Developing a National Bycatch Reporting System

FINAL REPORT

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Executive Summary

Bycatch from fishing (the unintended, non-targeted organisms caught when targeting particular species or sizes of species) remains one of the most important issues concerning the world's fisheries. And discards are considered the most important component of bycatch because they represent a perceived wastage of seafood resources, may include Threatened, Endangered and Protects (TEP) species, and attract significant controversy and interest for many stakeholders including other fisheries, conservation groups, eco-labelling organizations, stock assessment scientists and the general public (who own this part of the catch).

Whilst fisheries jurisdictions have recognised the need to report to the public and other stakeholders regarding the status of exploited stocks, there is growing acceptance and international, regional and national agreements that encourage (or require) governments to also report on the status of bycatches and discards. There have been several efforts to do such reporting including FAO's decadal global reports and the United States' very comprehensive National Bycatch Reporting process. But Australia currently does not have a process for reporting on bycatch, and this current project is aimed at developing such a methodology for commercial fisheries. We do this by examining how one could most effectively report on bycatches in 4 of Australia's 8 fisheries jurisdictions, selected to represent the diversity and size of commercial fisheries in Australia: New South Wales, Tasmania, Queensland and the Northern Territory.

The methodology developed allows Australia's jurisdictions to compile, summarise and report on discards from their commercial fisheries using a relatively simple 5 stage process. The process results in estimates of rates and annual quantities of discards (with associated variances) for the jurisdiction and the various fisheries within it, in addition to estimates of the relative quality of the information used. To summarise, the 5 steps are:

1. Identify the individual fisheries/methods in each jurisdiction, the annual landings and, if available, fishing effort for each. Express these as recent annual averages and associated SEs.
2. Gather all available papers, reports and datasets on fisheries bycatches, discards and TEPs interactions and from them derive retained:discard ratios and/or effort:discard ratios for each fishery/method. Again, express these as averages (if multiple ratios exist) with associated SEs.
3. For those fisheries/methods that lack ratios, identify and include any substitute ratios from similar fisheries/methods from other jurisdictions.
4. Multiply the average ratios from Steps 2 and 3 by the average landings data from Step 1 to obtain total estimated annual discards for each fishery/method and add these together to get a jurisdictional total. If (preferably) fishing effort is available and discard ratios are also available by fishing effort, do this step using effort as the multiplier. Use Goodman's (1960) formula for calculating the product of variances to derive the appropriate SEs associated with the extrapolated estimates.

5. Apply the steps in the US Tier Classification Scheme for estimating the quality of the discard information for each fishery/method, weighted by the estimated level of discards for each. Express these metrics as a percentage score for comparison purposes.

In developing this methodology, this project yielded a series of results concerning the reporting and management of discards in Australia. These included the following:

- By far the greatest quantity of estimated discards came from Queensland's fisheries (26,579 tonnes at a rate of 58%), and most of this from just one fishery – the East Coast Prawn Trawl fishery. And the lowest level came from the Northern Territory's fisheries (854 tonnes at a rate of 14%). Combining the data from the 4 case studies, we can estimate that, together, **45.5%** of their catches are discarded. While this is not a national average (only half Australia's jurisdictions were examined), it is still around 10% less than the only other estimate available for Australia (Kelleher, 2005) which had our national discard level at 55.3%. But once again, this is heavily influenced by the large quantity discarded by our prawn trawl fisheries and Queensland's in particular.
- The project also allowed an estimate to be made of the effect that the introduction of BRDs may have had on discards in certain NSW fisheries. Whilst the results are quite impressive (an estimated annual reduction of discards of 1,246 tonnes or 27.7 million fish), there remains significant work to do to further reduce discards in such fisheries.
- In applying the US Tier Classification system for determining the quality of the information used to estimate discards, we found that all 4 case studies were found to have fairly similar "pass-level" metrics for general discards of around 50% with the average across all 4 estimated as 52.7%. All 4 also had similar quality metrics for information about TEPs interactions but at a very low level of 10% and below (with an average score of 7.6%). So, while this project was able to produce reasonable estimates of general discards for most fisheries and methods, the same cannot be said for interactions with TEP species due to the scarcity of data, precluding the calculation of total estimates.

In developing its methodology, this project not only provided baseline information and metrics against which subsequent reports can be compared (for the case studies examined), but also identified key gaps in our information about discarding in Australia's fisheries and where future work should focus in terms of reporting, monitoring and reducing it. This led to a series of recommendations:

- A more comprehensive examination of our national discards would come from repeating the work done in this project for Australia's remaining 4 jurisdictions (the Commonwealth, South Australia, Western Australia and Victoria).
- To better estimate discards and resolve some of the many assumptions made in this project, future monitoring programs (using human observers and also Electronic Monitoring using cameras) in Australia should: (i) focus on getting at least some data from fisheries where none currently exist; (ii) concentrate on particularly problematic and non-

selective fishing gears (such as trawling), with (iii) less focus on those gear types that have been identified as having relatively few discards. This is not to say that we need lots of ongoing programs, but strategically-located and -timed programs that examine certain fisheries periodically. Such a system of "rolling" observer/EM programs will greatly improve the quality of discard information for Australia at a more modest expense.

- Observer programs and industry-based reporting (using conventional and electronic logbooks) should include reporting on the weights of discards (not just numbers of individuals) so that better extrapolations to whole fisheries and jurisdictions can be done with fewer assumptions (because the multiplier for extrapolations that is most often used involves landings by weight – not by numbers).
- Efforts to reduce discards should focus on those fisheries identified as having particularly high discards (in this study, oceanic prawn trawling, lobster and estuarine haul fisheries) by developing more selective gears, and/or better implementing and policing modifications that have already been developed.
- Substantial effort needs to focus on better ways to monitor interactions with TEP species, perhaps by embracing the current work occurring in the field of Electronic Monitoring using video and/or still photography as means to audit industry-based reporting.

Introduction

Background

Bycatch was once said to be the fisheries issue of the 1990's. Yet it still dominates fisheries management, policy and science, being a major component of EBFM processes, FAO's Ecosystem Approach and Code of Conduct, assessments by the Marine Stewardship Council and other eco-labelling organisations, the EU's Common Fisheries Policy (through its new Landing Obligation), and a host of state, national, regional and global instruments.

Whilst fisheries jurisdictions have recognised the need to report to the public and other stakeholders regarding the status of exploited stocks, there is growing acceptance that governments also need to report on the status of bycatches and discards. That is, while the public own fisheries resources right up to the point where fish are retained for sale or personal use, for discarded fish, this public ownership is perpetual; the public own all discarded fish, all the time. So governments (who are given the task of managing this property on behalf of that public) are expected to undertake those activities expected of anyone who is responsible for someone else's property, including its stewardship, management, monitoring and reporting (see also discussions in FAO, 2015; Kennelly, 2015).

In recent years, the importance of bycatch monitoring has been recognised in a variety of international agreements, guidelines and policies, such as FAO's International Guidelines on Bycatch Management and Reduction of Discards, and the European Union's Landing Obligation. But reporting on bycatches, and consolidating such reporting into jurisdictional summaries, is very different from reporting on landed catches because: (i) it is far more difficult to obtain bycatch data than landings data (usually by using quite expensive observer programmes and/or, in recent times, camera technology); and (ii) such reporting requires many assumptions and extrapolations.

There have, however, been several efforts to consolidate reporting on bycatch including FAO's global reports in 1994 and 2005 (Alverson et al, 1994; Kelleher, 2005), with a new revision due in 2018. And UN states have agreed via their endorsement of the FAO Guidelines on Bycatch Management and Reduction of Discards (FAO, 2011b) to also report on bycatches and discards for their own jurisdiction(s). The United States is the first nation to do so via their very comprehensive National Bycatch Reporting process (NMFS, 2011).

Australia currently does not have a process for reporting on fisheries bycatch – indeed, the only nationally consolidated estimate of bycatch for Australia (done by Kelleher, 2005) suggests that our commercial fisheries discard more than they retain (i.e. 55.3%). This figure may surprise many (including fishing industries, environmental groups and those concerned with seafood security) and has the potential to adversely affect Australia's well-earned brand as a responsible fisheries management nation. This current project aims to develop a process where more robust (and ongoing) estimates of bycatch and discards can be provided by Australia's fisheries jurisdictions. This was done by examining how one could most effectively report on bycatches in 4 of Australia's 8 fisheries jurisdictions (as case studies) and, using the lessons learned, we recommend a

methodology for regular (every 5-10 years) reporting by all jurisdictions. The 4 jurisdictions used as case studies were selected to represent a broad cross-section of the diversity and size of commercial fisheries in Australia. Originally, we selected New South Wales, South Australia, Queensland and the Northern Territory. However, after the NSW case study was completed and its draft report circulated to the Steering Committee, South Australia decided not to continue on the project, so Tasmania was selected as a substitute.

Scope and Definitions

It is important in any study about bycatch to establish (quite early) its scope and definitions - to set the boundaries around what is being described. In terms of scope, when negotiating the size, duration and budget for this project, it was decided, as a cost-effective way to develop a methodology, to restrict this project to examining the commercial marine fisheries for 4 of Australia's 8 fisheries' jurisdictions as case studies. It is anticipated that other jurisdictions, recreational, traditional and freshwater fisheries will eventually be incorporated into the system as the results from this first project are formulated into a National Bycatch Reporting System. Furthermore, because bycatch issues are always related to the particular fishing method(s) used in a fishery, this project attempted (where possible) to develop a reporting system that is specific to each fishing method used in each commercial fishery in each jurisdiction.

Regarding definitions in a project about bycatch, it is important to first identify the meaning of particular terms like "bycatch", "discards" and "by-product". There has been significant difficulty throughout the world in settling on a robust and standard definition of "bycatch" which may, depending on one's jurisdiction, include: discards, threatened, endangered or protected (TEP) species, retained and/or sold "by-product" species, juveniles, trash fish, pre-catch losses, slipped fish, fish released due to high-grading, mortalities due to ghost fishing, offal, discarded fish heads and frames, parts of sharks, and even broader ecosystem and habitat impacts of fishing (FAO, 2015). Notwithstanding this variety of definitions, the most commonly used definitions tend to settle on **"bycatch" being the unintended, non-targeted organisms caught while targeting particular species (or sizes of species)**. This bycatch is then most commonly then divided into those non-target organisms that are kept and eaten/sold ("landed bycatch" or "by-product") and "discards" which are those organisms thrown back into the sea.

It is this latter subset of bycatch (discards) which is the usual focus of studies and projects such as the present one, because it is this subset that represents perceived wastage of exploited resources, includes TEP species, attracts significant controversy, and is of interest to many stakeholders including conservation groups, interacting fisheries, eco-labelling organisations, stock assessment scientists and the general public. Consequently, most studies that report on bycatch tend to report on discards (as is the case for FAO's global bycatch reports and the US National Bycatch Report). This present project, therefore, focuses on discards as the key component of bycatch to report on, allowing one to concentrate on a relatively discrete subset of the catch whilst also providing a means to compare our estimates with those derived by others around the world. This means that the present project is not developing a system to report on items like the

landings of byproduct, pre-catch losses, offal, fish frames/heads/etc, ghost fishing, ecosystem or habitat effects of fishing, and other aspects of fishing that sometimes find their way into jurisdictions' definitions of bycatch.

In terms of reporting by weights or numbers of organisms, again there is an international norm that is becoming commonplace in the bycatch field (eg. Kelleher, 2005; NMFS, 2011) – where bycatches are usually expressed as weights for most organisms (i.e. general discards), except for TEP species where it is usual to report on interactions in terms of the numbers of individuals. In this project, we adhere to this practice.

Objectives

1. Using 4 jurisdictions as case studies, compile and synthesize all available reports/papers/datasets on fisheries bycatches, discards and TEPs interactions for each
2. Assess the quality of the data gathered using appropriate metrics
3. Develop templates and reporting processes, and identify programs, fisheries and/or species (including any surrogates/indicators), that together will form a national framework for bycatch reporting
4. Compile the above into a framework for future periodic bycatch reporting that dove-tails into the current SAFS system
5. Provide discard inputs (as available) for the Fisheries Health Check system being developed under FRDC 2014/008

Methods

Estimating Bycatch

The key variables used when quantifying bycatch are fishery- or fishing method-specific ratios that are derived from data collected using one of a variety of methods. These methods are described in Kennelly (2015) and are summarised here:

- Research vessels have been used to quantify bycatch (particularly early in the history of bycatch monitoring) but this relies on them being able to mimic normal commercial fishing operations.
- Coast guard inspections have also proven useful to monitor bycatches where vessels are boarded, and catches examined whilst at sea (e.g. as in Norway).
- Post-trip interviews of captains and crews are also used and, whilst such techniques can be quite inexpensive, the data collected on problematic (or controversial) discards (including TEP species) are considered to be less reliable than other methods. It is worth noting, however, that the accuracy of such information has been greatly improved when used in conjunction with Electronic Monitoring (using cameras) as an audit tool.
- Monitoring landed catches is considered an accurate way to quantify landed bycatch (byproduct) at low cost but does not quantify discards.
- Getting fishers to self-record data on bycatch and discards is used in many fisheries. This involves fishers completing logbooks and, more recently, recording information on laptops, phone and tablet apps which can be sent to scientists and managers in close-to real-time. However, like post-trip interviews, such data are considered less than accurate, particularly for the bycatch of problematic or controversial species, although, as mentioned above, Electronic Monitoring auditing is greatly improving this accuracy.
- Study fleets are also used – where particular, “trusted” captains and crews record data which are taken to be representative of the whole fleet.
- It is well-accepted that by far the most reliable and accurate way to collect bycatch information is through the use of onboard observer programs. These involve scientifically trained staff going out on normal fishing operations and recording all relevant data. Many such programs exist throughout the world and, in the past few decades, they have become a major, mainstream source of fisheries information for many uses – and particularly for estimating bycatch. However, such programs are also quite expensive – especially for smaller scale fisheries.
- In more recent years, significant developments have occurred in the use of onboard camera technology to replace human observers for the collection of certain types of bycatch data and (as mentioned above), as a means to audit industry-reported data. Many trials of this Electronic Monitoring technology have been completed throughout the world with several fisheries now adopting it as the main way such data are collected.

Bycatch Ratios for Extrapolations

Once estimates of bycatch have been obtained using one or more of the above method(s), estimates of bycatches by whole fisheries are then usually made using one of two extrapolation methods (see also Andrew and Pepperell, 1992; Kennelly, 1993; Kennelly et al, 1998; Kelleher, 2005):

- The "retained:bycatch ratio" method uses the known total production from a fishery to extrapolate observed mean bycatch ratios up to annual estimates for whole fleets. This is the most commonly used method because total retained catches by fisheries are often available.
- Alternatively, the "fishing effort:bycatch ratio" method uses the known total effort in a fishery to extrapolate mean bycatches observed over some unit of effort (like a day's fishing, a trip or a tow) up to estimates for whole fleets. This method is not as commonly used as the retained:bycatch ratio because fishing effort is not as commonly reported as landings data.

It is important to note however, that the incidences of bycatches in total catches are usually not correlated to the levels of retained (or targeted) catch, but are more likely to be correlated with fishing effort. Because of this, it is generally accepted that extrapolating estimates of bycatches is more accurately done using fishing effort multipliers (when they are, albeit rarely, available) than total catches (see FAO, 2015; Kennelly, 2015). Notwithstanding this, it is also well accepted, and indeed, the norm, to report bycatches as a percentage of the total retained catch - because stakeholders and decision-makers often wish to know about the relative quantities of bycatch compared to landings when assessing the relative environmental impacts of a fishery or fishing method compared to its provision of seafood.

Measurements of Error

When doing the above extrapolations, it is desirable to try to include some estimate of the potential errors (as variances or confidence limits) around one's estimates. However, whilst multiplying up average bycatch rates by average landings or fishing effort records is a straightforward calculation, deriving accurate estimates of variances around such extrapolations is difficult and, in many cases, invalid. This is because of several factors:

(i) Variances around bycatch estimates are often not provided in studies.
(ii) Where variances are provided, one cannot assume that they are applicable throughout the whole spatial or temporal scale(s) of one's extrapolation(s) for the particular fishery or fishing method under consideration.
(iii) Very large assumptions are often made when compiling jurisdictional bycatch estimates when one is forced to apply bycatch ratios from particular fisheries/methods to others that lack their own estimates (eg. due to there being little or no observer data). It is one thing to apply average ratios as "best guesses" in such situations due to the need to determine a total jurisdictional estimate – but it is an entirely different matter to assume that one can be "confident" about such an application by placing any sort of "confidence" limit (or

variance) around it. To do so would give one's audience a false impression of the accuracy with which one is making these estimates.

(iv) Finally, in virtually all cases where bycatch estimates have been made (with or without confidence limits), such confidence limits are mostly ignored by end-users anyway, who prefer to focus on the average estimates provided.

However, in situations where several studies have been done, it is possible to consider one's collection of bycatch estimates as replicate samples of the possible population of bycatch estimates throughout a fishery, method or jurisdiction, allowing one to calculate variances for the averages derived. This technique was used by Kelleher (2005) in his FAO global discard report and is the technique used in the present study – if such "replicate" ratios are available. Thus, any variances shown in this study derive from the population of bycatch ratios collected from replicate individual studies - they do not reflect the internal variance of individual records within those studies.

Quality/Performance Metrics

In designing a bycatch reporting system for Australia, it is important to include some way of identifying the quality of the estimates and extrapolations, and whether they are improving over time. In doing so, it would be remiss not to consider the very sophisticated performance measures and tracking tools developed in the US National Bycatch Report (NMFS, 2011 - for a summary see Kennelly 2014). Of particular interest here is the US's Tier Classification System which assists NMFS to track how they are improving the effectiveness of their bycatch monitoring programs, and the success (or otherwise) of their bycatch reduction programs. This system provides a measure of the relative quality of bycatch estimates via a detailed and prescriptive allocation of point scores (maximum of 73) against set criteria (see Table 1) using a series of guidelines (Table 2). The criteria assess many aspects of the data collected including the program design, its longevity, coverages, availability of "expansion factors" (used to extrapolate estimates to whole fisheries/jurisdictions), data collection biases, dataset management systems, analyses etc. The sophistication of the system reflects the large number and diversity of observer programs in the US and the corresponding resources provided by the US government to run them. One interesting point in this system is the very heavy weighting assigned to observer data (a maximum of 33 points) compared to industry-gathered data (a maximum of 2 points), illustrating the relative value that NMFS places on the accuracy of these two sources of bycatch information.

Table 1 - Criteria and scoring used to evaluate bycatch data quality and estimation methods in the US National Bycatch Report's tier classification system (from NMFS, 2011).

Tier Classification Criteria			**Maximum Scores**
Adequacy of Bycatch Data	Observer Data	Longevity of Observer Data	5
		Sampling Frame	3
		Sampling Design of Vessels/Permits/ Licenses	4
		Sampling Design of Trips	4
		Sampling Design of Hauls	4
		Spatial Coverage	2
		Temporal Coverage	2
		Vessel-Selection Bias	2
		Observer Bias	2
		Data Quality Control	5
		TOTAL	**33**
	Industry Data	**TOTAL**	**2**
	Supplementary Data	Data available as expansion factors for unobserved components	2
		Data available for stratification	2
		Data available for imputation	2
		Data available for model covariates	2
		Industry data verified	2
		TOTAL	**10**
	Database / IT	**TOTAL**	**2**
Quality of the Bycatch Estimate	Analytical Approach	Assumptions Identified, Tested, and Appropriate	10
		Peer Reviewed / Published Design	4
		Peer Reviewed / Published Analytical Approach	4
		Statistical Bias of Estimators	4
		Measures of Uncertainty	4
		TOTAL	**26**
TOTAL POINTS POSSIBLE			**73**

Table 2 - Table 3.1 from the US National Bycatch Report (NMFS, 2011) which provides the 20 criteria and associated scoring guidelines used to evaluate bycatch data quality and estimation methods through the Tier Classification system.

TIER CLASSIFICATION CRITERIA	SCORES
ADEQUACY OF BYCATCH DATA	
Observer Data	**33 points total maximum score, broken down as:**
Longevity of Observer Data	
0 = No observer program has ever been implemented.	5 points
1 = Observer program was conducted prior to 1995.	
2 = Observer program was conducted on one or more occasions during 1995–2000, but not annually.	
3 = Observer program was conducted annually during 1995–2000 and not subsequently.	
4 = Observer program was conducted on one or more occasions from 2001 to present, but not annually.	
5 = Observer program has been conducted annually from 2001 to present.	
Sampling Frame	
0 = No sampling frame	3 points
2 = Partial sampling frame	
3 = Complete sampling frame	
Sampling Design	
Sampling of Vessels/Permits/ Licenses	4 points
0 = No observer program, or sampling design does not support bycatch or total catch estimation.	
1 = Opportunistic or haphazard sampling, including voluntary observer programs, to support bycatch or total catch estimation.	
2 = Random sampling scheme or probability-based sampling with moderate observer coverage levels to support bycatch or total catch estimation.	
3 = Random sampling scheme or probability sampling with adequate observer coverage levels to support bycatch or total catch estimation.	
4 = Near-census of vessels with estimation required, or census of vessels with no estimation required.	
Sampling of Trips	4 points
0 = No observer program, or sampling design does not support bycatch or total catch estimation.	
1 = Opportunistic or haphazard sampling, including voluntary observer programs, to support bycatch or total catch estimation.	
2 = Random sampling scheme or probability-based sampling with pilot/baseline observer coverage levels to support bycatch or total catch estimation.	
3 = Random sampling scheme or probability sampling with adequate observer coverage levels to support bycatch or total catch estimation.	
4 = Near-census of trips with estimation required, or census of trips with no estimation required.	
Sampling of Hauls	4 points
0 = No observer program, or sampling design does not support bycatch or total catch estimation.	
1 = Opportunistic or haphazard sampling, including voluntary observer programs, to support bycatch or total catch estimation.	
2 = Random sampling scheme or probability-based sampling to support bycatch or total catch estimation.	
3 = Near-census of hauls with estimation required.	
4 = Census of hauls with no estimation required.	
Design Implementation	
Spatial Coverage	2 points
Add 0 points if no observer program has ever been implemented.	
Add 1 point if spatial coverage is limited.	
Add 2 points if spatial coverage is synoptic.	

