrease if boat ramp surveys suggest that fishers are not consistently catching the possession limit. -	

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Bycatch (non-SOCC)	• Smaller proportion of bycatch when compared to other fisheries. • Limited information on bycatch compositions for this fishery. • Interaction rates with non-target species will be relatively low. • Impacts on non-target species are likely to be higher when lost pots (commercial and recreational fishing) are taken into consideration. • Bycatch reduction devices used in the fishery but are not mandatory and there is limited information on the extent of their use, their effectiveness across sectors and their potential to impact catch rates of target species. • The impacts of ghost pots compounded by their capacity to self-bait / continue fishing without being checked.	Intermediate	*Likelihood* • There has been little research on bycatch in the C1 fishery or on catch compositions / rates for ghost pots. • There is some evidence that crab pots catch non SOCC bycatch species such as common fish species. Retention of all species other than crab species is prohibited. • From an operational perspective, the more an apparatus is worked the less impact to bycatch species *e.g.* the bycatch species can be returned to the water alive before being predated upon by crabs. • The biggest issue regarding interactions with bycatch species is from lost pots and ghost pots that continue to fish (self-bait). This impact is very difficult to quantify as this catch cannot be monitored.	Intermediate

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Bycatch (non-SOCC)			*Mitigation Measures / FWG Discussions* • The issue of ghost pots is being actively addressed in Queensland. QBFP conducts state-wide crab pot clean ups. • Additionally, the crab working group suggested the following potential options to address risks associated with ghost pots: - Organised rolling regional community clean ups; - Standardised heavier pots that are less likely to be lost; or - Implementing a trigger for further management action in the harvest strategy if the number of abandoned pots / ghost pots are not reducing over time. • Other measures being considered by the crab working group to reduce the impact on non-target species include: • Mandating the use of escape vents for crab pots (all sectors) to ensure smaller crab and	

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Bycatch (non-SOCC)			fish species can escape before being predated upon by other crabs • Restricting the use of lightweight pots (all sectors–but affects recreational mostly) which are more easily lost in big tides. • Introducing a ban on the use of light-weight pots, having a minimum weight requirement or standardising recreational and commercial apparatus. • The development of harvest strategies containing rules for further bycatch reductions reduction *e.g.* implementing a harvest strategy trigger for further management action in the harvest strategy if the number of abandoned pots/ghost pots are not reducing over time.	
Species of Conservation Concern (SOCC)				
Marine turtles	• Low but consistent number of interactions in the fishery. • Limited capacity to validate interaction rates and/or the extent of (potential) underreporting.	High	*Likelihood* • Risk is relevant to this fishery as marine turtles can become entangled with crab pot float lines and in the entrances of certain crab pots.	High

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating

Marine turtles	• Total number of interactions (commercial and recreational) and total mortality (in-situ, post-release) is potentially higher than what is recorded.
	• Increased potential for in-situ mortality due to fishing method and soak times
	• Significant risk posed by ghost pots and lost gear (commercial and recreational).
	• Overlap between key fishing grounds (commercial and recreational) and preferred habitats.
	• Ghost pots considered to be a significant issue for this subgroup. However there is limited information on pot loss in both the commercial and recreational fisheries.
	• Increased vulnerability due to life history traits
			• Risk is not limited or restricted to the commercial fishery with recreational fishing and ghost pots viewed as significant contributors of risk.
			• This risk is unlikely to be equal across the C1 Fishery and may be more applicable to areas where turtle populations are higher *e.g.* south east Queensland including Moreton Bay.
			• No real mechanisms in place to obtain information or quantify pot loss rates in either the commercial or recreational fishing sectors,
			
			Mitigation Measures / FWG Discussions
			• Some risks being actively addressed/discussed through the crab working group. This included the following options:
			  • Restricting the use of lightweight pots (all sectors–but affects recreational mostly) which are more easily lost in big tides;
			  • Introducing a ban on the use of light-weight pots, having a minimum weight requirement or standardising recreational and commercial apparatus.	

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Marine turtles			• Investigating the use of negatively buoyant float lines in Moreton Bay • The development of harvest strategies containing rules for further bycatch reductions reduction e.g. implementing a harvest strategy trigger for further management action in the harvest strategy if the number of abandoned pots/ghost pots are not reducing over time. • Cumulative risks including the impact of recreational fishers and ghost pots will be a broader risk factor for this subgroup.	
Sea snakes	• Low interaction but unknown mortality rates. • Limited spatial overlap between key fishing grounds and preferred habitats.	Low	*Likelihood* • Low interaction rates and subgroup expected to have high post release survival rates. *Mitigation Measures / FWG Discussions* • Reduced effort *e.g.* pots, not discussing sea snake mitigation in the crab working group as it is not considered to be a priority risk.	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Crocodiles	• Low interaction but unknown mortality rates. • Limited spatial overlap between higher effort fishing grounds (SEQ) and preferred habitats (possibly in FNQ). • Interactions with this fishery unlikely to have a long-term, detrimental impact on crocodile populations.	Low	<u>*Likelihood*</u> • Low but does occur, some fishers in the gulf use PVC bait tubes and this significantly reduces interactions with crocodiles. <u>*Mitigation Measures / FWG Discussions*</u> • Not discussion mitigation measures in the crab working group as it is not considered to be a priority risk.	Low
Dugongs	• Interactions with this fishery are unlikely, and if applicable will be infrequent and very low numbers. • Entanglement (*e.g.* in float lines) more likely than entrapment. • Limited spatial overlap between key fishing grounds and preferred habitats. • Indirect impacts (contact without capture, lost fishing gear, boat strike) considered to be higher risk than direct impacts (capture/discarding).	Low	<u>*Likelihood*</u> • Low to negligible. <u>*Mitigation Measures / FWG Discussions*</u> • Investigate negative/neutral buoyancy float lines in Moreton Bay • Developing harvest strategy that will contain decision rules for further bycatch reductions e.g. implementing a harvest strategy trigger for further management action in the harvest strategy if the number of abandoned pots/ghost pots are not reducing over time or interactions are increasing over time.	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Dugongs			• Risks posed to this subgroup not being actively discussed by the crab working group as it is not considered to be a priority.	
Cetaceans	• Low interactions and mortalities unlikely. • Entanglement (*e.g.* in float lines) more likely than entrapment; more relevant to the Blue Swimmer Crab Fishery. • Limited spatial overlap between key fishing grounds and preferred habitats. • Indirect impacts (contact without capture, lost fishing gear, boat strike) considered to be higher risk than direct impacts (capture/discarding).	Low	<u>*Likelihood*</u> • Low and more applicable to the Blue Swimmer Crab Fishery. <u>*Mitigation Measures / FWG Discussions*</u> • Investigate negative/ neutral buoyancy float lines in Moreton Bay • Developing harvest strategy that will contain decision rules for further bycatch reductions e.g. implementing a harvest strategy trigger for further management action in the harvest strategy if the number of abandoned pots/ghost pots are not reducing over time or interactions are increasing over time. • Risks posed to this subgroup not being actively discussed by the crab working group as it is not considered to be a priority.	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Teleosts (protected / SOCI only)	• Some potential for protected teleost to interact with crab pot apparatus • Degree of spatial overlap between key fishing grounds and preferred habitats • Mortality rates of captured animals anticipated low • Species most likely to be impacted are Queensland Groper (juvenile).	Low	<u>*Likelihood*</u> • Low interactions and subgroup is expected to survive interactions with active fishing pots *i.e.* those being checked. <u>*Mitigation Measures / FWG Discussions*</u> • Risks posed protected teleosts not being discussed directly by the crab working group. However, the working group is discussing broader bycatch mitigation measures. • The crab working group are examining the feasibility and applicability of a number of management initiatives including: - A potential requirement to use/install escape vents for crab pots (all sectors) to ensure smaller crab and fish species can escape before being predated upon by other crabs. - Restricting the use of lightweight pots (all sectors–but affects recreational mostly). There are some recreational crab pots that are not heavy and are lost on big tides. The crab working group have suggested banning these light weight pots by having a minimum weight	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Teleosts (protected/SOCI only)			requirement or standardising recreational apparatus. • Cumulative risks including the impact of recreational fishers and ghost pots will be a broader risk factor for this subgroup.	
Batoids	• Low interaction rates (overall) but limited information on catch compositions and mortality rates. • The life history and distribution of some species *e.g.* sawfish may place them at higher risk. • Limited capacity to validate interaction and mortality rates with this subgroup.	Batoids (exc. sawfish) - Low	<u>*Likelihood*</u> • There is evidence that crab pots interact with batoid species, albeit low. • If handled correctly, post release survival rates for this subgroup expected to be high. • Risk is considered to be higher for sawfish due to their contracted range, the potential for these species to interact with the Mud Crab Fishery	Batoids (exc. sawfish) - Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Batoids	• Moderate overlap between key fishing grounds and preferred habitats of some estuary and inshore species. • Fragmented populations and significant life-history constraints increases the risk for sawfish species; even at low levels of fishing mortality.	Sawfish - Intermediate	across their range and the increased risk of entanglement and injury. <u>*Mitigation Measures / FWG Discussions*</u> • Risks posed to this subgroup not being actively discussed by the crab working group as it is not considered to be a priority. • While not being actively discussed, subgroup may derive benefit from other initiatives. For example: - Proposals that include ITQ also require pots to be removed once quota has been reached. Less pots in the water under a quota managed fishery will result in less interactions with batoid and other bycatch species. - Restrict the use of lightweight pots (all sectors–but affects recreational mostly). There are some recreational crab pots that are not heavy and are lost on big tides. The crab working group have suggested banning these light weight pots by having a minimum weight requirement or standardising recreational and commercial apparatus.	Sawfish - Intermediate