TIER CLASSIFICATION CRITERIA	SCORES
ADEQUACY OF BYCATCH DATA	
Observer Data (cont.)	**33 points total maximum score, broken down as:**
Temporal Coverage	2 points
Add 0 points if no observer program has ever been implemented.	
Add 1 point if temporal coverage is limited.	
Add 2 points if temporal coverage is synoptic.	
Vessel-Selection Bias	2 points
Add 0 points if vessel-selection bias is high or unknown	
Add 2 points if vessel-selection bias is negligible or no bias exists.	
Observer Bias	2 points
Add 0 points if observer bias is high or unknown.	
Add 2 points if observer bias is negligible or no bias exists.	
Data Quality Control	
0 = No observer program, or no data quality control.	5 points
1 = Limited or incomplete observer training, no debriefing or other quality control.	
2 = One-time observer training, no debriefing or other quality-control measures.	
3 = Periodic observer training, minimal quality-control measures.	
4 = One time observer training, comprehensive quality-control measures.	
5 = Periodic observer training, comprehensive quality-control measures.	
Industry Bycatch Data	**2 points total maximum score, broken down as:**
0 = No industry bycatch data are available, or industry bycatch data are not used as a basis for bycatch estimates.	2 points
1 = Industry bycatch data available prior to 2000 are used as a basis for bycatch estimates.	
2 = Industry bycatch data available from 2000 to present are used as a basis for bycatch estimates.	
Supplemental Data	**10 points total maximum score, broken down as:**
Data available for use as expansion factors for unobserved components of the fishery.	
Add 0 points if supplemental data are not available as expansion factors.	2 points
Add 1 point if limited supplemental data are available as expansion factors.	
Add 2 points if extensive supplemental data are available or data are not necessary as expansion factors.	
Data available for stratification.	
Add 0 points if supplemental data are not available for stratification.	2 points
Add 1 point if limited supplemental data are available for stratification.	
Add 2 points if extensive supplemental data are available or data are not necessary for stratification.	
Data available for imputation.	
Add 0 points if supplemental data are not available for imputation.	2 points
Add 1 point if limited supplemental data are available for imputation.	
Add 2 points if extensive supplemental data are available or data are not necessary for imputation.	
Data available for model covariates.	
Add 0 points if supplemental data are not available for model covariates.	2 points
Add 1 point if limited supplemental data are available for model covariates.	
Add 2 points if extensive supplemental data are available or data are not necessary for model covariates.	

TIER CLASSIFICATION CRITERIA	SCORES
ADEQUACY OF BYCATCH DATA	
Supplemental Data (cont.)	**10 points total maximum score, broken down as:**
Industry data verified.	
Add 0 points if industry data are not verified or no industry data are available.	2 points
Add 1 point if some relevant industry data are verified.	
Add 2 points if all relevant industry data are verified.	
Database / IT Considerations	**2 points total maximum score, broken down as:**
0 = No observer data and/or supplemental data are available.	2 points
1 = Analytical approach is constrained because of database/IT considerations.	
3 = Analytical approach is not constrained because of database/IT considerations.	
QUALITY OF THE BYCATCH ESTIMATE	
Analytical Approach	**25 points total maximum score, broken down as:**
Assumptions Identified, Tested, and Appropriate	
0 = No bycatch estimation methodologies.	10 points
1 = Assumptions not identified or tested.	
3 = Assumptions identified and tested, but no assumptions have been resolved.	
5 = Minor assumptions identified, tested, and determined to be appropriate or resolved.	
8 = Critical assumptions identified, tested, and determined to be appropriate or resolved.	
10 = All assumptions identified, tested, and determined to be appropriate or resolved.	
Peer Reviewed / Published	
Observer Program Sampling Design	4 points
Add 0 points if the observer program sampling design has not been peer reviewed, or if the sampling design is found to be seriously flawed during peer review.	
Add 2 points if the observer program sampling design has been internally peer reviewed, or if problems were found during a peer review but they have not been fully addressed.	
Add 4 points if the observer program design has been externally peer reviewed.	
Analytical Approach	4 points
Add 0 points if the analytical approach has not been peer reviewed, or if the analytical approach is found to be seriously flawed during peer review	
Add 2 points if the analytical approach has been internally peer reviewed, or if problems were found during a peer review but they have not been fully addressed.	
Add 4 points if the analytical approach has been externally peer reviewed.	
Statistical Bias of Estimators	
0 = No bycatch estimation methodologies, or statistical bias is unknown.	4 points
2 = Estimators have high statistical bias.	
4 = Estimators have negligible statistical bias or are not statistically biased, or census sampling.	
Measures of Uncertainty	
0 = No bycatch estimation methodologies.	4 points
1 = Measures of uncertainty are not calculated.	
2 = Measures of uncertainty are calculated, but not at all levels (vessel/permit/license, trip, and haul).	
3 = Measures of uncertainty are calculated at all levels (vessel/permit/license, trip, and haul).	

Once scored using the above scheme, each region, bycatch category, stock and fishery is then placed into 5 tiers based on the scores as follows (Table 3):

Table 3 - Tier Descriptions used in the US system

Tier	Score	Description
4	66-73	Bycatch estimates were available and were based on the highest-quality data and analytical methods.
3	49-65	Bycatch estimates were also generally available but higher quality data (i.e., data that are more reliable, accurate, and/or precise than those used in lower tiers) were utilized to compute these estimates.
2	32-48	Bycatch estimates were generally available. However, these estimates would have benefited from improvements in data quality and/or analytical methods (such as improved sampling designs, increased coverage levels, and peer review of methods). Where by-catch estimates were not available, methods are being developed.
1	1-31	Bycatch data were available but were generally unreliable (e.g., from unverified or potentially biased sources). In some cases, higher quality data were available but analytical methods had not been implemented.
0	0	Bycatch data-collection programs or estimation methods did not exist and, therefore, bycatch estimates were not available.

In considering this system for use in an Australian context, we made one minor change to the scheme's criteria given in Table 2, by moving the key years against which longevity of programs were assessed forward by 9 years, from 1995, 2000 and 2001 to 2004, 2009 and 2010, respectively. This was because, in the US system, these years were selected to be 10 years and 5 years (respectively) prior to the latest year of data considered in the report (2005). In the present study, we are reporting on information whose latest year is 9 years later and so the necessary adjustment was required.

Case Study 1 – New South Wales

Introduction

NSW has a long and diverse history in bycatch quantification, beginning with Dannevig's (1904) pioneering work in Port Jackson – which was, in fact, one of the first observer studies done in the world. But it wasn't until the late 1990's that regular observer programs got underway in NSW with a large number of studies being done from that time to the present. However, unlike the use of continuous observer programs to monitor bycatch (as is the case in the US, Canada, regional tuna fisheries and some of Australia's Commonwealth fisheries), the limited resources available meant that NSW's observer programs have been strategic, short-term projects - where a particular fishery/fishing method is examined for a year or so before observer resources are moved onto another. The intention behind such a strategy was to do periodic (every decade or so) repeats of these targeted studies, but unfortunately this has rarely occurred (an exception being a current initiative to repeat the trawl observer work done 25 years ago). The overall result from these many studies is a large number of quite good, focussed projects being completed in NSW (and often published in international peer-reviewed journals), but few current programs, leaving one with estimates that are quite old. Notwithstanding this, the NSW bycatch studies provide an excellent and diverse basis (across many fishing methods and locations) on which one can derive state-wide estimates and begin to develop a methodology for ongoing reporting for all jurisdictions in Australia.

Catch and Effort Data

Since 2009 in NSW, we are fortunate in having available both forms of multiplier used to extrapolate bycatches from ratios – ie. total reported retained landings and fishing effort (as days fished) for all fisheries and fishing methods. This allows us to extrapolate bycatch ratios using both techniques. It is important to note, however, that either method has potential biases if there is any misreporting of catches and effort by fishers. For example, in NSW, it is believed that reports of landed catches are more accurate than fishing effort because fishers (and compliance officers) are able to check and verify landings records against sales receipts, co-op weigh-ins, etc., whereas estimates of the number of days spent fishing during each month have fewer opportunities for verification.

A data dump from the NSW Fishers' Catch Returns database provided annual records of reported landings and fishing effort records for each fishing method and some locations. Unfortunately, due to privacy provisions, large sections of the data were not able to be provided at a location-specific level, precluding a geographic examination of discarding in NSW at a finer scale than the whole state.

Table 4 contains summary information from the NSW Catch Returns Database on the average annual total landings and fishing effort reported by fishers for each fishery and method from 2009-10 to 2013-14. These data identified the commercial fisheries and fishing methods occurring in

NSW and formed the basis of the application of catch- and effort-based discard ratios throughout the jurisdiction.

Table 4 – Data from the NSW Catch Return Database on the mean (and SE's) for annual total landings and fishing effort reported by fishers for each fishery and method using the 5 years from 2009-10 to 2013-14.

Fishery	Method	Tonnes retained		Days fished	
		mean	SE	mean	SE
Estuary General	Meshing net	2024.02	48.43	17862	193.45
	Hauling net (general purpose)	948.35	132.90	3803.8	242.33
	Prawn net (set pocket)	157.84	24.84	1786.8	199.12
	Crab trap	111.28	11.10	7356.4	648.91
	Fish trap (bottom/demersal)	105.24	18.55	4038.4	296.37
	Flathead net	91.35	10.31	2197.2	124.69
	Eel trap	76.16	5.38	1601.4	124.88
	Prawn net (hauling)	73.75	6.09	1150.6	98.80
	Handgathering	73.60	14.41	4113.2	249.01
	Prawn running net	53.01	4.81	974	51.35
	Seine net (prawns)	44.52	5.14	805.4	67.78
	Bait net	19.03	4.87	61.25	14.01
	Garfish net (bullringing)	18.45	4.56	354.8	63.54
	Handline	13.69	1.81	633.2	78.82
	Pilchard, anchovy & bait net - beach based	6.59	1.08	29.4	2.68
	Setline	3.58	0.63	75	7.56
	Dip or scoop net (prawns)	0.50		8	
	Hoop or lift net	0.29	0.10	18.6	6.80
Estuary Prawn Trawl	Otter trawl net (prawns)	387.14	36.88	4679	246.93
Ocean Trawl	Otter trawl net (prawns)	1728.41	98.32	6446.8	177.62
	Otter trawl net (fish)	1253.93	90.15	1585.6	85.17
Ocean Haul	Hauling net (general purpose)	2382.16	162.68	2244.2	89.30
	Purse seine net	1780.64	291.51	1006.4	41.68
	Pilchard, anchovy & bait net - beach based	56.87	11.34	93	13.01
	Garfish net (hauling) - boat based	34.10	7.59	246.4	19.17

	Garfish net (hauling) - beach based	7.40	3.15	25.4	7.96
Ocean Trap & Line	Fish trap (bottom/demersal)	594.51	37.68	4916.8	168.29
	Handline	410.78	29.22	5657.2	304.07
	Trolling	173.17	31.39	2016.6	148.93
	Setline (demersal)	135.75	6.23	545.2	39.62
	Spanner crab net	111.00	12.08	835.2	62.15
	Jigging	87.09	9.73	849.8	38.24
	Dropline	72.46	13.67	673.2	95.41
	Setline	52.15	8.50	512.8	40.41
	Poling	45.28	15.57	105	17.06
	Trotline (bottom set)	28.06	9.43	304.4	31.71
	Driftline	16.61	7.81	139.4	17.00
Abalone	Diving	105.77	9.78	676.2	28.51
Lobster	Trapping	150.38	3.87	4706.8	100.68
Others	Danish seine trawl net (fish)	182.60	33.23	52.75	7.62
	Pilchard, anchovy & bait net - boat based	3.50	1.54	16.75	6.69
	Skindiving	1.63	0.94	26.75	14.59
Special Permits	Purse seine net	93.50	19.44	151	29.82
	Scallop Dredge	13.48	1.28	96	8.14
	Submersible Lift Net	11.02	3.69	26.6	4.52
	Eel trap	5.98	0.95	74	9.65

General Discards

All available papers, reports and datasets on fisheries bycatches, discards and TEPs interactions in NSW were gathered. This involved the collection and synthesis of approx. 50 documents and datasets. From these, retained:discard ratios and effort:discard ratios were derived. Sometimes this involved obtaining the ratios straight from the documents, sometimes it required making additional calculations from the data or graphs in the documents and sometimes it required interviewing individual authors or scientists. This work resulted in a reasonably large and diverse number of bycatch ratios for most commercial fishing methods used in NSW.

The first document that records bycatch levels in NSW and Australia (and one of the first in the world) is Dannevig's (1904) work in Sydney Harbour. Whilst this pioneering work quantified bycatches in a Port Jackson prawn fishery, the data provided did not include records of retained catches or fishing effort, precluding the use of the study to derive bycatch ratios for the method.

It was not until the late 1990's that more focussed, rigorous studies were done in NSW that allowed the determination of bycatch ratios (as weights retained:discarded and observed weights discarded per day fished) for many gear types and locations. The ratios from these studies are given in Table 5 and provide the basis upon which subsequent extrapolations for fisheries, fishing methods and the entire jurisdiction were done using the landings and effort records given in Table 4. On those occasions when more than one discard ratio was available for a fishery/method, the mean of the ratios was used as well as the SE around that mean. As noted earlier, on those occasions when SE's were provided for a discard ratio within a study, for the sake of consistency, only the ratio was used in subsequent calculations.

Extrapolated Estimates

The data in Table 5 were firstly combined with the data in Table 4 to compile extrapolated estimates of discard weights (Table 6) for those fishing methods where ratios were directly applicable. The gaps in Table 6 show where this was not possible. The notes provided in this table describe the various assumptions made when compiling these estimates. The calculations of SE's around these extrapolations used Goodman's (1960) technique for the calculation of the variance of products.

The next step was to try to reduce the gaps in Table 6 to obtain a more complete description of discards in the jurisdiction (Table 7). This involved applying ratios from similar fishing methods to those that lacked ratios, assuming negligible discards for certain methods and, where these could not be done, removing the fishing method from the table altogether (the latter involved removing methods responsible for just 4.3% of the retained catch and 5.3% of the days fished). The notes in the table provide details on the assumptions made during this exercise which involved significant consultation with NSW-based experts in the various fisheries.

As discussed earlier, using fishing effort to extrapolate discards is considered more accurate than using retained catches – as discards are more likely to be related to levels of fishing effort than to

the quantities of retained targeted catches. Therefore, the best available annual discard estimate for the NSW commercial fishing sector is 30.4% (SE 6.1) of the commercial catch (or 5,734 t).

Table 5 – Discard ratios as weights retained:discarded and observed weights of discards per day fished determined from all available NSW studies on bycatch. Data are provided for each fishery, fishing method and location examined.

Fishery	Method	Target spp.	Year(s)	Locations	Weights Retained: Discard ratio	Observed Kilograms Discards/day fished	Reference (s)	Note
Estuary General	Meshing Net	Mixed finfish	1999	Richmond River	1:0.023	1.58	Gray, 2002	
				Clarence River	1:0.333	23.73		
				Camden Haven	1:0.095	5.54		
				Port Stephens	1:0.333	23.73		
				Burrill Lake	1:0.451	36.38		
				Wallaga Lake	1:0.25	7.91		
			2001	Richmond River	1:0.021	5.67	Gray et al., 2005	
				Clarence River	1:0.052	6.35		
				Camden Haven	1:0.061	4.76		
				Wallis Lake	1:0.022	1.33		
				Lake Illawarra	1:0.041	7.14		
				Shoalhaven River	1:0.056	2.46		
	Estuarine Hauling Net (general purpose)		1998-99	Botany Bay	1:0.51	139.03	Gray et al., 2001	
				Lake Macquarie	1:1.353	389.92	Gray & Kennelly, 2003	
				St Georges Basin	1:1.464	342		
	Set Pocket (Stow) Net	Prawns	1991-93	Clarence River	1:0.38	8.7	Andrew et al., 1995	
			1999-2000	Lake Illawarra	1:0.09	13.45	Gray et al., 2006; Gray, 2004	
	Crab Trapping (pots)	Mud Crabs	2010	Corindi R., Wooli R.	1:0.171	na	Butcher et al., 2012	f
			2012	Corindi R	1:0.163	na	Broadhurst et al., 2015a	
			2012	Corindi R	1:0.113	na		
		Blue Swimmer crabs	2010	Wallis Lake	1:0.122	na	Leland et al., 2013	

	Fish Trapping	Bream	1999-2000	Statewide	1:0.14	na	Stewart & Ferrell, 2001; Stewart & Ferrell, 2003;	b
	Flathead gillnets	Dusky Flathead	2001	Wallis Lake	1:0.568	15.71	Gray et al., 2004	a
				Tuggerah Lake	1:1.431	36.07		
				Lake Illawarra	1:0.692	14.23		
	Prawn Net (hauling)	Prawns	1998-99	Richmond River	1:0.073	4.43	Gray et al., 2003; MacBeth & Gray, 2008	
				Manning River	1:0.522	35.44		
				Wallamba River	1:0.161	11.04		
				Shoalhaven River	1:0.253	4.58		
	Hand gathering	Pipis, Beachworms	2013	South Ballina Beach	1:0.11	4.49	Gray, 2016	
				Smoky, Killick, Goolawah Beaches	1:0.14	3.72		
	Running Net	Prawns	1999-2000	Lake Illawarra	1:0.12	5.79	Gray et al., 2006; Gray, 2004	
			2001	Tuggerah Lake	1:0.155	3.93	Gray, unpub data	
	Seine Net (Prawns)		1998-2002	Wallis Lake	1:0.32	12.5	MacBeth & Gray, 2008	
			1998-99	Tuggerah Lake	1:0.9	14.78	Gray, 2001	
			1999-2000	Lake Illawarra	1:0.25	10.2	Gray et al., 2006; Gray, 2004	
	Crab Trapping (hoop nets)	Mud Crabs	2012	Wallis Lake, Corindi R.	1:0.108	na	Broadhurst et al., 2015b	
		Blue Swimmer crabs	2010-2012	Wallis Lake, Corindi R.	1:0.034	na	Broadhurst et al., 2015b; Leland et al., 2013	
Estuarine Prawn Trawl	Prawn Trawl	Prawns	1989-92	Clarence River	1:0.238	20.77	Liggins & Kennelly, 1996; Kennelly, 1993	
				Lake Woolooweyah	1:0.333	20.3	Liggins & Kennelly, 1996; Kennelly, 1993	
				Hawkesbury River	1:1.18	34.8	Kennelly et al., 1992; Kennelly and Liggins, 1992; Kennelly, 1993	
				Botany Bay	1:2.262	54.29	Liggins et al., 1996; Kennelly, 1993	
				Port Jackson	1:1.81	31.18	Liggins et al., 1996; Kennelly, 1993	
		Squid	1991-92	Hawkesbury mouth	1:3.73	67.1	Kennelly, 1993; & unpub data	

Ocean Trawl	Prawn trawl	Prawns	1990-92	Ballina	1:5.137	795	Kennelly, 1993; Kennelly et al, 1998	c
				Iluka/Yamba	1:3.204	580.92		
				Coffs harbour	1:1.597	383.54		
				Port Stephens	1:1.991	245.77		
	Fish Trawl	Mixed Finfish	1993-95	North - Newcastle/Tuncurry	1:0.684	257	Liggins, 1996	
				Ulladulla	1:0.6	828		
				Eden	1:1.249	2319		
Ocean Haul	Hauling Net (general purpose)	Mixed finfish	2005	Statewide	1:0.002	5.97	MRAG, 2005	
	Garfish beach seine	Garfish	2005-06	Port Stephens	1:0.04	2.95	Stewart, 2007; Stewart, 2008	
Ocean Trap and Line	Fish Trapping	Mixed finfish	1999-2000	Statewide	1:0.056	13.79	Stewart & Ferrell, 2001; Stewart & Ferrell, 2003; Stewart & Hughes, 2008	
	Handline		2007-2009		1:0.14	6.72	MacBeth & Gray, 2016	
	Set/Trotline				1:0.15	53.68		
	Setline	Large sharks	2008-09	Several ports on North Coast	1:0.132	57.42	MacBeth et al., 2009	
	Dropline	Mixed finfish	2007-2009	Statewide	1:0.07	7.42	MacBeth & Gray, 2016	
	Spanner Crab Dillies	Spanner Crabs	2005-10	Northern NSW	1:0.31	na	DEEDI (2011f)	g
Abalone	Hand gathering	Abalone		State wide	1:0.09	na	Gibson et al., 2002	e
Lobster	Trap/pot	Lobster	1999-2002	State wide	1:0.84	17.86	NSW DPI, 2004	d

Notes:

a. Includes byproduct of crabs
b. Main 10 species used (other species not recorded). Weights derived from L/W keys (Stewart, pers.comm, Froese et al., 2013) because only numbers recorded.
c. Includes numerous byproduct species
d. Includes numerous byproduct species - main is hermit crabs
e. Uses lowest published figure for experienced divers of 11% discard because now only experienced divers operate. Uses average wts of retained as 0.336kg and discarded as 0.259kg
f. No observer data available so data from research trials of commercial gear were used. Retained and discarded quantities per day fished by commercial operators not available. No weight data available so average weights of retained (mud crabs 1.5kg, blue swimmers 0.5 kg) and discarded crabs (mud crabs 0.6kg, blue swimmers 0.2 kg) were used to convert numbers to weights.

g. Discards are mainly conspecifics and the data comes from the Queensland-based survey that includes NSW sites. A numbers to weight conversion had to be used where it was assumed average discarded individuals weighed one-third that of retained animals.

Table 6 – Annual discard estimates for each fishery and method, derived by multiplying together the data in Tables 4 and 5. SE's for mean discard rates (per weight retained and per day fished) are provided where replicate rates were available.

Fishery	Method	Tonnes Retained	SE	Days fished	SE	Mean discards /wt retained	SE	Discards/ day observed (kgs)	SE	Total Discards using retained wts to extrapolate (t)	SE	Total Discards using fishing effort to extrapolate (t)	SE	Notes
Estuary General	**Meshing net**	2024.02	48.43	17861.60	193.45	0.14	0.04	10.55	3.21	293.15	89.68	188.41	57.45	
	Hauling net (general purpose)	948.35	132.90	3803.80	242.33	1.11	0.30	290.32	76.90	1051.72	318.93	1104.31	300.27	
	Prawn net (set pocket)	157.84	24.84	1786.80	199.12	0.24	0.11	11.08	2.38	37.09	17.49	19.79	4.76	
	Crab trap	111.28	11.10	7356.40	648.91	0.14	0.01			15.83	2.25			a
	Fish trap (bottom/demersal)	105.24	18.55	4038.40	296.37	0.14	0.14			14.73	14.73			a,b
	Flathead net	91.35	10.31	2197.20	124.69	0.90	0.27	22.00	7.05	81.95	26.14	48.35	15.70	
	Eel trap	76.16	5.38	1601.40	124.88									c
	Prawn net (hauling)	73.75	6.09	1150.60	98.80	0.25	0.10	13.87	7.35	18.60	7.30	15.96	8.54	
	Handgathering	73.60	14.41	4113.20	249.01	0.13	0.02	4.11	0.39	9.20	2.10	16.88	1.88	
	Prawn running net	53.01	4.81	974.00	51.35	0.14	0.02	4.86	0.93	7.29	1.14	4.73	0.94	
	Seine net (prawns)	44.52	5.14	805.40	67.78	0.49	0.21	12.49	1.32	21.81	9.45	10.06	1.36	
	Bait net	19.03	4.87	61.25	14.01									c
	Garfish net (bullringing)	18.45	4.56	354.80	63.54									c
	Handline	13.69	1.81	633.20	78.82									c
	Pilchard, anchovy & bait net - beach based	6.59	1.08	29.40	2.68									c
	Setline	3.58	0.63	75.00	7.56									c
	Dip or scoop net (prawns)	0.50		8.00										c

	Hoop or lift net	0.29	0.10	18.60	6.80	0.07	0.04			0.02	0.01			a
Estuary Prawn Trawl	**Otter trawl net (prawns)**	387.14	36.88	4679.00	246.93	0.24	0.14	6.25	1.92	92.83	55.64	29.27	9.11	d
Ocean Trawl	**Otter trawl net (prawns)**	1728.41	98.32	6446.80	177.62	2.00	0.53	336.38	80.28	3458.69	941.86	2168.56	520.78	e
	Otter trawl net (fish)	1253.93	90.15	1585.60	85.17	0.84	0.20	1134.67	614.68	1058.74	265.99	1799.13	978.02	
Ocean Hauling	**Hauling net (general purpose)**	2382.16	162.68	2244.20	89.30	0.002	0.002	5.97	5.97	4.76	4.76	13.40	13.40	b
	Purse seine net	1780.64	291.51	1006.40	41.68									c
	Pilchard, anchovy & bait net - beach based	56.87	11.34	93.00	13.01									c
	Garfish net (hauling) - boat based	34.10	7.59	246.40	19.17									c
	Garfish net (hauling) - beach based	7.40	3.15	25.40	7.96	0.04	0.04	2.95	2.95	0.30	0.30	0.07	0.07	b
Ocean Trap & Line	**Fish trap (bottom/demersal)**	594.51	37.68	4916.80	168.29	0.02	0.02	4.63	4.63	11.30	11.30	22.76	22.76	b,f
	Handline	410.78	29.22	5657.20	304.07	0.14	0.14	6.72	6.72	57.51	57.51	38.02	38.02	b
	Trolling	173.17	31.39	2016.60	148.93									c
	Setline (demersal)	135.75	6.23	545.20	39.62	0.15	0.15	53.68	53.68	20.36	20.36	29.27	29.27	b
	Spanner crab net	111.00	12.08	835.20	62.15	0.31	0.02			34.90	4.54			
	Jigging	87.09	9.73	849.80	38.24									c
	Dropline	72.46	13.67	673.20	95.41	0.07	0.07	7.42	7.42	5.07	5.07	5.00	5.00	b
	Setline	52.15	8.50	512.80	40.41	0.13	0.13	57.42	57.42	6.88	6.88	29.44	29.44	b
	Poling	45.28	15.57	105.00	17.06									c
	Trotline (bottom set)	28.06	9.43	304.40	31.71									c
	Driftline	16.61	7.81	139.40	17.00									c
Abalone	**Diving**	105.77	9.78	676.20	28.51	0.09	0.09			9.52	0.88			a,b
Lobster	**Trapping**	150.38	3.87	4706.80	100.68	0.84	0.84	17.86	17.86	126.32	126.32	84.06	84.06	b
Others	**Danish seine trawl net (fish)**	182.60	33.23	52.75	7.62									c
	Pilchard, anchovy & bait net - boat based	3.50	1.54	16.75	6.69									c
	Skindiving	1.63	0.94	26.75	14.59									c
Special Permits	**Purse seine net**	93.50	19.44	151.00	29.82									c

	Scallop Dredge	13.48	1.28	96.00	8.14									c
	Submersible Lift Net	11.02	3.69	26.60	4.52									c
	Eel trap	5.98	0.95	74.00	9.65									c

Notes:

a. No daily discard rate available
b. Insufficient studies to calculate discard SE so mean was used as the SE
c. No discard data available
d. Excludes discard estimates for estuaries now closed to fishing and includes a 82.5% reduction in discards due to BRDs (Broadhurst & Kennelly, 1996)
e. Includes a 32.9% reduction in discards due to BRDs (Broadhurst & Kennelly, 1997)
f. Includes reductions in discards due to BRDs as estimated in Stewart & Ferrell (2001b)

Table 7 - Discard estimates (and SE's) for each fishery and method with total estimates for all fisheries and methods derived from Table 6. Where there were no discard data available (and one could not assume zero discards or use discard estimates from other methods), those methods were removed. These latter fisheries accounted for an average of just 591.24 tonnes/year retained catch and 4512.55 days fished/year (4.3% and 5.3%, respectively).

Fishery	Method	Tonnes Retained	SE	Days fished	SE	Total Discards using retained wts to extrapolate (t)	SE	Total Discards using fishing effort to extrapolate (t)	SE	Notes
Estuary General	**Meshing net**	2024.02	48.43	17861.60	193.45	293.15	89.68	188.41	57.45	
	Hauling net (general purpose)	948.35	132.90	3803.80	242.33	1051.72	318.93	1104.31	300.27	
	Prawn net (set pocket)	157.84	24.84	1786.80	199.12	37.09	17.49	19.79	4.76	
	Crab trap	111.28	11.10	7356.40	648.91	15.83	2.25	15.83	2.25	a
	Fish trap (bottom/demersal)	105.24	18.55	4038.40	296.37	14.73	14.73	14.73	14.73	a
	Flathead net	91.35	10.31	2197.20	124.69	81.95	26.14	48.35	15.70	
	Prawn net (hauling)	73.75	6.09	1150.60	98.80	18.60	7.30	15.96	8.54	
	Handgathering	73.60	14.41	4113.20	249.01	9.20	2.10	16.88	1.88	
	Prawn running net	53.01	4.81	974.00	51.35	7.29	1.14	4.73	0.94	

	Seine net (prawns)	44.52	5.14	805.40	67.78	21.81	9.45	10.06	1.36	
	Bait net	19.03	4.87	61.25	14.01	0.00	0.00	0.00	0.00	b
	Handline	13.69	1.81	633.20	78.82	1.92	1.92	4.26	4.26	c
	Pilchard, anchovy & bait net - beach based	6.59	1.08	29.40	2.68	0.00	0.00	0.00	0.00	b
	Setline	3.58	0.63	75.00	7.56	0.47	0.47	4.31	4.31	d
	Dip or scoop net (prawns)	0.50		8.00		0.00	0.00	0.00	0.00	b
Estuary Prawn Trawl	**Otter trawl net (prawns)**	387.14	36.88	4679.00	246.93	92.83	55.64	29.27	9.11	
Ocean Trawl	**Otter trawl net (prawns)**	1728.41	98.32	6446.80	177.62	3458.69	941.86	2168.56	520.78	
	Otter trawl net (fish)	1253.93	90.15	1585.60	85.17	1058.74	265.99	1799.13	978.02	
Ocean Hauling	**Hauling net (general purpose)**	2382.16	162.68	2244.20	89.30	4.76	4.76	13.40	13.40	
	Purse seine net	1780.64	291.51	1006.40	41.68	0.00	0.00	0.00	0.00	b
	Pilchard, anchovy & bait net - beach based	56.87	11.34	93.00	13.01	0.00	0.00	0.00	0.00	b
	Garfish net (hauling) - boat based	34.10	7.59	246.40	19.17	0.00	0.00	0.00	0.00	b
	Garfish net (hauling) - beach based	7.40	3.15	25.40	7.96	0.30	0.30	0.07	0.07	
Ocean Trap & Line	**Fish trap (bottom/demersal)**	594.51	37.68	4916.80	168.29	11.30	11.30	22.76	22.76	
	Handline	410.78	29.22	5657.20	304.07	57.51	57.51	38.02	38.02	
	Setline (demersal)	135.75	6.23	545.20	39.62	20.36	20.36	29.27	29.27	
	Spanner Crabbing	111.00	12.08	835.2	62.15	34.90	4.54	34.90	4.54	a
	Jigging	87.09	9.73	849.80	38.24	12.19	12.19	5.71	5.71	c
	Dropline	72.46	13.67	673.20	95.41	5.07	5.07	5.00	5.00	
	Setline	52.15	8.50	512.80	40.41	6.88	6.88	29.44	29.44	
	Poling	45.28	15.57	105.00	17.06	6.34	6.34	0.71	0.71	c
	Trotline (bottom set)	28.06	9.43	304.40	31.71	4.21	4.21	16.34	16.34	e
Abalone	**Diving**	105.77	9.78	676.20	28.51	9.52	9.52	9.52	9.52	a
Lobster	**Trapping**	150.38	3.87	4706.80	100.68	126.32	126.32	84.06	84.06	
Others	**Pilchard, anchovy & bait net - boat based**	3.50	1.54	16.75	6.69	0.00	0.00	0.00	0.00	b

	Skindiving	1.63	0.94	26.75	14.59	0.00	0.00	0.00	0.00	b
	TOTALS:	13155.35	394.43	81047.15	1003.36	6463.69	1045.13	5733.77	1154.66	
	DISCARD PERCENTAGES:					**32.95**	**5.33**	**30.35**	**6.11**	

Notes:

a. No daily discard rate available so used discard rate per weight retained
b. No data available but assume negligible discards
c. Assumes discard rate for ocean handline
d. Assumes discard rate for ocean setline
e. Assumes discard rate for ocean setline (demersal)

Threatened, Endangered and Protected (TEP) species

For TEP species, only one fishery in NSW had any discards recorded in the available observer studies examined (the Ocean Trap and Line Fishery) and the numbers of individuals observed were very small (Table 8). However, in addition, all commercial fishers in NSW are required to report any TEP interactions on a dedicated form. The data so gathered for the only complete year available (2014-15) are provided in Table 9.

Table 8 – Discard estimates of the numbers of TEP species recorded in NSW's studies on bycatch and the numbers of fishing days observed over which these individuals were observed.

Fishery	Method	Target spp.	Year(s)	Locations	Days Observed	All TEPs interactions during all days observed	Reference (s)
Ocean Trap and Line	Handline	Mixed finfish	2007-09	Statewide	142	1 Black Rock Cod, 1 Short-tail Shearwater, 1 Humpback Whale	MacBeth & Gray, 2016
	Dropline				77	18 Harrisons Dogfish, 3 Southern Dogfish	
	Set/Trotline				88	17 Southern Dogfish, 4 White Sharks, 2 Greynurse Sharks, 2 Eastern Blue Devil fish, 2 Great Hammerheads	
	Setline	Large sharks	2008-09	Several ports on North Coast	114	53 Scalloped Hammerheads, 6 White Sharks, 5 Greynurse Sharks, 2 Green Turtles	MacBeth et al., 2009

Table 9 – Number of TEP species reported as discarded in the NSW Commercial Fishers' Catch database for 2014-15.

Fishery	Method	All TEPs interactions reported
Ocean Trap and Line	Handline	1 Black Rockcod 1 Scalloped Hammerhead 1 White Shark 2 Greynurse Sharks 2 Great Hammerheads
	Dropline	2 White Sharks
	Trolling	1 Scalloped Hammerhead
	Setline	1 Scalloped Hammerhead
	Fish Trap	1 Leatherback Turtle

Ocean Trawl	Fish Trawl	1 seal 6 great hammerheads 8 scalloped hammerheads
	Prawn Trawl	1 grey nurse shark
Ocean Haul	Haul net	1 grey nurse shark
Estuary General	Haul net	44 green turtles
	Crab trap	12 green turtles

It is tempting to extrapolate the very limited observer data in Table 8 using the corresponding effort data from Table 4 (as done above for the general discard information). That is, because the average days fished/year (09/10 to 13/14) for each method (see Table 4) were: Handline 5657 days, Dropline 673 days, Set/Trotline 304 days and Setline (Large Sharks) 513 days, and the number of observed days in Table 8 for these methods were 142, 77, 88 and 114, the numbers of animals observed for each method could be multiplied by 39.8, 8.7, 3.5 and 4.5, respectively to give annual estimates of discards of these TEP species. However, the very small number of TEPs interactions recorded makes such extrapolations extremely tenuous (at best), probably erroneous, and dangerously controversial in terms of the total numbers of TEPs species that would be estimated from such extrapolations. We therefore do not provide such extrapolations here. This is further justified by a consideration of the relative quality of the NSW TEPs data obtained by applying the US Bycatch Report's Tier Classification Scheme's 20 quality criteria to the NSW TEPs information (see below and Appendix 2). The results (Table 11) reveal very poor information – an average of just 5.14% and a tier class of 0.4. Clearly information that yields such a low quality metric should not be used for extrapolations.

Quality/Performance Metrics

Table 10 contains the results from an application of the US National Bycatch Report's 20 Tier Classification criteria for estimating the quality/performance of bycatch estimation methods to the NSW information. The 920 estimated scores are contained in Appendix 1. The total points possible for each method/fishery is 73 with the 5 tiers ranked from 0 (for methods with no discard data) through to 4 (the best quality information) (see Tables 2 and 3).

Table 10 – The quality of NSW's discard information derived from an application of the US system's Tier Classification Criteria (see Appendix 1 for detailed scores). Also added is a weighted % score taking account of the relative quantity of discards estimated for each fishery and method (from Table 7).

Fishery	Method	TOTAL POINTS (maximum = 73)	% score (maximum = 100)	Tier (maximum = 4)	% score weighted by estimated discards	Note
Estuary General	**Meshing net**	40	54.79	2	1.81	
	Hauling net (general purpose)	40	54.79	2	10.62	
	Prawn net (set pocket)	39	53.42	2	0.19	
	Crab trap	17	23.29	1	0.06	
	Fish trap (bottom/demersal)	34	46.58	2	0.12	
	Flathead net	40	54.79	2	0.46	
	Eel trap	0	0.00	0	0.00	
	Prawn net (hauling)	40	54.79	2	0.15	
	Handgathering	43	58.90	2	0.17	
	Prawn running net	39	53.42	2	0.04	
	Seine net (prawns)	40	54.79	2	0.10	
	Bait net					1
	Garfish net (bullringing)	0	0.00	0	0.00	
	Handline	16	21.92	1	0.02	
	Pilchard, anchovy & bait net - beach based	0	0.00	0	0.00	
	Setline	14	19.18	1	0.01	
	Dip or scoop net (prawns)					1
	Hoop or lift net					1
Estuary Prawn Trawl	**Otter trawl net (prawns)**	41	56.16	3	0.29	
Ocean Trawl	**Otter trawl net (prawns)**	41	56.16	3	21.37	
	Otter trawl net (fish)	41	56.16	3	17.73	
Ocean Hauling	**Hauling net (general purpose)**	40	54.79	3	0.13	
	Purse seine net	0	0.00	0	0.00	
	Pilchard, anchovy & bait net - beach based	0	0.00	0	0.00	
	Garfish net (hauling) - boat based	0	0.00	0	0.00	
	Garfish net (hauling) - beach based	40	54.79	3	0.00	
Ocean Trap & Line	**Fish trap (bottom/demersal)**	34	46.58	2	0.19	

	Handline	39	53.42	3	0.36	
	Trolling	0	0.00	0	0.00	
	Setline (demersal)	39	53.42	3	0.27	
	Spanner crab net	14	19.18	1	0.12	
	Jigging	14	19.18	1	0.02	
	Dropline	39	53.42	3	0.05	
	Setline	39	53.42	3	0.28	
	Poling	14	19.18	1	0.00	
	Trotline (bottom set)	14	19.18	1	0.05	
	Driftline	0	0.00	0	0.00	
Abalone	**Diving**	11	15.07	1	0.03	
Lobster	**Trapping**	38	52.05	3	0.77	
Others	**Danish seine trawl net (fish)**	0	0.00	0	0.00	
	Pilchard, anchovy & bait net - boat based	0	0.00	0	0.00	
	Skindiving					1
Special Permits	**Purse seine net**	0	0.00	0	0.00	
	Scallop Dredge	0	0.00	0	0.00	
	Submersible Lift Net	0	0.00	0	0.00	
	Eel trap	0	0.00	0	0.00	
AVERAGE SCORES:		**21.43**	**29.35**	**1.38**		
TOTAL Weighted Quality Metric (%)					**55.08**	
[1]assumes zero discards and no need to quantify discards and therefore a quality metric is not applicable						

For NSW, average scores were 21.43 (out of 73) or 29.3% with an average tier of 1.4. However, these averages do not account for the relative level of discards that are estimated to have come from each method. That is, ideally having better quality data for those methods with high discards should elevate the overall quality score for the jurisdiction. The final column in Table 10 was therefore created to provide the percentage scores weighted by the amount of discards estimated to be associated with each method (from Table 7). Providing such a weighting increases the average quality score for NSW to 55.08%.

As mentioned above, a consideration of the relative quality of the NSW TEPs data obtained by applying the US Bycatch Report's Tier Classification Scheme's 20 quality criteria to the NSW TEPs information (Table 11) reveal very poor information – an average of just 5.14% and a tier class of 0.4.

Table 11 – Quality of discard data for TEP species derived from an application of the US system's Tier Classification Criteria (see Appendix 2 for detailed scores).

Fishery	Method	TOTAL POINTS (maximum = 73)	% score (maximum = 100)	Tier (maximum = 4)	Note
Estuary General	**Meshing net**	0	0.00	0	
	Hauling net (general purpose)	2	2.74	1	
	Prawn net (set pocket)	0	0.00	0	
	Crab trap	2	2.74	1	
	Fish trap (bottom/demersal)	0	0.00	0	
	Flathead net	0	0.00	0	
	Eel trap	0	0.00	0	
	Prawn net (hauling)	0	0.00	0	
	Handgathering				1
	Prawn running net	0	0.00	0	
	Seine net (prawns)	0	0.00	0	
	Bait net				1
	Garfish net (bullringing)	0	0.00	0	
	Handline	0	0.00	0	
	Pilchard, anchovy & bait net - beach based	0	0.00	0	
	Setline	0	0.00	0	
	Dip or scoop net (prawns)				1
	Hoop or lift net				1
Estuary Prawn Trawl	**Otter trawl net (prawns)**	0	0.00	0	
Ocean Trawl	**Otter trawl net (prawns)**	2	2.74	1	
	Otter trawl net (fish)	2	2.74	1	
Ocean Hauling	**Hauling net (general purpose)**	2	2.74	1	1
	Purse seine net	0	0.00	0	
	Pilchard, anchovy & bait net - beach based	0	0.00	0	
	Garfish net (hauling) - boat based	0	0.00	0	
	Garfish net (hauling) - beach based	0	0.00	0	
Ocean Trap & Line	**Fish trap (bottom/demersal)**	2	2.74	1	
	Handline	34	46.58	2	
	Trolling	2	2.74	1	
	Setline (demersal)	34	46.58	2	
	Spanner crab net	2	2.74	1	
	Jigging	0	0.00	0	
	Dropline	34	46.58	2	
	Setline	32	43.84	2	
	Poling	0	0.00	0	

	Trotline (bottom set)	0	0.00	0	
	Driftline	0	0.00	0	
Abalone	**Diving**				1
Lobster	**Trapping**	0	0.00	0	
Others	**Danish seine trawl net (fish)**	0	0.00	0	
	Pilchard, anchovy & bait net - boat based	0	0.00	0	
	Skindiving				1
Special Permits	**Purse seine net**	0	0.00	0	
	Scallop Dredge	0	0.00	0	
	Submersible Lift Net	0	0.00	0	
	Eel trap	0	0.00	0	
AVERAGE SCORES:		**3.75**	**5.14**	**0.40**	
[1]assumes zero interactions and no need to quantify them so a quality metric is not applicable					

Discussion

This case study's results indicate that NSW's commercial sector discards around 30% of its total catch (or approx. 5,700t) (Table 7). Of the 45 commercial fisheries examined, sufficient data to do an assessment were available for the majority (36 - see Table 7). For these, the vast majority of discards (88.5%) came from just three fisheries (Ocean Prawn Trawl – 37.8%, Ocean Fish Trawl – 31.4% and the Estuary General Haul Net fishery – 19.3%). This not only indicates that most of the fishing methods used in NSW have relatively few discards, but also identifies these 3 fisheries as those where bycatch reduction initiatives should be focussed which, for the most part, has been the case.

It is obvious that the results obtained in this case study required many assumptions when extrapolating up somewhat limited discard ratios (at least in time and often in space) by total retained catches and fishing effort. However, a positive corollary from these assumptions is the identification of where and how to improve subsequent monitoring and reporting of discards in this jurisdiction.

The most general assumption required in this study was the need to use quite dated discard ratios (often more than 20 years old). Much may have changed during the intervening years with regards to fishing practices in NSW and, whilst this study tried to account for some of these (such as the implementation of BRDs in some methods), an obvious priority for improvement in discard reporting would be to update these old ratios through repeated observer programs and/or other bycatch monitoring methods (like camera-audited industry logbooks). A similar conclusion is obvious for those methods where no ratios are available but where discards were assumed to be negligible (Bait net, Pilchard, anchovy & bait net - beach based, Dip or scoop net (prawns), Purse seine net, Pilchard, anchovy & bait net - beach based, Garfish net (hauling) - boat based, Pilchard, anchovy & bait net - boat based and Skindiving), or where ratios were substituted from other methods and fisheries (Estuarine Handline and Setline, Jigging, Poling and Trotline - bottom set,

Spanner crabbing), from experimental studies or some other data (Crab trapping, Estuarine fish trapping and Abalone). Clearly such gaps would ideally be filled with empirical data - even if small-scale studies were done occasionally (or even just once) for methods considered to have low levels of discarding. And, for those methods where no such substitutions were possible at all and so they were simply removed from the summary tables (Garfish net (bullringing), Driftline, Danish seine trawl net (fish) and the Special Permit fisheries of Purse seine net, Eel Traps, Scallop Dredging and Submersible Lift Net – albeit accounting for just 4.3% and 5.3% of the total catch and effort, respectively), one ideally would obtain at least some discard estimates. This is especially the case for the "Special Permit" fishing methods where it is surprising that the collection of discard information is not required as part of the permit conditions.

The data quality metric developed here for NSW (Table 10 - which was simply a weighted version of the quite rigorous US Tier Classification system) provided a "pass-level" score of 55% for general discards. Not surprisingly, for TEP species, the situation is starker, as there are basically too few reliable data available (a data quality metric of 5.4% - Table 11) to make any sort of confident total estimate regarding interactions with these species.

But again, this sort of information serves well to inform future monitoring programs which, in the case for particularly problematic TEP species (in NSW these might include Greynurse Sharks, green turtles, etc), may need to be tailored for those particular interactions – perhaps using the new techniques that continue to be developed using observers, industry-based study fleets and especially automated camera technology to audit logbook data (eg. McElderry et al, 2007).

Notwithstanding the above assumptions that are necessary in a study like this, the results suggest that the discard information for NSW is, by most standards, relatively robust – at least for general discards, if not for TEP species. That is, the information proved sufficient to provide an estimate of the total amount of discards and an overall discard rate (with reasonably small variances), across what is quite a diverse array of 36 fisheries/methods. The availability of NSW's discard ratios across such a wide variety of fishing methods also provides a useful pool of substitutes that may be able to fill gaps in fisheries with similar methods in other jurisdictions. Further, the data from NSW allowed the more accurate use of effort data for discard extrapolations rather than retained catches - a relatively rare situation in many of the world's jurisdictions. And finally, the whole process yielded a data quality metric for general discards (based on the quite rigorous US system) that is, by most international standards, relatively good (55%).