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Batoids			- Developing harvest strategy that will contain decision rules for further bycatch reductions reduction e.g. implementing a harvest strategy trigger for further management action in the harvest strategy if the number of abandoned pots / ghost pots are not reducing over time. • Cumulative risks including the impact of recreational fishers and ghost pots will be a broader risk factor for this subgroup.	
Sharks	• Low interaction rates (overall) but limited information on catch compositions and mortality rates. • Catchability declines quickly within increasing body size/mass. • Fished area may overlap with the spatial distribution of river sharks (*Glyphis* spp.) but the extent of these interactions is unknown.	Low/Intermediate	<u>*Likelihood*</u> • There is evidence that shark species can interact with crab pots and get trapped (partially or wholly) within the apparatus. • Risk to most species considered to be low. Risk overall is elevated due to the potential for the fishery to interact with river sharks (*Glyphis* spp.) across there range. • Total number of interactions may be masked due to misidentifications.	Low/Intermediate

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating

Sharks			<u>*Mitigation Measures / FWG Discussions*</u>
			• Risks posed to this subgroup not being actively discussed by the crab working group as it is not considered to be a priority.
			• While not being actively discussed, subgroup may derive benefit from other initiatives. For example:
			  • Proposals that include ITQ also require pots to be removed once quota has been reached. .Less pots in the water under a quota managed fishery will result in less interactions with batoid and other bycatch species.
			  • Restrict the use of lightweight pots (all sectors–but affects recreational mostly). There are some recreational crab pots that are not heavy and are lost on big tides. The crab working group have suggested banning these light weight pots by having a minimum weight requirement or standardising recreational and commercial apparatus.
			  • Developing harvest strategy that will contain decision rules for further bycatch reductions reduction e.g. implementing a harvest	

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Sharks			strategy trigger for further management action in the harvest strategy if the number of abandoned pots/ghost pots are not reducing over time.	
Syngnathids	• No reported interactions and subgroup unlikely to interact with the crab apparatus. • Interactions (if any) would be more likely in the blue swimmer crab fishery and are not expected to have long-term implications for regional populations.	Negligible	*Likelihood* • N/A as interaction rates (if applicable) are unlikely to have long term implications for regional populations. *Mitigation Measures / FWG Discussions* • Risks posed to this subgroup not being actively discussed by the crab working group as it is not considered to be a priority.	Negligible
Seabirds	• Small number of reported through SOCI logbooks and interaction rates (overall) anticipated to be low. • Risks likely to be more relevant to diving species.	Low	*Likelihood* • Low number of interactions and fishery is unlikely to have long term implications for regional populations. *Mitigation Measures / FWG Discussions* • Risks posed to this subgroup not being actively discussed by the crab working group as it is not considered to be a priority.	Negligible/Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Terrestrial Mammal	• Low number of interactions but misidentifications are a significant issue for this subgroup. • Interactions have a higher probability of ending in mortality. • Limited information on spatial overlap with fishery and the propensity of the species to interact with the crab fishery. • Interactions more likely with pots set in intertidal waters; primarily in the mud crab fishery.	Low	<u>*Likelihood*</u> • Some potential for species to interact with this subgroup; particularly if set above the low water mark. • Degree of uncertainty regarding final risk rating due to increased potential for misidentifications to occur *i.e.* may be negligible or higher. <u>*Mitigation Measures / FWG Discussions*</u> • Risks posed to this subgroup not being actively discussed by the crab working group as it is not considered to be a priority. • The crab working group is trying to define and regulate 'actively worked pots'. The may reduce interactions with terrestrial mammals. • Cumulative risks including the impact of recreational fishers and ghost pots will be a broader risk factor for this subgroup.	Low

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
Marine Habitats	• Direct impacts to marine environment will be low for active operations. • Direct impacts expected to be localised and more prevalent during the pot setting and retrieval process. • The overall risk posed by crab fishing to marine habitats is elevated due to the prevalence and impact of ghost posts and their associated float lines.	Intermediate/High	*Likelihood* • There is evidence that he act of potting has direct impact to the marine ecosystem e.g. interaction with seagrass in shallow environments and damage to mangroves setting and retrieving pots. • Regional impacts of ghost pots evident in clean up patrols undertaken by QBFP. *Mitigation Measures / FWG Discussions* • The issue of ghost pots is being actively addressed in Queensland. QBFP conducts state-wide crab pot clean ups. • Discussion at the crab working group, to date, have focussed on effort reductions (fisher reductions) and reducing ghost pots. These discussions include option to: - Restrict the use of lightweight pots (all sectors–but affects recreational mostly). There are some recreational crab pots that are not heavy and are lost on big tides. The crab working group have suggested banning these light weight pots by having a minimum	Intermediate/High

Ecological Component	Key Issues / Sources of Risk	Risk Characterisation (Preliminary rating)	Considerations of Likelihood	Level 1 Risk Rating
			weight requirement or standardising recreational apparatus. - Developing harvest strategy that will contain decision rules for further bycatch reductions reduction e.g. implementing a harvest strategy trigger for further management action in the harvest strategy if the number of abandoned pots/ghost pots are not reducing over time.	
Ecosystem processes**	• Fishery interacts with a comparatively small range of species. • The potential of the C1 Fishery to affect or key ecosystem processes is limited.	Low	*Likelihood* • Unknown but expected to be low given the species being targeted and the nature of the fishing apparatus. *Mitigation Measures / FWG Discussions* • Risks posed to this subgroup not being actively discussed by the crab working group as it is not considered to be a priority.	Low