In conclusion, as a first case study to develop a national bycatch reporting system for Australia, the NSW jurisdiction has provided an excellent starting point.

Case Study 2 – Tasmania

Introduction

There are 8 commercial wild harvest fisheries in Tasmania: the Abalone, Commercial Dive and Shellfish, Giant Crab, Southern Rock Lobster, Scalefish, Octopus, Scallop and Seaweed fisheries.

Each of these fisheries have different bycatch and discarding issues, and most have little data about them. Some of these fisheries can be expected to have little (or no) discarding, as the principal method used is hand-gathering. These include the large Abalone fishery and the Commercial Dive and Shellfish fishery (which harvests Sea Urchins, Oysters, Whelks, Periwinkles, Clams, etc.). For such fisheries, discard rates can be assumed to be negligible with only a small number of individuals likely to be discarded due to being undersize, in excess of bag limits or otherwise undesirable. For the Seaweed fishery, which is based around the collection of washed-up beach wrack, discards of animals are also likely to be minimal.

But for the other commercial fisheries in Tasmania, which involve methods like pots, traps, nets, etc., discards are not likely to be negligible and are probably similar in scale to fisheries elsewhere that employ such methods. But the main problem associated with reporting on discards from these fisheries is the fact that there exists virtually no data that directly quantifies these discards. In fact, despite a close examination of the available reports, papers and datasets, the only ongoing, systematic estimates of bycatches in any of these fisheries come from the Rock Lobster fishery whose CrayBase dataset provides bycatch estimates (in numbers of individuals) of species derived from research surveys and observer data.

Indeed, the recording of discards as numbers of individuals and not weights occurs in most instances where discard data were found for Tasmania's commercial fisheries. While estimating discards this way is appropriate for the uses of such data in this jurisdiction, such estimates can prove problematic when extrapolating estimates and when making comparisons with other jurisdictions and fisheries. That is, as noted earlier, when one uses total retained catches (which are reported as weights) to extrapolate discard rates to fishery/method/jurisdictional levels, and when one reports discards as percentages of the catch (as done by FAO, the US and most jurisdictions), one requires discard estimates as weights (not numbers).

Despite the above issues, we continued to explore ways to report on discards from Tasmania's commercial fisheries using the methodology developed for NSW earlier.

Catch data

As for NSW, we begin by listing the various fisheries in Tasmania by method and their average landings over the most recent 5 years when data are available (Table 12). Unlike NSW, fishing effort data for these fisheries are not available.

Table 12 – Retained annual average catches (and SE's) from Tasmania's commercial fisheries, using the most recently available 5 years of data.

Fishery	Method	Years	Target	Retained catch (tonnes)	SE	Note
Abalone	Dive	2011-15	Blacklip and Greenlip Abalone	2139.8	124.5	
Southern Rock Lobster	Pots		Southern Rock Lobster	1126.7	52.6	1
Scallop	Dredge		Commercial Scallop	677.9	185.7	
Octopus	Pots (unbaited)		Palid Octopus	79.5	14.3	
Giant Crab	Pots		Giant Crab	29.4	2.8	
Scalefish	Automatic squid jig	2010-14	Squid	251.0	183.6	
	Beach seine		Mixed finfish	243.7	62.2	
	Purse seine			239.6	198.6	
	Graball net			105.9	5.8	
	Hand line			81.0	2.8	
	Danish seine			70.5	8.7	
	Squid-jig		Squid	51.4	3.9	
	Dip-net		Mixed finfish	19.3	1.5	
	Small mesh net			11.0	1.7	
	Troll			8.8	1.5	
	Fish trap			8.5	0.4	
	Drop-line			5.2	1.0	
	Spear			4.2	0.3	
	Hand collection		Other species	2.7	0.8	
Dive and Shellfish	Hand Collection	2011-15	Shellfish	42.9	4.6	
Seaweed	data not available					

[1]Includes an average of 12.1 tonnes (SE 1.5) of non-lobster retained bycatch, recorded by fishers in logbooks.

General Discards

The next step in reporting on discards in these fisheries was to identify any discard rates that were available for each fishery/method. However, as mentioned above, there are very few of these rates that are directly available. Taking each in turn:

The Tasmanian Abalone fishery, which uses hand-gathering, can be expected to have very little discarding - although there may be occasional discarding from vessels of undersize/undesirable/over-quota individuals, and this may vary with the experience of divers. Whilst this has not been estimated for the Tasmanian fishery, we saw earlier (Table 5) that, in NSW, such discarding may be around 8.3% of landings (or a retained: discard ratio of 1:0.09 - Gibson et al., 2002).

For the Rock Lobster fishery, Emery et al. (2016) notes that retained bycatch (by-product) includes a variety of species, mainly dominated by Octopus, Leatherjackets, Conger Eels, various species of crabs, cods and wrasses, and account for only 1.1% of landings. Discards from this fishery (as

estimated by observers) include smaller or undesired individuals of these same species but also include Hermit Crabs (the majority of non-lobster discards by number). The total number of all these individuals discarded per year was estimated (from observer data) to be an average of 9,226,059 (SE 1,021,496). However, in addition, due to size limits, 71% of all lobsters caught were estimated to also be discarded - from 2000 to 2010, an average of 6,684,122 (± 95% CI of 448,325) annually. This means that, annually 15,910,181 animals (SE 1,026,605) can be estimated to be discarded from this fishery.

A problem with these discard estimates, however, as mentioned above, concerns their units - the number of individuals of each species discarded, with no equivalents given in weights. The latter are required to provide discard rates for the entire fishery (as a percentage of catch), to provide a basis for comparisons with other fisheries and jurisdictions, and also to use landings records as extrapolators to derive total estimates. For example, whilst one could simply use the estimate of individuals discarded and apply it to landings weights, this would be erroneous because the average weight of discarded animals should be much less than that for retained animals. Clearly estimates of the average weights of discarded individuals from this fishery are required to determine a fishery-specific discard rate, and estimates of total discards. In the absence of any discard weight estimates, one could simply apply the estimates obtained in NSW for a similar fishery (a ratio of 1:0.84 or 45.65% discarding – NSW DPI, 2004). But for the purposes of the present exercise, and to use the Tasmanian data available, we have assumed that, on average, discarded lobsters and other discarded individuals in this fishery weigh one third that of the average retained lobster. This provides a weight-based retained:discard ratio for the fishery of 1:1.94 (or a discard rate of 66.02%).

For the Tasmanian Scallop fishery, despite there being a significant number of published reports about the fishery and even one tantalizingly titled “Juvenile Scallop Discard Rates and Bed Dynamics: Testing the Management Rules for Scallops in Bass Strait” (Haddon et al., 2006), very few actual rates of discarding are available. For example, while Haddon et al. (2006) examines the efficacy of the 20% “trashing rule” for discards of juvenile scallops, the authors do not provide estimates of the actual level of discards, basically assuming it to be 20% or less - because if it were more than 20%, the fishery would not operate. This logic is also confirmed by DEH (2005) who even note that “operators are not required to record discarded scallops in their logbooks, even though discards would generally consist of undersized or damaged scallops” because “DPIWE states that it is not necessary to collect quantitative data on discards from commercial fishers since discard criteria, such as percent of undersized scallops, is used to determine if areas are suitable to open for commercial dredge fishing. If the discard rate is too high, the area remains closed to fishing”. AFMA (2015) also note that the Harvest Strategy for the Commonwealth portion of the fishery directs the industry co-management committee to voluntarily close scallop beds that do not meet the discard rate of less than 20 per cent of scallops smaller than 85mm in length. And it is also reported that fishers tend to voluntarily avoid areas found to contain undersized scallops because it is not in their commercial interests to continue fishing these locations. However, AFMA (2015) also note that all concession holders in their fishery are required

to complete a logbook - which includes scope to record information about discards, other bycatch species and interactions with TEP species. So it would seem that at least some discard data (albeit from Commonwealth logbooks and not observer programs) may be available for this fishery. But these were not provided for this study.

Despite this lack of data, if one assumes that the scallop fishery operates at around half the 20% scallop discard level (by weight) and there is negligible discarding of any other species, then one could estimate that the retained:discard ratio for the fishery is 1: 0.11.

For the Octopus fishery, whilst Emery and Hartmann (2016) give a recreational discard rate of the number of cephalopods discarded as 61.8% of the total catch, no data are provided on discards from the commercial fishery. Gardner (pers. comm.) advises that there are three components in the commercial octopus fishery: (i) byproduct of *Octopus maorum* from the lobster fishery; (ii) hand collection of *O. maorum* from knee-deep water; and (iii) trapping of *O. palidus* and *O. tetricus*. There are noted to be negligible discards for all three components - there is no size limit and the pots used in the main targeted fishery (iii above) are designed to catch larger animals - so we assume a zero discard rate for this fishery.

For the Giant Crab fishery, Emery et al. (2015b) notes that observer work and industry logbooks reveal negligible discards of undersize crabs on the east coast but approx. 0.4 crabs/potlift on the west coast (NB. "potlifts" are standardised to be soak days of pots because pots can be set for many days). With an average weight of undersize crabs at approx. 2.5 kg, and approx. 15,000 potlifts per annum, this leads to a state-wide estimate of approx. 15 tonnes of undersize giant crabs discarded per year (a discard rate of approx. 33.78%). With regard to other discards, in 2009-10, an examination was made of the discards recorded in photographs taken by fishers of approx. 1900 pot lifts (Hartmann and Gardner, 2011). The most common species discarded were Draughtboard Sharks (29% of the total bycatch) and Hermit Crabs (25%). Smaller quantities of Southern Whiptail, Jackass Morwong, Pink Ling, Antlered Crab, Brittle Stars, Southern Rock Lobster, Bearded Cod and Knifejaw were also discarded. Actual numbers or weights of these discards were not provided but can be assumed to be very low. For byproduct, logbook data indicate~~s~~ negligible levels of landed species (for bait or sale) - in 2013/2014, just 52 kgs were recorded, comprised of unspecified crabs, Ling, Conger Eels, Morwong, Striped Trumpeter and Octopus.

For the multi-method Scalefish fishery, most methods have no discard rates available (Emery et al., 2015a). But for some methods (the two squid jig methods, dip-nets, spears, purse-seine and hand collection), one could assume negligible discards. For the others, however, discarding would almost certainly be occurring. Some discard data exists for the graball gillnet and small mesh net methods, summarised by Lyle et al. (2014) as "discard rates for by-catch species for these methods tended to exceed 80%, whereas discard rates for species typically targeted or retained as by-product typically ranged between 10 – 20%". Table A1.3 in Lyle et al. (2014) gives the retention rate of each species (by numbers) caught by commercial fishers by each of these nets (based on-

board observations), and Table 13 below summarises the discard data that are derived from such estimates.

Table 13 – Discard rates (by numbers of individuals) summarised from Lyle et al. (2014) for the gillnet and small mesh net methods of the Tasmanian Scalefish fishery.

Method	**No. caught**	**No. discarded**	**Discard rate (%)**
Banded Morwong net	3143	1638.2	52.1
Standard Graball net	254	125.0	49.2
Both Graball nets combined	**3397**	**1763.2**	**51.9**
Small Mesh Net	**603**	**400.94**	**66.5**

For other methods in this fishery, and in the absence of Tasmanian discard rates, one could use those rates estimated in NSW for similar methods. These are beach seine (NSW ratio of 1:0.002), handline (NSW ratio of 1:0.14), fish trap (NSW ratio of 1:0.02) and dropline (NSW ratio of 1:0.07). For the other methods with no estimates available at all (troll, Danish seine and seaweed harvesting), no discard estimation is possible.

Based on the above, Table 14 summarises the ratios and discard rates derived.

Table 14 – Assumed retained:discard ratios and discard rates (by weights) for Tasmania's various fisheries and methods.

Fishery	**Method**	**Retained: Discarded Ratio**	**Discard %**	**Notes**
Abalone	Dive	1:0.09	8.26	1
Southern Rock Lobster	Pots	1:1.94	66.02	2
Scallop	Dredge	1:0.11	10.00	3
Octopus	Pots (unbaited)	1:0.00	0.00	5
Giant Crab	Pots	1:0.51	33.78	4
Scalefish	Automatic squid jig	1:0.00	0.00	5
	Beach seine	1:0.00	0.20	1
	Purse seine	1:0.00	0.00	5
	Graball net	1:0.36	26.45	2
	Hand line	1:0.14	12.28	1
	Danish seine			
	Squid-jig	1:0.00	0.00	5
	Dip-net	1:0.00	0.00	5
	Small mesh net	1:0.66	39.82	2
	Troll			
	Fish trap	1:0.02	1.96	1
	Drop-line	1:0.07	6.54	1
	Spear	1:0.00	0.00	5

	Hand collection	1:0.00	0.00	[5]
Dive and Shellfish	Hand Collection	1:0.00	0.00	[5]

[1]Uses NSW estimate
[2]Assumes average weight of discarded individuals is one third that of retained individuals
[3]Assumes scallop fishery operates at around half the mandatory 20% scallop discard level
[4]Assumes negligible non-Giant Crab discards
[5]Assumes zero discards

Extrapolated Estimates

The next step to estimate discards for the commercial fisheries of Tasmania is to derive the product of the estimated average retained catches for each fishery (Table 12) and the assumed discard rates (Table 14) for each fishery/method and the total for the jurisdiction (Table 15).

Table 15 - Discard estimates (and SE's) for each fishery and method with total estimates for all fisheries and methods derived from combining the data in Tables 12 and 14. Where there were no discard data available (and one could not assume zero discards or use discard estimates from NSW or other methods), those methods were removed (Danish seine and Troll).

Fishery	**Method**	**Retained catch (tonnes)**	**SE**	**Discarded catch (tonnes)**	**SE**
Abalone	Dive	2139.80	124.50	192.58	192.58
Southern Rock Lobster	Pots	1126.70	52.60	2188.66	174.14
Scallop	Dredge	677.90	185.70	74.57	74.57
Octopus	Pots (unbaited)	79.50	14.30	0.00	0.00
Giant Crab	Pots	29.40	2.80	15.00	15.00
Scalefish	Automatic squid jig	251.00	183.60	0.00	0.00
	Beach seine	243.70	62.20	0.49	0.49
	Purse seine	239.60	198.60	0.00	0.00
	Graball net	105.90	5.80	38.09	38.09
	Hand line	81.00	2.80	11.34	11.34
	Danish seine	70.50	8.70		
	Squid-jig	51.40	3.90	0.00	0.00
	Dip-net	19.30	1.50	0.00	0.00
	Small mesh net	11.00	1.70	7.28	7.28
	Troll	8.80	1.50		
	Fish trap	8.50	0.40	0.17	0.17
	Drop-line	5.20	1.00	0.36	0.36
	Spear	4.20	0.30	0.00	0.00
	Hand collection	2.70	0.80	0.00	0.00
Dive and Shellfish	Hand Collection	42.90	4.60	0.00	0.00
Totals		**5199.00**	**360.76**	**2528.54**	**273.55**
	Overall Discard % =			**32.72**	**3.54**

These data show that, by far, the greatest amount of discards in Tasmania occurs in the Southern Rock Lobster fishery (accounting for 86.6% of the total weight of discards for the jurisdiction). However, this estimate, and the others, could be inaccurate as they depend heavily on the assumption that the average weight of discarded individuals is one third that of retained individuals. A better estimate of this relationship or, better still, estimates of discards given as weights instead of numbers of individuals, would provide improved estimates for the jurisdiction. In any case, it is important to note that such a high rate of discard for the lobster fishery does not reflect incidental mortality of these animals. It is, in fact likely that the discard mortality of species like lobsters and hermit crabs is minimal (see Mills and Gardner, 2006 and Green and Gardner, 2009).

Threatened, Endangered and Protected (TEP) species

Information about interactions with TEPs in Tasmania comes from 2 sources: compulsory logbook reporting by fishers and independent observer reporting. As found elsewhere in the world, the data show that interaction rates are much higher in the observer data which throws doubt on the validity of the logbook data. However, despite the existence of the observer dataset, there is little consolidation of TEPs interactions available from those data.

In the Rock Lobster fishery, logbook data are considered to be too unreliable to provide meaningful estimates of TEPs interactions. But in research sampling from 1990 to the end of 2007, a total of just 7 interactions were recorded, each involving the drowning of a cormorant. This occurred in a total of 69,441 potlifts and represented an incidence of just 0.000101 cormorant deaths per potlift. If similar rates occurred in commercial and recreational pots, then the average annual number of cormorant deaths in lobster pots would be around 140. However, such an estimate would significantly overstate probable cormorant deaths as the research sampling was biased to shallow water. Two Sygnathids (a pipefish and a seahorse) were also recorded as by-catch in the research survey and both were released apparently unharmed.

In the Giant Crab fishery, no interactions were reported by fishers targeting crabs in 2013/14 and none have been recorded in any research or observer sampling on commercial vessels in the history of the fishery.

For the Octopus fishery, Emery and Hartmann (2016) noted that protected species interactions were also minimal, seals being the only species for which interactions have been recorded. These occurrences are relatively rare with just 28 interactions occurring from 2000 to 2015.

For the Tasmanian scalefish fishery, Lyle et al (2014) do not provide any consolidated data on TEPs interactions for the commercial fishery although a number of interactions were observed in the research study, involving Fur Seals, seabirds, Sygnathids, and the Maugean Skate. Fur Seals were commonly observed in the vicinity of gillnets, the majority of direct interactions with the gear typically involved removal and consumption of entangled fish with no observed instances involving

the entanglement of seals. However, the entanglement and drowning of seabirds (cormorants and Little Penguins) in gillnets was observed, though these were rare. Sygnathids (Seahorses and Seadragons) were also encountered in very low numbers with all individuals appearing to use the gillnet meshes as a substrate on which to hang and thus were unharmed. The Maugean Skate was caught regularly in gillnets set in depths of between about 5 – 15m in Macquarie Harbour, one of only two known localities inhabited by the species. Individuals captured during daytime deployments (<6h) were in excellent condition (typically only lightly meshed) and were lively when released. While the vast majority of individuals caught in overnight sets were also in excellent condition, a small proportion (approx. 10%) were either in poor condition, or had died, confirming some by-catch mortality associated with these longer soak durations.

Quality/Performance Metrics

Table 16 contains the results from an application of the US National Bycatch Report's 20 Tier Classification criteria for estimating the quality/performance of bycatch estimation methods for the Tasmanian information. The 400 estimated scores are contained in Appendix 3. The total points possible is 73 with the 5 tiers ranked from 0 (for fisheries/methods with no discard data) through to 4 (the best quality information).

Table 16 – The quality of Tasmania's discard information derived from an application of the US system's Tier Classification Criteria (see Appendix 3 for detailed scores). Also added is a weighted % score taking account of the relative amount of discards estimated for each fishery and method (from Table 4).

Fishery	**Method**	**TOTAL POINTS (maximum = 73)**	**% score (maximum = 100)**	**Tier (maximum = 4)**	**% score weighted by estimated discards**	**Note**
Abalone	Dive	8	10.96	1	1.98	
Southern Rock Lobster	Pots	40	54.79	2	47.43	
Scallop	Dredge	12	16.44	1	1.15	
Octopus	Pots (unbaited)					1
Giant Crab	Pots	38	52.05	2	0.73	
Scalefish	Automatic squid jig					1
	Beach seine	8	10.96	1	0.01	
	Purse seine	0	0.00	0	0.00	
	Graball net	38	52.05	2	1.86	
	Hand line	8	10.96	1	0.12	
	Danish seine	0	0.00	0	0.00	
	Squid-jig					1
	Dip-net					1
	Small mesh net	38	52.05	2	0.00	
	Troll	0	0.00	0	0.00	

	Fish trap	8	10.96	1	0.00	
	Drop-line	8	10.96	1	0.00	
	Spear					1
	Hand collection					1
Dive and Shellfish	Hand Collection					1
AVERAGE SCORES:		**15.9**	**21.7**	**1.08**	**49.9**	
[1]assumes zero discards and no need to quantify discards and therefore a quality metric is not applicable						

For Tasmania, average scores were 16.5 (out of 73) or 22.6% with an average tier of 1.1. However, these averages do not account for the relative level of discards that are estimated to have come from each method. That is, ideally having better quality data for those methods with high discards should elevate the overall quality score for the jurisdiction. As for NSW, the final column in Table 5 was therefore created to provide the percentage scores weighted by the amount of discards estimated to be associated with each method (from Table 15). Providing such a weighting increases the average quality score for Tasmania to 49.1% due to the dominating contribution of the relatively good discard information assumed for the fishery with the greatest discards (the Southern Rock Lobster Fishery).

Table 17 summarises an application of the same US Tier Classification System to the Tasmanian TEPs information. The results reveal very poor information – an average of just 6.2% and a tier class of 1.0 (which is mostly due to reasonably accurate information assumed for the Giant Crab data). As for NSW, clearly information that yields such a low quality metric should not be used for extrapolations to whole fisheries or jurisdictions.

Table 17 – Quality of discard data for TEP species derived from an application of the US system's Tier Classification Criteria (see Appendix 4 for detailed scores).

Fishery	**Method**	**TOTAL POINTS (maximum = 73)**	**% score (maximum = 100)**	**Tier (maximum = 4)**	**Note**
Abalone	Dive				1
Southern Rock Lobster	Pots	3	4.11	1	
Scallop	Dredge	3	4.11	1	
Octopus	Pots (unbaited)	3	4.11	1	
Giant Crab	Pots	23	31.51	1	
Scalefish	Automatic squid jig				1
	Beach seine	3	4.11	1	
	Purse seine	3	4.11	1	
	Graball net	3	4.11	1	
	Hand line	3	4.11	1	
	Danish seine	3	4.11	1	
	Squid-jig				1
	Dip-net				1

	Small mesh net	3	4.11	1	
	Troll	3	4.11	1	
	Fish trap	3	4.11	1	
	Drop-line	3	4.11	1	
	Spear				1
	Hand collection				1
Dive and Shellfish	Hand Collection				1
AVERAGE SCORES:		**4.54**	**6.22**	**1.00**	
[1]assumes zero interactions and no need to quantify them so a quality metric is not applicable					

Discussion

The extrapolated estimates that indicate possible levels of general discards from Tasmania's commercial fisheries (Table 15) illustrate the dominant contribution that the Southern Rock Lobster fishery makes to the total (86.6%). The discard estimates for the other fisheries are quite low, due in part to their use of quite benign methods such as hand-gathering which are assumed to have negligible discards. For others, however, the data suffer from having to use surrogate discard rates from NSW and assumptions regarding number/weight conversions. However, due to the scales involved, and the dominant contribution from the Southern Rock Lobster fishery, it is difficult to argue that gaining access to better data from other fisheries would make much difference to the overall pattern - a pattern which implies that, at least in comparison to the Southern Rock Lobster fishery, most fisheries in Tasmania have quite modest levels of discarding.

For interactions with TEP species, and similar to the situation in most fisheries in the world, the limited Tasmanian data available shows that such interactions occur rarely and sporadically. And, because of this, as for NSW, we are precluded from doing any sort of meaningful extrapolations for TEP species to a fishery or jurisdictional level. One reason for this lack of evidence of TEPs interactions in these fisheries may, however, be due to the self-reported nature of much of the data. More interactions with TEP species may occur in Tasmania's fisheries – it is just that they are unreported.

In terms of estimating quality/performance metrics for this jurisdiction, like NSW, Tasmania's overall metric is around 50%, mostly due to the contribution of what is assumed to be quite good information for the dominating Southern Rock Lobster Fishery. For TEP species, however, the situation is much starker than for general discards, as there are basically too few reliable data available (an average data quality metric of just 6.2%, with all fisheries except the Giant Crab Fishery scoring very low due to the reliance on self-reported logbook data) to make any sort of confident estimate regarding the capture and discarding of these species.

Case Study 3 - Queensland

Introduction

The fisheries jurisdiction in Queensland manages 20 commercial fisheries grouped into 5 categories according to the broad fishing methods used (harvesting by hand, line, nets, pots and trawls). The jurisdiction provides an outstanding, publicly-available, easy-to-use, web-based system for reporting on the catch and effort in these fisheries, along with access to regular reports on the status of those fisheries. The system truly is an excellent example of public status-reporting on fisheries.

In terms of reporting on bycatch and discards, however, Queensland's system is less impressive - not because of a scarcity of observer-gathered discard information, but difficulties concerning access to those data due to problems of accuracy and confidentiality.

While Queensland's history in monitoring bycatches and discards may not extend back as far as NSW's, Queensland has certainly done more regular, recent and longer-term observer-based monitoring of bycatches in its fisheries than NSW and most other state jurisdictions in Australia. This included a formal observer program (part of the "Long Term Monitoring Program") that lasted from 2007 until 2012. The existence of this observer dataset was central to the decision to include Queensland as one of the case studies in this current project because it represented a rare long-term observer dataset among Australia's state jurisdictions (the Commonwealth have had observer programs in several fisheries for decades).

The problem is that the observer dataset could not be provided to this project because much of it had not been checked, is known to contain errors and there are concerns regarding its confidentiality (Engstrom, pers. comm.).

Despite this problem, we have been able to obtain some discard information for several Queensland fisheries using a less direct approach - by interrogating information in various reports and papers by Queensland researchers over the past 20 years or so. Of particular assistance were the annual status reports for most fisheries provided on Queensland's web portal – which sometimes included references to discard rates. Whilst this information was not as recent, nor probably as thorough as the data from the recently completed observer program, this information (augmented by discard rates for similar fisheries/methods in other jurisdictions and other assumptions) nevertheless permitted us to derive at least some discard estimates for most of Queensland's commercial fisheries. An exception to this indirect approach was the very thorough discard information provided by Dr Courtney in the draft report by Wang et al. (in prep.) which includes the latest observer-based discard information for Queensland's East Coast Otter Trawl and Fin Fish (Stout Whiting) Trawl Fisheries.

The following pages therefore attempt to work through the best Queensland bycatch data available, using the methodology developed earlier in this project for the other jurisdictions.

Catch data

As done for NSW and Tasmania, we begin reporting on Queensland's discards by listing the various fisheries in Queensland by method together with their average landings and fishing effort over the most recent 5 years when data are available (Table 18). Like NSW, in addition to catch data, fishing effort data for Queensland's fisheries are also available, however, as we will see, there are few discard data available on an effort basis - precluding our extrapolation of discards using that method.

Table 18 – Average annual retained catches and fishing effort (and SE's) in Queensland's commercial fisheries during the 5 year period, 2010-11 to 2014-15.

Fishery type	Fishery	Retained Catch (t)	SE	Fishing Effort (Days)	SE	Notes
Harvest	Coral	88.4	6.39	808.8	26.70	
	Crayfish and Rocklobster	153.4	11.93	664.2	61.86	
	East Coast Pearl	0.05	0.04	5.2	3.71	1
	Marine Aquarium Fish	32.1	2.73	1114.4	87.33	2
	Eel Fishery - adults	19	3.74	537.6	102.49	
	Eel Fishery - juveniles	0.0342	0.02	23	10.46	
	Sea Cucumber Fishery (East Coast)	346.2	12.83	532.2	21.16	
	Trochus	7.4	4.15	9.6	5.80	
Line	Coral Reef Finfish	1388.8	33.05	11857.6	284.35	
	Deep Water Finfish	3	1.48	7.2	4.45	
	East Coast Spanish Mackerel	300.2	15.47	4472.8	218.55	
	Gulf of Carpentaria Line	194.8	16.16	759.6	57.59	
	Rocky Reef Finfish	142.4	8.81	3928.4	125.91	
Nets	East Coast Inshore Finfish Fishery	4598.6	84.09	28297.8	869.13	
	Gulf of Carpentaria Inshore Finfish	1952.6	219.92	8154.6	468.84	
Pots	Blue Swimmer Crab	361.6	12.27	8711.8	233.24	
	Mud Crabs	1357.2	50.02	43849.2	747.34	
	Spanner Crabs	1086.8	66.35	3141	133.58	3
Trawl	East Coast Otter Trawl	6770.8	256.37	34266	560.34	
	Fin Fish (Stout Whiting) Trawl	711.2	38.21	284	13.58	
	Gulf of Carpentaria Developmental Fin Fish Trawl	187.6	115.93	85.4	60.99	
	River and Inshore Beam Trawl	223.8	25.89	2498.6	132.54	

1 - Retained catches are in numbers
2 - Retained catches are in numbers ('000)
3 - Fishing effort is also available as an average of 1,000,400 dilly lifts (SE 42,980)

General Discards

The next step in reporting on discards in these fisheries is to identify any discard rates that are available for (or that could be applied to) each fishery/method. Taking each in turn:

Harvest Fisheries

These fisheries are mostly characterised by employing hand-gathering as the principle method, meaning that there are virtually no non-retained species (ie. zero discards).

The Coral Fishery involves the hand-collection of live anemones, soft and hard corals, ornamental corals, live rock, coral rubble and coral sand (DEEDI, 2011a). The Crayfish and Rocklobster Fishery targets Tropical Rock Lobster using hookah to collect lobsters by hand, nooses or spears (DEEDI, 2011b). The East Coast Pearl Fishery gathers Silverlip and Blacklip Pearl Oysters by hand, the Marine Aquarium Fish Fishery collects Damselfish, Anemone Fish, Butterflyfish, Bannerfish, Angelfish, Wrasses and Gobies – again by hand, and the East Coast Trochus Fishery uses hand-held non-mechanical implements to harvest Topshells (or Topsnails) (DEEDI, 2010a).

The Sea Cucumber Fishery (East Coast) targets all species of Sea Cucumber including the White Teatfish, Burrowing Blackfish and Curryfish. Harvesting is by hand, using free-diving methods or with hookah or SCUBA. Bycatch occurs due to the release of undersized specimens of the target species after collection (DAFF, 2012a), although no data are available on the levels of such discarding.

The Queensland Eel Fishery targets Longfin and Southern Shortfin Eels in rivers and freshwater impoundments at two stages in their lifecycles, as adults (> 30 cm) and as elvers (glass eels) (< 30 cm). The methods involve baited eel or round traps (with floated cod ends), fyke nets (with floated cod ends), dip nets and flow traps. Bycatch has not been measured in this fishery (nor in the other eel fisheries in jurisdictions examined in this project) so no discard estimates are available or could be applied, although significant interactions have been recorded with TEPs species in this fishery (see below).

Line Fisheries

The Coral Reef Fin Fish Fishery is predominantly a line-only fishery that targets a range of bottom-dwelling reef fish. The commercial sector focuses primarily on live coral trout and mainly operates in the Great Barrier Reef Marine Park. Commercial fishing operations generally consist of a number of smaller tender boats (dories) and a larger primary fishing vessel to hold fish.

Despite the volume caught in this fishery (Queensland's 4th largest), limited information on bycatches are available. While Ryan et al (2003) noted that bycatch comprised less than 25% of the total catch, the most comprehensive data comes from Andersen et. al. (2004) who summarised an observer program (Mapstone et al., 2001) where approximately 225 dory days of fishing were observed. This observer program revealed that the discards were dominated by undesired target species (ie usually under the legal size), especially Coral Trout, which was

responsible for greater than 50 percent of the bycatch. Other species discarded were Red-Throat Emperor, Grassy Sweetlip, Stripey Seaperch, Hussar, Trevally species and Blacktip Rockcod.

The results indicated that, for dead fishing operations, of 5,376 individuals caught, 4,036 (75.1%) were retained for a discard rate of 24.9% (by number). For live fishing operations, of 4,645 individuals caught, 2,679 (57.7%) were retained for a discard rate of 42.3% (by number). This gives a total discard rate (by number) of 33.0%.

As we saw earlier for Tasmania, the recording of discards as numbers of individuals and not weights create something of a problem when reporting on discards for jurisdictions because, when using total retained catches (which are virtually always reported as weights) to extrapolate discard rates to fishery/method/jurisdictional levels, one requires such rates as weights (not numbers). That is, whilst it is useful to have estimates of discards as numbers of individuals, the weights of discards are required to provide discard rates for the entire fishery (as a ratio of landings) and to use landings records as extrapolators to derive total discard estimates. For example, whilst one could simply use the above 33% estimate of individuals discarded in this fishery and extrapolate it up using weights of landings, this would be erroneous as the average weight of discarded animals should be much less than that of retained animals due to the discarded fish being below a legal minimum length. Estimates of the average weights of discarded individuals from this fishery (especially the discarded target species which comprise the bulk of discards) are required to determine a fishery-specific discard rate and, then, estimates of total discards. In the absence of any discard weights, for the purpose of the present exercise (and as we did earlier for Tasmania), we have assumed that, on average, discarded individuals in this fishery weigh one third that of average retained individuals. This provides a weight-based retained:discard ratio for the fishery of 1:0.16 (or a discard rate of 14.1%).

Commercial operators working in Queensland's Deep Water Finfish Fishery target Blue Eye Trevalla and Bar Cod using trotlines or droplines. Bycatch information has been collected by observers in Queensland's Long Term Monitoring Program (DEEDI, 2010b) but, as discussed earlier, the data are not available. We therefore assumed that this fishery has similar discard rates as those derived for fisheries using similar methods in NSW - an average retained:discard ratio of 1:0.123 (SE 0.018) (MacBeth and Gray 2016, Macbeth et al., 2009) or a discard rate of 10.95%.

The East Coast Spanish Mackerel Fishery is a line-only fishery in which the target species, Spanish Mackerel, are generally caught trolling. As above, there has been an observer program completed in the fishery but no data are currently available from it. However, DEEDI (2011c) notes that the level of bycatch in this fishery is considered low due to its targeted nature and the constant attendance of troll lines while fishing. The little bycatch caught is mainly comprised of undersized individuals of the targeted Spanish Mackerel and COA (2004) states that "….. the occurrence of undersize individuals is rare". Further, Sly (2003) notes that the bycatch in a similar fishery (the Northern Territory Spanish Mackerel Fishery) is negligible and that a large proportion of the other species caught whilst targeting Spanish Mackerel are retained as byproduct for sale.

The Gulf of Carpentaria Line Fishery is a multispecies fishery which harvests a range of pelagic (open water) and demersal (bottom-dwelling) fish with Spanish Mackerel accounting for the majority of the catch. Other species taken include Trevally, small Mackerels, Tropical Snappers, Cods and Emperors. The methods include surface trolls and hand lines. Whilst little work has been done on bycatch in this fishery, Roelofs (2004a) notes that, although bycatch is considered negligible (G. McPherson, pers. comm. 2003 and SOQ, 2013), Barracuda, Sharks, Tunas, Swordfish and Rays are sometimes caught and discarded. Roelofs (2004) also notes that bycatch in the demersal hand line component of this fishery should be similar to that in the east coast Coral Reef Fin Fish Fishery, given the similar methods and species caught (ie. a retained:discard ratio of 1:095, a discard rate of 8.69%).

The Rocky Reef Finfish Fishery targets Snapper, Pearl, Teraglin and Cobia using hook and line. There is said to be limited bycatch in this fishery as recorded by observers and this consists mostly of undersized target species or other pelagic species that are retained as by-product (DEEDI, 2011d). Other released species in the fishery include Red Emperor, Red Throat Emperor and other Groupers. In the absence of any data on bycatch levels, we could use the retained:discard ratio of 1:0.10 (SE 0.03) or a discard rate of 9% from a similar fishery in the Northern Territory (the Timor Reef fishery – see the next case study).

Net Fisheries

The East Coast Inshore Finfish Fishery targets Sea Mullet, Sharks, Whiting, Bream, Flathead, Tailor, small Mackerels, Threadfins and Barramundi. The gear permitted includes mesh, haul (seine), tunnel and cast nets and hook and line. Most fishers prefer to use net sizes that selectively catch fish of a certain size to meet market demand. The number of nets permitted to be used, mesh size and length depends on the species targeted and whether the fisher is operating in near-shore or offshore waters.

DEEDI (2010c) notes that bycatch levels in the fishery are low compared to the retained component of the catch, indicating the gear and methods used are quite selective. Observers reported 27% total bycatch in net operations targeting sharks although these were preliminary results. An observer program was implemented in 2009 but the data from that program are unavailable.

Halliday et al. (2001) reported on bycatch levels in this fishery (as estimated by observers), concluding that bycatch levels were similar across the various components of the fishery (7 – 28% by number) even though the size ranges of species targeted differed considerably. The discard rates (by numbers of individuals) provided were: for the East coast “mixed estuary” fishery 15.3%; for the East coast Barramundi fishery 13%; for the Small Mackerel fishery 16.3%; for the Whiting fishery 27.5%; and for the Sea Mullet fishery 5.7%. If we take the average of these estimates as indicative of the whole fishery, we get a discard rate of 15.5% (SE 3.51). And to convert this to a weight-based estimate using the above-mentioned assumption that discarded individuals weigh

one-third that of retained individuals, we get a retained-discard ratio of 1:0.061 (SE 0.012) or a discard rate of 5.76%.

Like the above fishery, the Gulf of Carpentaria Inshore Finfish Fishery employs fishing gears and methods that are thought to be quite selective at harvesting the nominated target species (Halliday et al. 2001). Bycatch is generally comprised of fish and elasmobranchs. Early, stand-alone observer programs have provided reliable data on bycatch in various parts of the fishery as reported by Halliday et al. (2001) and Roelofs (2004b). In summary, these indicate that the Gulf of Carpentaria Mixed Estuary Fishery has a discard rate of 13.4% by number and the Gulf of Carpentaria Barramundi fishery, 13.1% by number (an average of 13.25%). And again, to convert this to a weight-based estimate using the above-mentioned assumption that discarded individuals weigh one-third that of retained individuals, we get a retained-discard ratio of 1:0.051 or a discard rate of 4.84%.

Pot Fisheries

Rigid or collapsible crab pots are the main methods used in the Queensland Blue Swimmer Crab Fishery. DAFF (2012b) notes that bycatch in this fishery is generally low and consists of undersized target or non-permitted species, but no data were available to quantify these discards. In the absence of such data, we use the retained:discard ratio of 1:0.122 (a discard rate of 10.87%) derived for the NSW estuarine Blue Swimmer Crab fishery (Leland et al., 2013).

Commercial crab pots (with rigid or collapsible frames) are used in the Queensland Mud Crab Fishery. DEEDI (2011e) notes that, in an observer program, of 1452 trap lifts observed (on 801 unique pots) the bycatch was predominately comprised of soft male, undersized male and female mud crabs (98% of the bycatch by number), with the remaining 2% of the bycatch by number being teleosts (mostly Yellowfin Bream, Goldspotted Rockcod and Gobies). Unfortunately, however, there are no data available relating this bycatch to retained catches. In its absence, we can apply the average NSW retained:discard ratio for its Mud Crab fishery (Butcher et al., 2012; Broadhurst et al., 2015; Leland et al., 2013) but doubled to try to account for the fact that all female mud crabs are discarded in Queensland. This gives a ratio of 1:0.298 (SE 0.036) or a discard rate of 22.96%.

Commercial fishers in the Queensland Spanner Crab Fishery use prescribed dillies as the fishing method. DEEDI (2011f) reported minimal discards of non-Spanner Crabs in the fishery. Brown et al (2001) noted that animals other than Spanner Crabs that are occasionally taken include Blue Swimmer Crabs, juvenile Flathead and Flounder, as well as small gastropod and bivalve molluscs, solitary corals, sipunculids, Brittle-Stars and Sea Urchins. But the incidence of non-Spanner Crab bycatch is noted to be very rare and was reported as just 4 grams per dilly lift from data obtained in a 2001 survey – around 4 tonnes per year for the fishery. However, many undersize spanner crabs are discarded in this fishery. The data indicated that, over a 10 year period from 2001 to 2010, the average discard rate of undersize crabs was 41.3% (SE 1.52) by number. To convert this number-based estimate to a weight-based estimate, we again assumed that discarded crabs

weighed one-third that of retained crabs and derived a retained:discard ratio of 1:0.23 (SE 0.005) or a discard rate of 19% for the fishery.

Trawl Fisheries

The East Coast Otter Trawl Fishery mainly targets a variety of species of prawns, scallops, bugs, squid, and several other by-product species. It uses demersal otter board trawling as the principal method. The Fin Fish (Stout Whiting) Trawl Fishery is a small fishery with just 5 operators (owned by two companies) who use otter trawls and Danish seines to target Stout Whiting. As for any trawl fishery, bycatch and discards can be expected to be significantly greater in these fisheries than in all of the other Queensland fisheries discussed so far.

These two fisheries had the best bycatch information available to this project due to the recent work of Wang et al. (in prep) which used data from various research projects as well as Queensland's recent observer dataset (the data from which was not available to this current project for other methods). That manuscript provides an exhaustive assessment of various ways to estimate discards in these fisheries (using weight-based, effort-based and swept area-based extrapolation methods). The summary data in the paper's Fig. 7 provides estimates of total discards for these 2 fisheries which, averaged over the most recent 5 years (2010-2014) was 24,926 tonnes (SE 2,704). Comparing this with the retained data available in Table 1 for these two fisheries we get a retained:discard ratio of 1:3.35 (SE 0.14) or a discard rate of 77%.

Operators in the Gulf of Carpentaria Developmental FinFish Trawl Fishery use a semi-demersal fish otter trawl to fish particular shoals. DEEDI (2011g) states that the percentage of reported bycatch in the fishery increased from 36% (272 t) in 2009 to 39% (237 t) in 2010. All of the bycatch was recorded as fish.

The River and Inshore Beam Trawl Fishery targets Bay Prawns, Banana Prawns, School Prawns and Squid in certain rivers and creeks, towing a single 5 m head-rope trawl. The only exception is Laguna Bay, where a small otter trawl net may be used. An early study by Robins and Courtney (1998) gave a catch:bycatch ratio for the fishery of 1:3.5 but DEEDI (2009) reports that preliminary analysis of more recent observer data indicated an average ratio (by weights) of retained:discarded of 1:0.25 (a far lower discard rate of 20%).

Based on the above information, Table 19 summarises the ratios and general discard rates derived for Queensland's commercial fisheries.

Table 19 – Assumed general retained:discard ratios and discard rates (by weights) for Queensland's various fisheries and methods. SE's are provided when replicate discard estimates were available.

Fishery	Retained: Discarded Ratio	SE*	Discard %	Notes
Coral	1:0	0	0	1
Crayfish and Rocklobster	1:0	0	0	1
East Coast Pearl	1:0	0	0	1
Marine Aquarium Fish	1:0	0	0	1
Eel Fishery	na	na	na	2,3
Sea Cucumber Fishery (East Coast)	na	na	na	2
Trochus	1:0	0	0	1
Coral Reef Finfish	1:0.16		14.1	4,5
Deep Water Finfish	1:0.123	0.018	10.95	6
East Coast Spanish Mackerel	na	na	na	2
Gulf of Carpentaria Line	1:0.095		8.69	4,5,7
Rocky Reef Finfish	1:0.10	0.03	9	6
East Coast Inshore Finfish Fishery	1:0.061	0.012	5.76	5
Gulf of Carpentaria Inshore Finfish	1:0.051		4.84	4,5
Blue Swimmer Crab	1:0.122		10.87	4,6
Mud Crabs	1:0.298	0.036	22.96	8
Spanner Crabs	1:0.23	0.005	19	5
East Coast Otter Trawl	1:3.35	0.14	77	9
Gulf of Carpentaria Developmental Fin Fish Trawl	1:0.639		39	4
River and Inshore Beam Trawl	1:0.25		20	4

*SE of discard component of ratio
[1]Assumes zero discards
[2]No discard estimates available
[3]Combines data for the adult and juvenile components of the fishery
[4]Insufficient replicate ratios to derive an SE
[5]Assumes average weight of discarded individuals is one third that of retained individuals
[6]Uses NT estimate
[7]Uses same ratio as the Coral Reef Fin Fish Fishery
[8]Uses double NSW estimate to account for all females discarded
[9]Includes data for the Fin Fish (Stout Whiting) Trawl fishery

Extrapolated Estimates

The next step to estimate total general discards for these fisheries is to combine the estimated average retained catches for each fishery (Table 18) with the assumed discard rates for each (Table 19) to provide estimates of total discards for each fishery/method and the total for the jurisdiction (Table 20).

Table 20 - Discard estimates (and SE's) for each fishery and method with total estimates for all fisheries and methods derived from combining data in Tables 18 and 19. Where there were no discard data available (and one could not assume zero discards or use discard estimates from other jurisdictions or methods), those fisheries/methods were removed (these were the Eel, Sea Cucumber and East Coast Spanish Mackerel fisheries).

Fishery	Retained Catch (t)	SE	Total discards (t)	SE	Notes
Coral	88.40	6.39	0.00	0.00	
Crayfish and Rocklobster	153.40	11.93	0.00	0.00	
East Coast Pearl	0.05	0.04	0.00	0.00	1
Marine Aquarium Fish	32.10	2.73	0.00	0.00	2
Trochus	7.40	4.15	0.00	0.00	
Coral Reef Finfish	1388.80	33.05	222.21	222.21	
Deep Water Finfish	3.00	1.48	0.37	0.19	
Gulf of Carpentaria Line	194.80	16.16	18.51	18.51	
Rocky Reef Finfish	142.40	8.81	14.95	5.06	
East Coast Inshore Finfish Fishery	4598.60	84.09	280.51	55.41	
Gulf of Carpentaria Inshore Finfish	1952.60	219.92	99.58	99.58	
Blue Swimmer Crab	361.60	12.27	44.12	44.12	
Mud Crabs	1357.20	50.02	404.45	51.05	
Spanner Crabs	1086.80	66.35	253.96	16.20	4
East Coast Otter Trawl	7482.00	259.20	25064.70	1360.11	5
Gulf of Carpentaria Developmental Fin Fish Trawl	187.60	115.93	119.88	119.88	
River and Inshore Beam Trawl	223.80	25.89	55.95	55.95	
TOTALS	**19,260.55**	**381.35**	**26,579.18**	**1391.02**	
TOTAL DISCARD RATE (%):			**57.98**	**3.03**	

[1]Retained catches have assumed an average weight of 500g per oyster
[2]Retained catches have assumed an average weight of 250g per fish
[3]Combines data for the adult and juvenile components of the fishery
[4]Includes 4 tonnes of non-spanner crab discards
[5]Includes data for the Fin Fish (Stout Whiting) Trawl fishery

Threatened, Endangered and Protected (TEP) species

The data obtained from all available sources regarding interactions with TEPs species (or, as they are known in Queensland, Species of Conservation Interest – SOCI) mostly came from self-reported fishers' logbooks (augmented occasionally by data from observer programs). Only 8 of Queensland's 22 fisheries indicated any interactions with TEP species:

The Queensland Eel Fishery recorded a total of 2,833 interactions with protected species in fishers' logbooks in 2011 (DAFF, 2013a). Most of these (2,599) were with the Krefft's River Turtle, with the remainder being smaller numbers of several other species of turtle.

It was mentioned in DEEDI (2010c) that the East Coast Inshore Finfish Fishery interacted with turtle species more frequently than with other protected species but no data are available.

The Gulf of Carpentaria Inshore Finfish Fishery also is thought to have some rare incidents when marine turtles, dolphins, crocodiles, dugongs and sea snakes are caught (Roelofs, 2004b)

For the Blue Swimmer Crab Fishery fishers' logbooks list four interactions with loggerhead turtles in 2003, four in 2004, none during 2005–06 and two in 2007 and Leslie (2014) notes that the fishery did not report interacting with any protected species during 2012. A fishery observer-based study of the Moreton Bay Blue Swimmer Crab pot fishery recorded only one turtle interaction in 220 observed fishing days.

DEEDI (2011e) notes that, in an observer program, of 1452 trap lifts observed (on 801 unique pots) in the Mud Crab Fishery, there were no interactions with SOCI and only one captured elasmobranch (Spotted Wobbegong). But in 2010, there were two reported interactions with SOCI (water rats).

In 2010 the Spanner Crab Fishery had two recorded interactions with SOCI; one with a green turtle and one with a humpback whale.

Robins (1995) estimated the numbers of turtles caught in the Queensland East Coast Otter Trawl Fishery to be an average rate of 0·068 turtles per day fished. Loggerhead (50.4%), green (30.1%) and flatback turtles (10.9%) comprised the main species caught. This equated to an estimated 5295 ± 1231 turtles being caught annually by the fishery, which then had an annual fishing effort of 80,558 days. These estimates come from a period prior to the introduction of Turtle Exclusion Devices (TEDs) in the fishery so current bycatches of such SOCI can be expected to be far less than these former estimates. DEEDI (2012) identified that, in 2008, just 3 flatback turtles, 3 narrow sawfish and 4 seahorses were caught but 1,657 sea snakes were caught and discarded. No SOCI interactions were reported in 2009 for the Fin Fish (Stout Whiting) Trawl Fishery (DEEDI, 2011h). However, these estimates that come from the SOCI logbook data should be viewed with some caution. For sea snakes, for example, (Courtney et al. 2010) estimates that 105,210 (SE 18,288), composed of 12 species, were being discarded in the trawl fishery per year - using data from research projects, at-sea observers and a voluntary crew member program. This is two orders of magnitude greater than the 1,657 reported in the logbooks. However, one needs to note that this latter estimate came from 2003-2007 data and fishing effort has declined markedly in the fishery since that time, and so this annual estimate has also likely declined.

Operators in the Gulf of Carpentaria Developmental FinFish Trawl Fishery reported 5 SOCI interactions, including four freshwater Sawfish and one Flatback Turtle, during the 2010 season.

The above TEPs interactions are summarised in Table 21.

Table 21 – Summary of data concerning Queensland's commercial fisheries' interactions with TEP species (SOCI).

Fishery	SOCI Interactions
Coral	nil
Crayfish and Rocklobster	nil
East Coast Pearl	nil
Marine Aquarium Fish	nil
[1]Eel Fishery	In 2011, 2833 turtles (2599 were Krefft's river turtle)
Sea Cucumber Fishery (East Coast)	nil
Trochus	nil
Coral Reef Finfish	nil
Deep Water Finfish	nil
East Coast Spanish Mackerel	nil
Gulf of Carpentaria Line	nil
Rocky Reef Finfish	nil
East Coast Inshore Finfish	Some turtles mentioned but no data
Gulf of Carpentaria Inshore Finfish	"Rarely" catch turtles, dolphins, crocodiles, dugongs and sea snakes but no data
Blue Swimmer Crab	Between 0 and 4 Loggerhead Turtles/year
Mud Crabs	In 2010, 2 water rats
Spanner Crabs	In 2010, 1 Green Turtle and 1 Humpback Whale
East Coast Otter Trawl	In 2008, 3 Flatback turtles, 3 Narrow Sawfish, 4 seahorses. In 2010, 105,210 (SE 18,288) of 12 species of sea snakes
Fin Fish (Stout Whiting) Trawl	nil
Gulf of Carpentaria Developmental Fin Fish Trawl	In 2010, 4 freshwater Sawfish and 1 Flatback Turtle
River and Inshore Beam Trawl	nil
[1]Combines data for the adult and juvenile components of the fishery	

Quality/Performance Metrics

Table 22 contains the results from an application of the US National Bycatch Report's 20 Tier Classification criteria for estimating the quality/performance of bycatch estimation methods to the Queensland information on general discards. The 400 estimated scores are contained in Appendix 5. The total points possible is 73 with the 5 tiers ranked from 0 (for fisheries/methods with no discard data) through to 4 (the best quality information).

For Queensland, average scores were 17.1 (out of 73) or 23.5% with an average tier of 1.27. However, these averages do not account for the relative level of discards that are estimated to have come from each fishery. That is, ideally having better quality data for those methods with high discards should elevate the overall quality score for the jurisdiction. The final column in Table 22 was therefore created to provide the percentage scores weighted by the amount of discards estimated to be associated with each method (from Table 20). Providing such a weighting

increases the average quality score for Queensland to 51.58% due to the dominating contribution of the relatively good discard information for the fishery with the greatest discards (the East Coast Trawl Fishery).

Table 22 – The quality of Queensland's general discard information derived from an application of the US system's Tier Classification Criteria (see Appendix 5 for detailed scores). Also added is a weighted % score taking account of the relative amount of discards estimated for each fishery and method (from Table 4).

Fishery	TOTAL POINTS (maximum = 73)	% score (maximum = 100)	Tier (maximum = 4)	% score weighted by estimated discards	Note
Coral					1
Crayfish and Rocklobster	0	0	0	0	
East Coast Pearl					1
Marine Aquarium Fish					1
Eel Fishery	0	0	0	0	
Sea Cucumber Fishery (East Coast)					1
Trochus					1
Coral Reef Finfish	29	39.73	1	0.33	
Deep Water Finfish	14	19.18	1	0	
East Coast Spanish Mackerel	0	0	2	0	
Gulf of Carpentaria Line	14	19.18	1	0.01	
Rocky Reef Finfish	14	19.18	1	0.01	
East Coast Inshore Finfish Fishery	29	39.73	2	0	
Gulf of Carpentaria Inshore Finfish	29	39.73	2	0.15	
Blue Swimmer Crab	14	19.18	1	0.03	
Mud Crabs	14	19.18	1	0.29	
Spanner Crabs	14	19.18	1	0.18	
East Coast Otter Trawl	39	53.42	3	50.55	
Gulf of Carpentaria Developmental Fin Fish Trawl	16	21.92	1	0.10	
River and Inshore Beam Trawl	31	42.47	2	0.09	
AVERAGE SCORES:	**17.13**	**23.47**	**1.27**		
TOTAL Weighted Quality Metric (%)				**51.58**	

[1]assumes zero discards and no need to quantify discards and therefore a quality metric is not applicable

Table 23 summarises an application of the same US Tier Classification System to the Queensland TEPs (or SOCI) information. The results reveal very poor information – an average of just 8.86% and a tier class of 1.07 (which is mostly due to reasonably accurate information assumed for the East Coast Trawl data). As for the other jurisdictions examined in this project, clearly information

that yields such a low quality metric should not be used for extrapolations to whole fisheries or jurisdictions.

Table 23 – Quality of discard data for TEP species (SOCI) derived from an application of the US system's Tier Classification Criteria (see Appendix 6 for detailed scores).

Fishery	TOTAL POINTS (maximum = 73)	% score (maximum = 100)	Tier (maximum = 4)	Note
Coral				1
Crayfish and Rocklobster	3	4.11	1	
East Coast Pearl				1
Marine Aquarium Fish				1
Eel Fishery	3	4.11	1	
Sea Cucumber Fishery (East Coast)				1
Trochus				1
Coral Reef Finfish	3	4.11	1	
Deep Water Finfish	3	4.11	1	
East Coast Spanish Mackerel	3	4.11	1	
Gulf of Carpentaria Line	3	4.11	1	
Rocky Reef Finfish	3	4.11	1	
East Coast Inshore Finfish Fishery	3	4.11	1	
Gulf of Carpentaria Inshore Finfish	3	4.11	1	
Blue Swimmer Crab	14	19.18	1	
Mud Crabs	14	19.18	1	
Spanner Crabs	3	4.11	1	
East Coast Otter Trawl	33	45.21	2	
Gulf of Carpentaria Developmental Fin Fish Trawl	3	4.11	1	
River and Inshore Beam Trawl	3	4.11	1	
AVERAGE SCORES:	**6.47**	**8.86**	**1.07**	
[1]assumes zero interactions and no need to quantify them so a quality metric is not applicable				

Discussion

The extrapolated estimates of general discards from Queensland's commercial fisheries (Table 20) illustrate the dominant contribution that the East Coast Otter Trawl and Fin Fish (Stout Whiting) Trawl fisheries make to the total (94.3%). As noted earlier, the discard estimates for the other fisheries suffer from the lack of access to Queensland's observer data, requiring many assumptions to be made including number/weight conversions and the use of discard rates from other jurisdictions and fisheries. However, due to the relative sizes of the fisheries involved, and the dominant contribution from the two trawl fisheries, it is difficult to argue that gaining access to the more recent and detailed data from the observer database for the other fisheries would

make much difference to the overall pattern. A pattern which implies that, at least in comparison to these two trawl fisheries, most fisheries in Queensland have quite modest levels of discarding.

For interactions with TEP species (or SOCI), and similar to the situation in most fisheries in the world, the Queensland logbook data shows that such interactions (with the exception of sea snakes – see below) occur rarely, sporadically and with significant uncertainty. And, because of this, as for the other jurisdictions, we are not confident in making any sort of meaningful extrapolations for SOCI species to a fishery or jurisdictional level (the Quality metric for such data was estimated to be very low – 8.86% - see below). In common with the other jurisdictions, one reason for this lack of evidence of TEPs interactions in these fisheries may be due to the self-reported nature of much of the data. In fact, a comparison for the data obtained for one group of TEP species (sea snakes) indicates a very significant level of under-reporting in the self-reported SOCI logbooks. 105,210 (SE 18,288) sea snakes, composed of 12 species, were estimated to be caught in the trawl fishery per year using data from research projects, at-sea observers and a voluntary crew member program (Courtney et al. 2010) compared to estimates of just 1,657 from the logbook data (DEEDI, 2012) – 2 orders of magnitude less. This comparison suggests that many more interactions with other TEP species may be evident in the full observer database (across all fisheries) than were recorded in the logbook data reported here.

In terms of estimating quality/performance metrics for this jurisdiction, like NSW and Tasmania, Queensland's overall metric is above 50%, mostly due to the contribution of quite good discard information for the East Coast Trawl Fishery. However, this metric would have been improved if the observer data were available for the various non-trawl fisheries. For SOCI species, however, the situation is much starker than for general discards, as there are basically too few reliable data available (an average data quality metric of just 8.86%, with all fisheries except the East Coast Trawl Fishery scoring very low due to the reliance on self-reported logbook data) to make any sort of confident estimate regarding the capture and discarding of these species. Once again, greater inclusion of observer data (rather than relying on the self-reported logbook data) would probably have elevated this metric.

Case Study 4 – Northern Territory

Introduction

Due to their exclusively tropical location, most of the Northern Territory's fisheries differ from those in the more southern jurisdictions of Australia. There are 11 commercial marine fisheries in the Territory: the Demersal, Timor Reef, Barramundi, Offshore Net and Line, Spanish Mackerel, Mud Crab, Coastal Line, Restricted Bait, Coastal Net, Trepang and Aquarium Fish/Display Fish fisheries. Nine of these could be expected to have at least some discarding – the latter two (the Aquarium Fish/Display Fish and Trepang fisheries), whose methods are mainly hand gathering, are not likely to have significant discards.

Catch data for most of these fisheries are derived from compulsory monthly logbooks submitted by commercial licensees, summaries of which have been provided since 2013 in annual "Status of Key Northern Territory Fish Stocks Reports" (NTG, 2015, 2016, 2017). NT Fisheries provided all relevant data from these fisheries to this project - going back as far as 1983.

In addition, and of particular relevance, is the Northern Territory's observer programmes where regular monitoring of catches and bycatches (including discards) occurs in several fisheries – these are among the few extant observer programs running in Australia's non-Commonwealth jurisdictions. All data collected from these programmes since 2011 were provided to this project by NT Fisheries (Saunders, pers. comm.) and mainly concerned the largest (and more non-selective) fisheries in the jurisdiction – the Demersal, Timor Reef, Barramundi and Offshore Net and Line fisheries.

Catch data

As for the other case studies in this project, we begin by listing, in order of retained catches, the various fisheries in the Northern Territory by method and their average landings over the most recent 5 years (Table 24).

Table 24 – Retained annual average catches (and SE's) from the Northern Territory's commercial fisheries, using the most recently available years of data.

Fishery	Methods	Years	Retained (t)	SE	Notes
Demersal	Traps, hand lines, droplines, demersal trawls	2012-2016	2453.17	197.26	1
Timor Reef	Traps, hand lines, droplines, demersal longlines, trawls	2012-2016	722.93	35.60	
Barramundi	Gillnets	2012-2016	718.01	123.15	
Offshore Net and Line	Gillnets, longlines	2012-2016	613.58	158.81	
Spanish Mackerel	Trolls, baited lines	2012-2016	255.23	34.11	

Mud Crab	Pots and bait gillnets	2012-2016	224.16	50.39	
Coastal line	Hook and line	2012-2016	111.88	8.36	
Trepang	Hand gathering	2012, 13, 15-16	51.56	13.11	
Restricted Bait	Bait nets	2012-2016	31.44	7.03	2
Aquarium Display	Hand gathering	2012-2016	10.21	2.16	
Coastal net	Gillnets	2012-2016	6.53	1.54	
[1] Includes 2012 data from the Finfish Trawl fishery which merged into the Demersal fishery after this time [2] Includes small catches from the bait net fishery in 2012 and 2015					

General Discards

The next step in reporting on discards in these fisheries was to identify any discard rates that are available for each fishery/method. As mentioned above, some of these are available from observer programs run in the more important fisheries in the jurisdiction. Taking each fishery in turn:

The Demersal fishery targets a range of Tropical Snappers (*Lutjanus* spp. and *Pristipomoides* spp.) using fish traps, hand lines, droplines and demersal trawl nets (the latter permitted only in two defined zones). Turtle Exclusion Devices are required in the trawl gear and operators use square mesh codends to reduce unwanted bycatches and improve catch quality. Bycatch in this fishery is routinely quantified by on-board observers. Discards (by weight) reported from the observer programme across the variety of methods used were provided from 2011 to 2017 (Saunders, pers. comm.). These data yielded an estimated annual average retained:discard ratio of 1:0.14 (SE 0.02) for a discard rate of 12.1% (SE 2.02). Discarded species included Trevallies, Scads and Sharks.

The Timor Reef fishery also targets Tropical Snappers (*Lutjanus* spp. and *Pristipomoides* spp.) using baited traps, hand lines, droplines and demersal longlines. Trawl gear is also being trialled in the fishery. Like the Demersal fishery above, Turtle Exclusion Devices are required in the trawl gear and operators use square mesh codends to reduce unwanted bycatches and improve catch quality. On-board observers routinely validate the proportion and composition of bycatch in the fishery. Reported discards (by weight) from the observer programme from 2011 to 2017 yielded an annual average ratio of 1:0.10 (SE 0.03) for a discard rate of 9% (SE 2.7). Discarded species included Crabs (Portunus spp.), Tropical Snappers (Lutjanus spp.), Triggerfish (Family Balistidae), Catfish, Red Bass (Lutjanus bohar), Sharks, Scads, Black Tripodfish (*Trixiphichthys weberi*), Common Saury (*Saurida tumbil*), Largehead Hairtail (*Trichiurus lepturus*) and Chinaman fish (Symphorus nematophorus).

The Barramundi fishery targets Barramundi and King Threadfin using gillnets. Discards (by weight), as estimated by observers in 2005 and from 2007 to 2011 yielded an average annual ratio of 1:0.32 (SE 0.2) for a discard rate of 24.2%. Discarded species included Catfish, Blue Threadfin, Queenfish, Trevallies and Sharks.

The Offshore Net and Line fishery targets Australian Blacktip Sharks (*Carcharhinus tilstoni*), Common Blacktip Sharks (*C. limbatus*), Spottail Sharks (*C. sorrah*) and Grey Mackerel (*Scomberomorus semifasciatus*) using pelagic gillnet and longline gear. Bycatch is routinely quantified by on-board observers. Discards (by weight) as estimated by these observers in 2003, 2007 to 2014 and 2016 to 2017 yielded an average annual ratio of 1:0.18 (SE 0.04) for a discard rate of 14.4% (SE 2.9). Discarded species included the Tawny Shark (Nebrius ferrugineus), Rays (Family Dasyatidae), Trevallies and Queenfish.

The Spanish Mackerel fishery targets Spanish Mackerel (*Scomberomorus commerson*) using trolled lures or baited lines from a mother ship and/or dories. Observers have only opportunistically conducted monitoring on these vessels. While bycatch was not explicitly measured, it was estimated to be <1% of the total catch and consisted of Trevallies and other smaller Mackerel species. In 2013, discards (by weight) were estimated to be approximately 0.1% of the total harvest, based on logbook catches, and consisted exclusively of Trevallies (Family Carangidae), most of which were released alive (NTG, 2015). There was no recorded discards during 2014, and a small number of Trevallies were recorded as discards during 2015 (NTG, 2017). As was the situation for the Queensland Spanish Mackerel fishery, we lack any definitive information regarding discards and discard rates for this fishery that we can use as a substitute.

The Mud Crab fishery targets Mud Crabs (*Scylla* spp.) using baited pots. Fishers may also use gillnets to catch fish for use as crab bait. There has been no observer programme in this fishery so no NT-based discard estimates are available. Instead, as we did in the Queensland case study where, similarly, no discard data were available, we can apply the average NSW retained:discard ratio for its mud crab fishery (Butcher et al., 2012; Broadhurst et al., 2015; Leland et al., 2013). This is a ratio of 1:0.15 (SE 0.02) or a discard rate of 13%.

The Coastal Line fishery mainly targets Black Jewfish (*Protonibea diacanthus*) using hook and line, but several other gears are also permitted: cast nets (for bait only), scoop nets, gaffs and fish traps. No bycatch was reported by commercial operators in this fishery during 2013, 2014 and 2015. Observers have only opportunistically conducted monitoring on these and, while bycatch was not explicitly measured, it was estimated to be <1% of the total catch and consisted mainly of Sharks and Catfish. The Queensland Gulf of Carpentaria Line and Coral Reef Finfish fisheries are similar fisheries to this one and these have a retained:discard ratio of 1:0.095 and a discard rate of 8.69%.

The Trepang fishery targets Sandfish (*Holothuria scabra*; a type of Sea Cucumber), using hand-gathering while hookah diving. Selective harvesting by the fishery avoids bycatch so discards can be assumed to be negligible. The very small Restricted Bait fishery uses a variety of bait nets and is also assumed to have negligible discards. The Aquarium Fish/Display fishery supplies a range of aquarium fishes, plants and invertebrates (including corals) to pet retailers and wholesalers. Fishers can use several types of nets, hand pumps, freshwater pots and hand-held instruments to collect specimens. All methods are considered highly selective with negligible discards.

The Coastal Net fishery harvests a range of species including Mullets (Family Mugilidae), Blue Threadfin (*Eleutheronema tetradactylum*), Sharks and Queenfish (*Scomberoides* spp.). The main fishing method used are gillnets, with cast nets also occasionally used. Nets must be cleared in water not less than 30 cm deep to facilitate the release of any bycatch or prohibited species. There was no reported bycatch in this fishery by licensees during 2013, 2014 and 2015 and there are no observer data available. However, it is unlikely that such a fishery would have no discards so we assume discard levels from the similar Queensland Gulf of Carpentaria Inshore Finfish fishery – a ratio of 1:0.051 and a discard rate of 4.84%.

Based on the above, Table 25 summarises the ratios and discard rates derived.

Table 25 – Assumed average retained:discard ratios and discard rates (by weights) for the Northern Territory's commercial fisheries.

Fishery	**Retained:discard ratio**	**SE***	**Discard %**	**Notes**
Demersal	1:0.16	0.01	13.8	
Timor Reef	1:0.10	0.03	9.0	
Barramundi	1:0.32	0.20	24.2	
Offshore Net and Line	1:0.18	0.04	14.4	
Spanish Mackerel	na	na	na	1
Mud Crab	1:0.15	0.02	13.0	2
Coastal line	1:0.10		8.7	3, 5
Trepang	1:0.00	0.00	0.0	4
Restricted Bait	1:0.00	0.00	0.0	4
Aquarium Display	1:0.00	0.00	0.0	4
Coastal net	1:0.05		4.8	3, 5

*SE of discard component of ratio
[1]No discard estimates available or able to be substituted
[2]Uses NSW estimate
[3]Uses Queensland estimate
[4]Assumes zero discards
[5]Insufficient replicate ratios to derive an SE

Extrapolated Estimates

The next step in estimating discards for the commercial fisheries of the Northern Territory is to combine the estimated average retained catches for each fishery (Table 24) with the assumed discard rates for each (Table 25) to provide estimates of total discards for each fishery and the total for the jurisdiction (Table 26).

Table 26 - Discard estimates (and SE's) for each fishery in the Northern Territory with total estimates for all fisheries and methods, derived by combining data in Tables 24 and 25. Where there were no discard data available (and one could not assume zero discards or use a discard estimate from another jurisdiction), this fishery was removed (the Spanish Mackerel fishery).

Fishery	Retained catch (tonnes)	SE	Discarded catch (tonnes)	SE
Demersal	2453.17	197.26	393.23	35.90
Timor Reef	722.93	35.60	75.39	23.75
Barramundi	718.01	123.15	228.83	148.72
Offshore Net and Line	613.58	158.81	112.73	39.11
Spanish Mackerel	255.23	34.11		
Mud Crab	224.16	50.39	33.40	8.48
Coastal line	111.88	8.36	10.63	10.63
Trepang	51.56	13.11	0.00	0.00
Restricted Bait	31.44	7.03	0.00	0.00
Aquarium Display	10.21	2.16	0.00	0.00
Coastal net	6.53	1.54	0.33	0.33
TOTALS:	**5198.72**	**290.81**	**854.53**	**160.27**
Overall Discard % =			**14.12**	**2.65**

Threatened, Endangered and Protected (TEP) species

Information about interactions with TEPs in the Northern Territory's commercial fisheries comes from the 3 recent status reports (NTG, 2015, 2016, 2017) which summarise data from industry logbooks and the observer programmes. These are summarised below.

The Demersal and Timor Reef fisheries are required to have turtle exclusion devices by law and are reported to have consistently few interactions with TEPS compared to similar fisheries elsewhere (eg in Western Australia). Most interactions are with Narrow Sawfish and Scalloped Hammerhead Sharks.

The Offshore Net and Line Fishery is also reported to have relatively low interaction levels with TEPS. In particular, nets are required by law to be set above the bottom which minimises interactions with sawfish species. However, this fishery does interact with a significant number of Scalloped Hammerhead Sharks and, at its peak, approximately 50 t of this species were caught per year. A northern Australian TAC of 200 t has been set for this species.

The gears used in the Spanish Mackerel fishery (trolled lures and baited lines), the Mud Crab fishery (pots) and the Coastal Line fishery (hook and line) are considered to pose little risk of interaction with TEPS. Also, the selective harvesting methods used in the Trepang, Restricted Bait and Aquarium Fish/Display fisheries are assumed to pose negligible risks of interaction with TEPS. Finally, the small number of licensees in the Coastal Net fishery (five), in conjunction with its restricted area, is considered to limit the risk of interactions with TEPS.

A summary of the available information on TEP species interactions is provided below in Table 4.

Table 27 – Estimates of interactions between the Northern Territory's commercial fisheries and TEP species.

Fishery	**Year**	**Source**	**Interactions with TEP species**
Demersal	2013	Observers	16 interactions over 30 days with sea snakes, Narrow Sawfish and turtles
	2014	Observers	18 interactions over 40 days with sea snakes, Narrow Sawfish, two dolphins and a turtle
	2015	Observers	8 interactions over 31 days with sea snakes, Narrow Sawfish and a Grey Nurse Shark
	2016	Observers	106 interactions over 60 days with Scalloped Hammerhead Sharks, Narrow Sawfish, Sea snakes with 11 turtles and one Devil Pygmy Ray caught
	2017	Observers	49 interactions over 36 days with Scalloped Hammerhead Sharks, Narrow Sawfish with 1 Dolphin and Pygmy Devil Ray
Timor Reef	2013-14	Observers	none
	2015	Observers	3 interactions over 35 days with two sea snakes and a Narrow Sawfish
	2016	Observers	13 interactions over 40 days with sea snakes, Narrow Sawfish, Pipefish and a Whale Shark
	2017	Observers	14 interactions over 36 days with Scalloped Hammerhead Sharks and one each of Green Sawfish, Pipefish and Grey Nurse Shark
Barramundi	2013-15	Logbooks	Less than 100 interactions per year with Saltwater Crocodiles and Sawfish
Offshore Net and Line	2013	Observers	16 interactions over 30 days with sea snakes, Narrow Sawfish and turtles
	2014	Logbooks	22 sawfish, 22 turtles, 15 Mobulid rays, two river sharks and one dolphin over 621 days
	2015	Logbooks	27 sawfish, 13 turtles, one Mobulid ray, and one dolphin over 588 days

Spanish Mackerel	2013-15	Logbooks	None
Mud Crab	2013-15	Logbooks	None
Coastal line	2013-15	Logbooks	None
Trepang	2013-15	Logbooks	None
Restricted Bait	2013-15	Logbooks	None
Aquarium Display	2013-15	Logbooks	None
Coastal net	2013-15	Logbooks	None

Quality/Performance Metrics

Table 28 contains the results from an application of the US National Bycatch Report's 20 Tier Classification criteria for determining the quality/performance of methods for estimating general discards in the Northern Territory's fisheries. The 220 estimated scores are contained in Appendix 7. The total points possible is 73 with the 5 tiers ranked from 0 (for fisheries with no discard data) through to 4 (the best quality information).

Table 28 – The quality of Northern Territory's general discard information derived from an application of the US system's Tier Classification Criteria (see Appendix 7 for detailed scores). Also added is a weighted % score taking account of the relative amount of discards estimated for each fishery (from Table 4).

Fishery	**TOTAL POINTS (maximum = 73)**	**% score (maximum = 100)**	**Tier (maximum = 4)**	**% score weighted by estimated discards**	**Note**
Demersal	41	56.16	2	25.85	
Timor Reef	41	56.16	2	4.96	
Barramundi	41	56.16	2	15.04	
Offshore Net and Line	41	56.16	2	7.41	
Spanish Mackerel	2	2.74	1	0.00	
Mud Crab	13	17.81	1	0.70	
Coastal line	13	17.81	1	0.22	
Trepang					1
Restricted Bait					1
Aquarium Display					1
Coastal net	13	17.81	1	0.00	
AVERAGE SCORES:	**25.6**	**35.1**	**1.5**	**54.2**	
[1]assumes zero discards and no need to quantify discards and therefore a quality metric is not applicable					

For the Northern Territory, average scores were 25.6 (out of 73) or 35.1% with an average tier of 1.5. However, these averages do not account for the relative level of discards that are estimated to have come from each fishery. That is, ideally having better quality data for those fisheries with high discards should elevate the overall quality score for the jurisdiction. The final column in Table 5 was therefore created to provide the percentage scores weighted by the amount of discards estimated to be associated with each fishery (from Table 26). Providing such a weighting increases the average quality score for the Northern Territory to 54.2% due to the dominating contribution of the relatively good discard information available for those fisheries with the greatest discards (the Demersal, Timor Reef, Barramundi and Offshore Net and Line fisheries).

Table 29 summarises an application of the same US Tier Classification System to the Northern Territory TEPs information. The results reveal poorer information – an average of 10.3% and a tier class of 1.0. As for the other jurisdictions, information that yields such a low quality metric should not be used to determine extrapolations about TEP species interactions to whole fisheries or jurisdictions.

Table 29 – Quality of discard data for TEP species derived from an application of the US system's Tier Classification Criteria (see Appendix 8 for detailed scores).

Fishery	**TOTAL POINTS (maximum = 73)**	**% score (maximum = 100)**	**Tier (maximum = 4)**	**Note**
Demersal	11	15.07	1	
Timor Reef	11	15.07	1	
Barramundi	11	15.07	1	
Offshore Net and Line	11	15.07	1	
Spanish Mackerel	4	5.48	1	
Mud Crab	4	5.48	1	
Coastal line	4	5.48	1	
Trepang				1
Restricted Bait				1
Aquarium Display				1
Coastal net	4	5.48	1	
AVERAGE SCORES:	**7.5**	**10.3**	**1.0**	
[1]assumes zero discards and no need to quantify discards and therefore a quality metric is not applicable				

Discussion

The extrapolated estimates of general discards for the commercial fisheries of the Northern Territory (Table 26) show the lowest levels of discarding of all case studies examined in this project

(ie just 14.1%). The greatest quantity of discards was estimated to occur in the Demersal and Barramundi fisheries (together representing 72.8% of total discards), less occurring in the Offshore Net and Line and Timor Reef fisheries (22%) and much smaller amounts occurring in the other fisheries. The data suggest that, given the estimated level of discards, the application of the Northern Territory's observer effort to these 4 main fisheries is appropriate. However, some estimates from those fisheries that currently lack any data from which discard rates and ratios can be estimated (especially the Spanish Mackerel, Mud Crab and Coastal Line fisheries) would benefit the overall estimate of discards for the jurisdiction.

For interactions with TEP species, the limited data available from the Northern Territory shows that such interactions occur rarely and sporadically. But unlike many jurisdictions, the opportunistic observer work done in the Territory at least provides some indications of the (quite low) levels of interactions with TEP species that occur for the Demersal and Torres Strait Fisheries. Nevertheless, as for the other case studies in this project (and as for most jurisdictions in the world), the lack of data precludes one from providing any sort of definitive estimates of TEP species interactions for the entire jurisdiction.

In terms of estimating quality/performance metrics for this jurisdiction, the Northern Territory's overall metric of 54.2% is similar to the NSW score and slightly higher than the other case studies examined here. This is due to the quite good information for the 4 main fisheries and the fact that NT Fisheries operates one of the only ongoing observer programmes in Australia's non-Commonwealth jurisdictions.

For TEP species, the Northern Territory information is also of a better quality than the other jurisdictions although still quite low (10.3% compared to 5.1% for NSW, 8.9% for Queensland and 6.2% for Tasmania). Once again, this is due to the existence of the Northern Territory's ongoing observer programmes but nevertheless, the information still precludes any sort of confident estimate being made regarding total numbers of interactions with these species.

General Discussion

Total Discards

Table 30 summarises total estimated general discards from the 4 case studies examined in this project.

Table 30 – Summary of estimated total retained catches, discards and discard rates for each case study examined in this project and their totals.

Jurisdiction	Retained catch (tonnes)	SE	Discards (tonnes)	SE	Discard %	SE
NSW	13,155	394	5,734	1,155	30.3	6.1
Tasmania	5,199	361	2,529	274	32.7	3.5
Queensland	19,261	381	26,579	1,379	58.0	3.0
Northern Territory	5,199	291	855	160	14.1	2.7
Totals	42,814	717	35,606	1,827		
Overall Discard Rate:					**45.5**	**2.3**

By far the greatest quantity of estimated discards comes from Queensland, and most of this from just one fishery – the East Coast Prawn Trawl fishery (see also below). And the lowest level of estimated discards comes from the Northern Territory which has quite a small (14%) discard rate – no doubt due to the lack of a significant trawl fishery there.

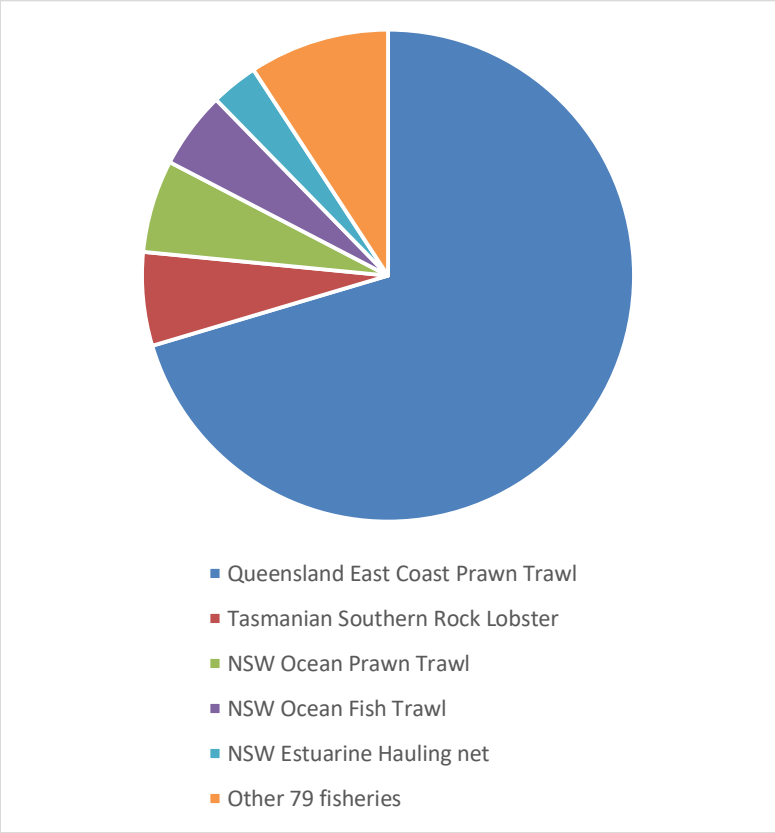
Combining the data from the 4 jurisdictions to obtain an overall discard percentage, we can estimate that, together, 45.5% of their catches are discarded. But once again, this is heavily influenced by the large quantity discarded by Queensland and its prawn trawl fishery. Whilst this combined figure cannot be said to be Australia's national discard level (because it comes from only half of Australia's fisheries jurisdictions), one could argue that the remaining 4 jurisdictions (the Commonwealth, South Australia, Western Australian and Victoria) together may have similar discard rates as those examined here because they have fisheries that use similar methods, across similar geographies, as those covered by the case studies here. Indeed, 3 of these jurisdictions have significant prawn trawl fisheries which we know are the main discarders. If we then assume a national discard rate of 45.5%, whilst it is quite high compared to, for example the USA's 17% for its federally managed fisheries (NMFS, 2011), it is nevertheless a lower figure than the only other estimate available for Australia which has our national discard level at 55.3% (FAO's report by Kelleher, 2005). To give some further international context, out of 139 jurisdictions examined by Kelleher's study, Australia would now rank as the 19th highest discarder based on this present study - in 2005, Australia ranked 14th. But such conclusions are purely speculative at this stage –

until discards for the remaining 4 Australian jurisdictions are examined and Kelleher's global estimates are updated - which will probably change national rankings).

Discards for Various Fisheries/Methods

Figure 1 shows the relative contribution of the 84 fisheries for which discards were estimated in this project. Across all 4 jurisdictions, the Queensland East Coast Prawn Trawl fishery clearly dominates the total amount of discarding, with far less quantities coming from (in order) the Tasmanian Rock Lobster fishery, NSW's Ocean Prawn Trawl, Fish Trawl and Estuarine Hauling fisheries. Compared to these, far fewer discards came from the remaining 79 fisheries.

Fig. 1 – The percentage contribution to total discards across the 4 case studies of the various fisheries/methods examined.



Perhaps the most surprising result in this figure is the 2nd highest discarding fishery – the Tasmanian lobster fishery. Most people would consider lobster trapping as a reasonably selective fishing method yet this study estimated that 66% of the catch in this fishery is discarded (an estimate that, as we recall, relied on significant assumptions regarding the weights of discards because only numbers of individuals were recorded). However, it is important to note that most of these discards are hermit crabs and undersize lobsters – both of which are believed to have very high survival rates after discarding - so the actual impact of such discarding on populations may be quite minimal.

But the dominant discarding method in the 4 case studies is, by far, oceanic prawn trawling. Because of the gear used (with relatively small mesh), prawn trawling is well-known as the least selective fishing method used throughout the world – especially in warmer waters where the quantity and diversity of the fauna caught is greatest. So it is not surprising that Queensland's large East Coast Prawn Trawl fishery (which mainly operates in warmer waters) dominates the discards across the 4 case studies with an estimated 25,065 tonnes at a discard rate of 77%. This level of discards is also comparable to another Australian tropical prawn trawl fishery not covered here but examined in another project done by IC Independent Consulting as part of the UN FAO's current update of global discards. In that project (FAO, in prep.), it was estimated that the Commonwealth-managed Northern Prawn Fishery, with average annual landings of 8733 tonnes, discards around 22,456 tonnes at a discard rate of 72%. These high levels of discards are the main reason for the significant amount of research that has occurred throughout the world (and particularly in Australia) to modify prawn trawl gears so that they fish more selectively. Modifications such as various grids and square mesh panels have been shown to greatly reduce discards in these fisheries, and the next section attempts to estimate their effects. Nevertheless, the results shown here indicate that there remains significant work to be done to reduce discards in such methods.

Effects of Bycatch Reduction Devices (BRDs)

When gathering the many pieces of information for this project, it became apparent that the historically well-documented discard estimates from NSW's observer programmes, coupled with that jurisdiction's well-documented research into bycatch reduction, allowed an examination of the role that certain BRDs may have had in reducing discards in that state. Table 31 shows the total estimated discards from the 3 fishing methods where BRDs have been implemented in recent years in NSW, with and without adjustments for the decrease in discards expected from these BRDs (assuming that the discard reduction attributable to the BRDs now used in the fishery are similar to those estimated from the experimental work). The impact of the new BRDs was calculated to be a reduction in annual discards throughout the state of 1,246 t (or 27.7 million individuals).

Table 31 – The impact of allowing for discard reductions due to Bycatch Reduction Devices being implemented in NSW's Estuarine Prawn Trawl, Ocean Prawn Trawl and Ocean Fish Trap fisheries.

		Total Discards using retained wts to extrapolate (t)	**SE**	**Total Discards using fishing effort to extrapolate (t)**	**SE**
ALLOWING FOR BYCATCH REDUCTION DEVICES	Estuary Prawn Trawl	92.83	55.64	29.27	9.11
	Ocean Prawn Trawl	3458.69	941.86	2168.56	520.78
	Ocean Fish trap (bottom/demersal)	11.30	11.30	22.76	0.78
	NSW TOTAL:	**6463.69**	1045.13	**5733.77**	1154.66
	DISCARD PERCENTAGES:	**32.95**	5.33	**30.35**	6.11

WITHOUT ALLOWING FOR BYCATCH REDUCTION DEVICES	Estuary Prawn Trawl	530.47	317.96	167.24	52.06
	Ocean Prawn Trawl	5154.54	1403.66	3231.83	776.12
	Ocean Fish trap (bottom/demersal)	33.29	33.29	67.80	67.80
	NSW TOTAL:	**8619.17**	1508.13	**6980.05**	1292.71
	DISCARD PERCENTAGES:	**39.58**	6.93	**34.67**	6.42
ESTIMATED ANNUAL REDUCTION OF DISCARDS DUE TO BRDs:				**1,246 tonnes**	
				27.7 million individuals *	
*Uses average weight per discarded individual of 44.9 gm (Kennelly & Liggins, 1998)					

The reader may be surprised to learn that, despite NSW pioneering a great deal of BRD research over the past two decades, the jurisdiction still has significant discards occurring for fishing methods for which BRDs are available (ie. prawn and fish trawling). But the data in Table 31 show that, where BRDs have been implemented, quite significant reductions in discards may have occurred. Of course, such a conclusion relies on the above-mentioned assumption that the actual reduction in discards that is occurring as a result of the implementation of BRDs is similar to those quantities estimated from the experimental work – and this may not be the case. In Australia's Northern Prawn Fishery, for example, scientific studies yielded much higher bycatch reduction rates compared to those when the same modifications were used by the fishing industry (Brewer et al, 2004). Clearly, in addition to the legislative implementation and proper enforcement of devices that have already been developed, and the assessment of their impacts as used in the fishery, more research into selective gears is needed in Australia, especially for those methods above that show the greatest levels of discards.

Threatened, Endangered and Protected Species Interactions

Whilst the work done in this project was able to produce reasonable estimates of general discards for most fisheries and methods in the 4 case studies examined, the same cannot be said for interactions with TEP species. As mentioned several times previously, this is because interactions between commercial fisheries and such species are usually rare and sporadic (an exception are interactions with species like sea horses which can be quite common – see above). Further, in any case, fishers' willingness to report such interactions (on logbooks) can be influenced by the controversy that such interactions can incur as well as a degree of caution on how the information may be used if reported. As a result, the data available that describe such interactions are very few with large variances.

Whilst it is tempting to extrapolate the very limited data about such interactions to whole fisheries and jurisdictions using total catch and/or effort multipliers (as done for the general discard information), the very small number of TEP species interactions recorded makes such extrapolations extremely tenuous (at best), probably erroneous, and dangerously controversial in terms of the total numbers of interactions that could be estimated. We therefore do not provide such extrapolations here. This is further justified by considering the relative quality of the TEPs

data obtained from applying the US Bycatch Report's Tier Classification Scheme's 20 quality criteria to the TEPs information (see below – Table 32). The results reveal very poor information for such interactions – an average of just 7.6% with an average tier class of 0.66. Clearly information that yields such low quality metrics should not be used for extrapolations.

But these 4 jurisdictions are far from being alone in not having the information needed to estimate total numbers of interactions with TEPs. This is a common issue throughout the world, even for jurisdictions that run observer programmes for the express purpose of providing such information (and, indeed for any dataset with an inadequate sample size that tries to extrapolate rare events to total estimates). When dealing with such rare events, the only sure way to estimate total interactions for a fishery is to increase the sample size to such a level that variances around the average numbers of interactions are reduced to an acceptable level. And of course, the best way to achieve this is via 100% observer coverage – as done in several fisheries like IATTC's observer program which focusses on dolphin and seabird interactions of its tuna fleet (Hall, 1998). But such programs are expensive – far too expensive for the scale of most of the fisheries we have in Australia – and possibly unnecessary, given the relative number of interactions that, intuitively, our fisheries may have with TEP species compared to fisheries in other regions.

In recent years, a potential solution to this issue is emerging due to developments in the Electronic Monitoring (EM) of fisheries where video and/or still cameras are used to monitor operations. (McElderry et al., 2007). Such programs can nominally provide 100% coverage and so capture all interactions with TEPs (and other species). The problem is the cost associated with viewing all such footage/images - which can be resolved by only viewing a fraction of the information as a means to verify fishers' logbook recordings of interactions. Where this has been done, a marked improvement in the incidence of reported interactions has usually ensued. Also, an alternative to this is currently under development in several places throughout the world where image recognition software could, within a few years, be able to obtain data from footage/images without the need for human viewers.

We believe that it will not be long until such developments, combined with more streamlined tools to aid the electronic reporting of catches and bycatches by fishers, and faster, cheaper data transfers will lead to the "holy grail" of industry-based data collection from fisheries: simple, hand-held, real-time data collection tools whose data are validated by random, periodic subsampling of video/images from EM cameras.

Quality/Performance Metrics

Table 32 summarises the results obtained in this study with respect to the quality of the 4 case studies' discard information – as estimated by applying the US Tier Classification system.

Table 32 – Summary of the quality metrics derived for the case studies examined for general discards and TEPs interactions.

Jurisdiction	No. of fisheries	No. of Fisheries with discards estimated	No. of Fisheries not requiring a quality metric	General Discards Quality %	TEPs Quality %
NSW	46	36	4	55.08	5.14
Tasmania	20	18	7	49.9	6.22
Queensland	20	17	5	51.58	8.86
Northern Territory	11	10	3	54.2	10.3
TOTALS	97	81	19		
AVERAGE				52.7	7.63

Of the 97 commercial fisheries in these 4 jurisdictions, 81 were able to have some sort of discard estimate determined. Of these, there were some fisheries (19) that did not require a quality metric to be estimated because it was assumed that discards were negligible (these were the intuitively highly selective fisheries involving hand-gathering, spearing, etc.). All 4 case studies were found to have fairly similar quality metrics for general discards of around 50% with the average across all 4 estimated as 52.7%. And all 4 also had similar quality metrics for information about TEPS interactions but at a very low level of 10% and below (with an average score of 7.6%). But, as we discussed above, Australia is far from alone in this regard as most jurisdictions have problems in obtaining reasonable estimates of interactions with rare species to allow fishery- or fishing method- wide extrapolations. Even the USA, with its large number of observer programs (several of which are designed to just focus on TEPs interactions), has far lower tier scores for TEP species than is the case for general discards (see Table 33).

These metrics allow one to conclude that, for general discards, our 4 case studies have reasonable information (albeit with plenty of room for improvement – see below for some suggestions), whilst our information about TEPS interactions is quite poor. But the main value of these metrics is in providing a baseline measure against which future metrics can be compared to allow us to gauge improvements (or diminishments) in our information about these interactions. Notwithstanding this future use, we can, however, compare our quality metrics with those derived by the NMFS for USA fisheries – at least in terms of the proportions of fisheries in each tier class (the US report did not provide detailed scores for each fishery nor a total score for the whole jurisdiction precluding that particular comparison).

Table 33 – Comparisons of the tier classifications estimated in this study across 4 Australian jurisdictions (81 fisheries assessed) for general discards and TEPs interactions with those for the USA (152 fisheries assessed). Data are the percentage of fisheries in each tier class and, in the final row, the average tier class (maximum is 4).

	General Discards		TEPs Interactions	
	Australia's 4 case studies	USA	Australia's 4 case studies	USA
Tier 4	0	3	0	3
Tier 3	14	43	0	43
Tier 2	28	18	7	13
Tier 1	33	23	54	11
Tier 0	25	13	39	30
Average Tier Class	1.32	2.00	0.66	1.79

For general discards, our 4 case studies had fewer fisheries in the higher tiers and more in the lower ones than the USA with an average tier of 1.32 compared to the USA's 2.00. For TEPs interactions, the situation is even starker with our case studies' average at 0.66 compared to the USA's 1.79.

These results reflect the far fewer (and mostly out-of-date) observer programs occurring in Australia than in the US. But such a comparison is understandable given the fact that US fisheries tend to be far larger (and more valuable) than those in Australia and therefore can afford to run large and numerous observer programs which are often subsidised by government. Indeed, considering the relatively small size and value of Australia's commercial fisheries compared to those in the US, a quality metric of 52.7% for general discards would, by most international standards, be considered quite satisfactory. Notwithstanding this, as noted earlier, such a metric will, in any case, form a useful baseline for future comparisons while also identifying the focus for future bycatch monitoring programs whether by human observers (which can be costly) and/or by EM programs that audit industry reporting (a cheaper option). That is, such programs would ideally focus on the main discarding fisheries identified in this study (especially the oceanic prawn trawl fisheries) and therefore lead to improvements in this metric over time. In this vein, it is pleasing to note that NSW DPI is in fact currently doing just this for 2 of the 5 highest discarding fisheries identified here (the NSW Ocean Prawn and Fish Trawl fisheries).

A Bycatch Reporting System for Australia

This project has developed a methodology by which jurisdictions can estimate and report on the quantities of discards from their commercial fisheries (the most important and controversial component of bycatch). This methodology involves a series of simple steps, examples of which are contained in the tables provided in this report's 4 case studies. To summarise, the 5 steps involved are:

1. Identify the individual fisheries/methods managed in each jurisdiction for which discards are to be estimated, the annual landings for each and, if available, the annual fishing effort occurring for each (ideally averaged over the past few years). Express these data as averages and associated SEs.
2. Gather all available papers, reports and datasets on fisheries bycatches, discards and TEPs interactions. From these, try to derive retained:discard ratios and effort:discard ratios for each fishery/method. Express these as averages (if multiple ratios exist) with associated SEs.
3. For those fisheries/methods that lack ratios in Step 2, identify and include any substitute ratios from similar fisheries/methods from other jurisdictions.
4. Multiply the average ratios from Steps 2 and 3 by the average landings data from Step 1 to obtain total estimated annual discards for each fishery/method and add these together to get a jurisdictional total. If fishing effort is available, and discard ratios are also available by fishing effort, do this step using effort as the multiplier. Use Goodman's (1960) formula for calculating the product of variances to derive the appropriate SEs associated with the extrapolated estimates.
5. Apply the steps in the US Tier Classification Scheme for estimating the quality of the discard information for each fishery/method, weighted by the estimated level of discards for each. Express these metrics as a percentage score for comparison purposes.

Recommendations

Further developments

The work done in this project has highlighted several areas where improvements can be made in how to monitor and report on bycatches and discards in Australia's commercial fisheries:

- This study only examined 4 of Australia's 8 fisheries jurisdictions. A more comprehensive examination of our national discards would come from repeating this work for the remaining 4 jurisdictions (the Commonwealth, South Australia, Western Australia and Victoria).
- Future bycatch monitoring programs in Australia should: (i) focus on getting at least some data from fisheries where we have no discard data at all; (ii) but mainly concentrate on particularly problematic and non-selective fishing gears (such as trawling), with (iii) less focus on those gear types that have been identified as having relatively few discards. This is not to say that we need lots of ongoing (and often expensive) observer programs, but strategically-located and -timed programs that examine certain fisheries periodically. Such a system of "rolling" observer programs will greatly improve the quality of discard information for Australia at a more modest expense. Alternatively, the use of camera technology to audit industry reported information is proving to be an adequate (and cheaper) way to obtain such information.

- Such programs should include reporting on the weights of discards (not just numbers of individuals) so that better extrapolations of rates to whole fisheries and jurisdictions can be done (because the multiplier for extrapolations that is most often used involves landings by weight – not by numbers).
- Efforts to reduce discards should focus on those fisheries identified as having particularly high discards (in this study, oceanic prawn trawling, lobster and estuarine haul fisheries) by developing more selective gears, better handling practices and/or better implementing modifications that have already been developed.
- Substantial effort needs to focus on better ways to monitor interactions with TEP species, perhaps by embracing current work occurring in the field of Electronic Monitoring using video and/or still photography to augment and audit industry-based reporting.

Conclusions

By examining the discard information available for 4 of Australia's 8 fisheries jurisdictions, this project was able to develop a methodology by which all Australia's jurisdictions can compile, summarise and report on discards from their commercial fisheries. This methodology involves a relatively simple 5 stage process that produces estimates of rates and annual quantities of discards (with associated variances) for the jurisdiction and the various fisheries within it, in addition to estimates of the relative quality of the information used.

In developing this methodology, this project has not only provided baseline information and metrics against which subsequent reports can be compared, but also identified the key gaps in our information about discarding in these fisheries and where future work on discards in Australia should focus in terms of reporting, monitoring and reduction.

Implications

The provision of this methodology that allows Australia's fisheries jurisdictions to report on commercial discards will allow those jurisdictions that adopt it to periodically report to its public on the status of discarding in their fisheries and the quality of the information used to determine it. In so doing, it also permits Australia's jurisdictions to satisfy any requirements for discard reporting to national and/or international agencies/agreements and for individual fisheries to satisfy similar requirements of eco-labelling organisations and similar bodies.

The work done in this project also identifies those areas where future work on discards in Australia should focus in terms of reporting, monitoring and reduction. As a first step, the work in this project on 4 case studies has implications for those jurisdictions not included – where, if only for the sake of completeness, similar discard reporting should be attempted.

This project has also identified that, to better estimate discards empirically and resolve many of the assumptions made, more strategic use of observer programs and/or Electronic Monitoring is required (the latter in particular for estimating TEPs interactions). But such programs are not

necessarily needed for all fisheries, all the time – but mainly for those fisheries that have been identified as having quite high levels of discards (such as trawl fisheries) and only periodically (every few years instead of continually). Further, this project has identified those fishing methods where, despite decades of research, still more work is needed to reduce discards.

Extension and Adoption

The main target audience for the work done in this project is Australia's fisheries jurisdictions and individual fisheries that wish to quantify and report on bycatch and discards. Other users of the information may be jurisdictions and fisheries in other countries as they also seek ways to do the same.

Of particular importance will be the examination of this project by the Australian Fisheries Management Forum and the 8 fisheries jurisdictions of the country as they consider implementing (or not) the bycatch reporting system developed here as a periodic feature of fisheries reporting.

Other avenues for the dissemination of this report will be on appropriate websites to ensure that the information is made available to the general public (the actual owners of fisheries' discards). Of immediate interest concerns applying the discard estimates determined in this project for individual fisheries to fishery reporting systems being developed as part of Whichfish (www.whichfish.com.au), a risk assessment tool for environmental risks of Australian fisheries.

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Appendices

Appendix 1 – Spreadsheet used to score NSW general discard data according to the US Tier Classification system.

		Adequacy of Bycatch Data																	Quality of the Bycatch Estimate					TOTAL	% score					
		Observer Data										Industry Data	Supplementary Data					Database/IT	Analytical Approach											
		Longevity of Observer Data	Sampling Frame	Sampling Design of Vessels	Sampling Design of Trips	Sampling Design of Hauls	Spatial Coverage	Temporal Coverage	Vessel-Selection Bias	Observer Bias	Data Quality Control	Score	Data available as expansion factors for unobserved components	Data available for stratification	Data available for imputation	Data available for model covariates	Industry data verified	Score	Assumptions Identified, Tested, and Appropriate	Peer Reviewed / Published Design	Peer Reviewed / Published Analytical Approach	Statistical Bias of Estimators	Measures of Uncertainty			Tier:	Total Discards using fishing effort to extrapolate (t)	Prop of total discards	% score weighted by estimated discards	Note
	Maximum Scores	5	3	4	4	4	2	2	2	2	5	2	2	2	2	2	2	2	10	4	4	4	4	73	100					
Estuary General	**Meshing net**	1	3	2	2	3	2	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	40	54.79	2	188.41	0.03	1.80	
	Hauling net (general purpose)	1	3	2	2	3	2	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	40	54.79	2	1104.31	0.19	10.55	
	Prawn net (set pocket)	1	3	2	2	3	1	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	39	53.42	2	19.79	0.00	0.18	
	Crab trap	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	3	4	2	2	2	17	23.29	1	15.83	0.00	0.06	
	Fish trap (bottom/demersal)	1	2	1	1	3	2	2	1	2	2	1	1	1	1	0	0	1	3	4	2	2	1	34	46.58	2	14.73	0.00	0.12	
	Flathead net	1	3	2	2	3	2	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	40	54.79	2	48.35	0.01	0.46	
	Eel trap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0			0.00	
	Prawn net (hauling)	1	3	2	2	3	2	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	40	54.79	2	15.96	0.00	0.15	
	Handgathering	4	3	1	2	3	2	2	2	2	3	0	2	2	1	0	0	1	3	4	2	2	2	43	58.90	2	16.88	0.00	0.17	
	Prawn running net	1	3	2	2	3	2	2	1	2	3	0	2	2	1	0	0	1	3	3	2	2	2	39	53.42	2	4.73	0.00	0.04	
	Seine net (prawns)	1	3	2	2	3	2	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	40	54.79	2	10.06	0.00	0.10	
	Bait net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0.00	0.00		1
	Garfish net (bullringing)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0			0.00	
	Handline	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	3	4	2	2	1	16	21.92	1	4.26	0.00	0.02	
	Pilchard, anchovy & bait net - beach based	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00	0.00	
	Setline	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	3	2	2	2	1	14	19.18	1	4.31	0.00	0.01	
	Dip or scoop net (prawns)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0.00	0.00		1
	Hoop or lift net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						1
Estuary Prawn Tra	**Otter trawl net (prawns)**	1	3	2	3	3	2	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	41	56.16	3	29.27	0.01	0.29	
Ocean Trawl	**Otter trawl net (prawns)**	1	3	2	3	3	2	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	41	56.16	3	2168.56	0.38	21.24	
	Otter trawl net (fish)	1	3	2	3	3	2	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	41	56.16	3	1799.13	0.31	17.62	
Ocean Hauling	**Hauling net (general purpose)**	2	3	2	2	3	2	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	1	40	54.79	3	13.40	0.00	0.13	
	Purse seine net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00	0.00	
	Pilchard, anchovy & bait net - beach based	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00	0.00	
	Garfish net (hauling) - boat based	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00	0.00	
	Garfish net (hauling) - beach based	2	3	2	2	3	1	2	1	2	3	0	2	2	1	0	0	1	3	4	2	2	2	40	54.79	3	0.07	0.00	0.00	
Ocean Trap & Line	**Fish trap (bottom/demersal)**	1	2	1	1	3	2	2	1	2	2	1	1	1	1	0	0	1	3	4	2	2	1	34	46.58	2	22.76	0.00	0.18	
	Handline	2	3	2	3	3	2	2	1	2	3	0	2	2	1	0	0	1	3	2	2	2	1	39	53.42	3	38.02	0.01	0.35	
	Trolling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0			0.00	
	Setline (demersal)	2	3	2	3	3	2	2	1	2	3	0	2	2	1	0	0	1	3	2	2	2	1	39	53.42	3	29.27	0.01	0.27	
	Spanner crab net	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	1	3	0	2	0	2	14	19.18	1	34.90	0.01	0.12	
	Jigging	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	3	2	2	2	1	14	19.18	1	5.71	0.00	0.02	
	Dropline	2	3	2	3	3	2	2	1	2	3	0	2	2	1	0	0	1	3	2	2	2	1	39	53.42	3	5.00	0.00	0.05	
	Setline	2	3	2	3	3	2	2	1	2	3	0	2	2	1	0	0	1	3	2	2	2	1	39	53.42	3	29.44	0.01	0.27	
	Poling	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	3	2	2	2	1	14	19.18	1	0.71	0.00	0.00	
	Trotline (bottom set)	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	3	2	2	2	1	14	19.18	1	16.34	0.00	0.05	
	Driftline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00	0.00	
Abalone	**Diving**	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	2	2	1	11	15.07	1	9.52	0.00	0.03	
Lobster	**Trapping**	1	2	2	2	3	2	2	2	2	3	1	2	2	1	0	0	1	3	2	2	2	1	38	52.05	3	84.06	0.01	0.76	
Others	**Danish seine trawl net (fish)**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0			0.00	
	Pilchard, anchovy & bait net - boat based	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00	0.00	
	Skindiving	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0.00	0.00		1
Special Permits	**Purse seine net**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0			0	
	Scallop Dredge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0			0	
	Submersible Lift Net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0			0.00	
	Eel trap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0			0.00	
																						totals:					5733.77	1.00		
																						average score:		21.43	29.35	1.38			55.075239	

1 - assumes zero discards and no need to quantify discards and therefore a quality metric is not applicable

Appendix 2 – Spreadsheet used to score NSW TEPs discard data according to the US Tier Classification system.

		Adequacy of Bycatch Data																	Quality of the Bycatch Estimate					TOTAL POINTS	% score		
		Observer Data										Industry Data	Supplementary Data					Database / IT	Analytical Approach								
		Longevity of Observer Data	Sampling Frame	Sampling Design of Vessels/ Permits/ Licenses	Sampling Design of Trips	Sampling Design of Hauls	Spatial Coverage	Temporal Coverage	Vessel-Selection Bias	Observer Bias	Data Quality Control	Score	Data available as expansion factors for unobserved components	Data available for stratification	Data available for imputation	Data available for model covariates	Industry data verified	Score	Assumptions Identified, Tested, and Appropriate	Peer Reviewed / Published Design	Peer Reviewed / Published Analytical Approach	Statistical Bias of Estimators	Measures of Uncertainty			Tier:	Note
	Maximum Scores	5	3	4	4	4	2	2	2	2	5	2	2	2	2	2	2	2	10	4	4	4	4	73	100		
Estuary General	**Meshing net**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Hauling net (general purpose)	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2.74	1	
	Prawn net (set pocket)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Crab trap	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2.74	1	
	Fish trap (bottom/demersal)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Flathead net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Eel trap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Prawn net (hauling)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Handgathering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
	Prawn running net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Seine net (prawns)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Bait net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
	Garfish net (bullringing)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Handline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Pilchard, anchovy & bait net - be	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Setline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Dip or scoop net (prawns)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
	Hoop or lift net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
Estuary Prawn Tra	Otter trawl net (prawns)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
Ocean Trawl	**Otter trawl net (prawns)**	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2.74	1	
	Otter trawl net (fish)	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2.74	1	
Ocean Hauling	**Hauling net (general purpose)**	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2.74	1	
	Purse seine net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Pilchard, anchovy & bait net - be	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Garfish net (hauling) - boat base	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Garfish net (hauling) - beach bas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
Ocean Trap & Line	**Fish trap (bottom/demersal)**	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2.74	1	
	Handline	2	3	2	3	3	2	2	1	2	3	2	1	1	1	0	0	1	1	2	2	0	0	34	46.58	2	
	Trolling	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2.74	1	
	Setline (demersal)	2	3	2	3	3	2	2	1	2	3	2	1	1	1	0	0	1	1	2	2	0	0	34	46.58	2	
	Spanner crab net	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2.74	1	
	Jigging	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Dropline	2	3	2	3	3	2	2	1	2	3	2	1	1	1	0	0	1	1	2	2	0	0	34	46.58	2	
	Setline	2	3	2	3	3	2	2	1	2	3	0	1	1	1	0	0	1	1	2	2	0	0	32	43.84	2	
	Poling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Trotline (bottom set)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Driftline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
Abalone	**Diving**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
Lobster	**Trapping**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
Others	**Danish seine trawl net (fish)**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Pilchard, anchovy & bait net - bo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Skindiving	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
Special Permits	**Purse seine net**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Scallop Dredge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Submersible Lift Net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
	Eel trap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	
																						average score:		3.75	5.14	0.40	

1 - assumes zero interactions and no need to quantify them so a quality metric is not applicable

Appendix 3 - Spreadsheet used to score Tasmania's general discard data according to the US Tier Classification system.

		Adequacy of Bycatch Data				General Discards													Quality of the Bycatch Estimate					TOTAL	% score					
		Observer Data										Industry Data	Supplementary Data					Database /IT	Analytical Approach											
Fishery	**Method**	Longevity of Observer Data	Sampling Frame	Sampling Design of Vessels	Sampling Design of Trips	Sampling Design of Hauls	Spatial Coverage	Temporal Coverage	Vessel-Selection Bias	Observer Bias	Data Quality Control	Score	Data available as expansion factors for unobserved components	Data available for stratification	Data available for imputation	Data available for model covariates	Industry data verified	Score	Assumptions Identified, Tested, and Appropriate	Peer Reviewed / Published Design	Peer Reviewed / Published Analytical Approach	Statistical Bias of Estimators	Measures of Uncertainty			Tier:	Total Discards (t)	Prop of total discards	% score weighted by estimated discards	Note
Maximum Scores:		5	3	4	4	4	2	2	2	2	5	2	2	2	2	2	2	2	10	4	4	4	4	73	100					
Abalone	Dive	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3	0	2	0	0	8	10.96	1	192.58	0.07616	0.83	
Southern Rock Lobster	Pots	4	2	2	2	2	2	2	2	2	3	2	2	2	2	0	0	2	3	0	2	0	2	40	54.79	2	2188.66	0.86558	47.43	
Scallop	Dredge	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	2	1	3	0	2	0	0	12	16.44	1	74.57	0.02949	0.48	
Octopus	Pots (unbaited)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
Giant Crab	Pots	4	2	2	2	2	2	2	2	2	3	2	2	2	2	0	0	2	3	0	2	0	0	38	52.05	2	15.00	0.00593	0.31	
Scalefish	Automatic squid jig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
	Beach seine	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3	0	2	0	0	8	10.96	1	0.49	0.00019	0.00	
	Purse seine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00000	0.00	
	Graball net	4	2	2	2	2	2	2	2	2	3	2	2	2	2	0	0	2	3	0	2	0	0	38	52.05	2	38.09	0.01506	0.78	
	Hand line	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3	0	2	0	0	8	10.96	1	11.34	0.00448	0.05	
	Danish seine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00000	0.00	
	Squid-jig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
	Dip-net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
	Small mesh net	4	2	2	2	2	2	2	2	2	3	2	2	2	2	0	0	2	3	0	2	0	0	38	52.05	2	7.28	0.00288	0.00	
	Troll	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00000	0.00	
	Fish trap	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3	0	2	0	0	8	10.96	1	0.17	0.00007	0.00	
	Drop-line	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3	0	2	0	0	8	10.96	1	0.36	0.00014	0.00	
	Spear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
	Hand collection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
Commercial Dive and Shellfish	Hand Collection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
																						totals:				2528.54	0.92384		
																						average score:		16.50	22.60	1.08			49.060495	

1 - assumes zero discards and no need to quantify discards and therefore a quality metric is not applicable

Appendix 4 - Spreadsheet used to score Tasmania's data on TEPs interactions according to the US Tier Classification system.

		Adequacy of Bycatch Data																	Quality of the Bycatch Estimate					TOTAL	% score		
		Observer Data										Industry Data	Supplementary Data						Database /IT	Analytical Approach								
Fishery	**Method**	Longevity of Observer Data	Sampling Frame	Sampling Design of Vessels	Sampling Design of Trips	Sampling Design of Hauls	Spatial Coverage	Temporal Coverage	Vessel-Selection Bias	Observer Bias	Data Quality Control	Score	Data available as expansion factors for unobserved components	Data available for stratification	Data available for imputation	Data available for model covariates	Industry data verified	Score	Assumptions Identified, Tested, and Appropriate	Peer Reviewed / Published Design	Peer Reviewed / Published Analytical Approach	Statistical Bias of Estimators	Measures of Uncertainty			Tier:	Note
Maximum Scores:		5	3	4	4	4	2	2	2	2	5	2	2	2	2	2	2	2	10	4	4	4	4	73	100		
Abalone	Dive	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3	0	2	0	0				1
Southern Rock Lobster	Pots	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
Scallop	Dredge	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
Octopus	Pots (unbaited)	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
Giant Crab	Pots	4	2	0	0	0	2	2	2	2	3	2	0	0	0	0	0	2	0	0	2	0	0	23	31.51	1	
Scalefish	Automatic squid jig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
	Beach seine	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
	Purse seine	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
	Graball net	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
	Hand line	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
	Danish seine	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
	Squid-jig	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0				1
	Dip-net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
	Small mesh net	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
	Troll	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
	Fish trap	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
	Drop-line	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
	Spear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
	Hand collection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1
Commercial Dive and Shellfish	Hand Collection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0				1
																						totals:					
																						average score:		4.54	6.22	1.00	
1 - assumes zero interactions and no need to quantify them so a quality metric is not applicable																											

Appendix 5 - Spreadsheet used to score Queensland's general discard data according to the US Tier Classification system.

	Adequacy of Bycatch Data				General Discards												Quality of the Bycatch Estimate					TOTAL	% score					
	Observer Data										Industry Data	Supplementary Data					Database /IT	Analytical Approach										
	Longevity of Observer Data	Sampling Frame	Sampling Design of Vessels	Sampling Design of Trips	Sampling Design of Hauls	Spatial Coverage	Temporal Coverage	Vessel-Selection Bias	Observer Bias	Data Quality Control	Score	Data available as expansion factors for unobserved components	Data available for stratification	Data available for imputation	Data available for model covariates	Industry data verified	Score	Assumptions Identified, Tested, and Appropriate	Peer Reviewed / Published Design	Peer Reviewed / Published Analytical Approach	Statistical Bias of Estimators	Measures of Uncertainty			Tier:	Total Discards (t)	Prop of total discards	% score weighted by estimated discards	Note
Maximum Scores	5	3	4	4	4	2	2	2	2	5	2	2	2	2	2	2	2	10	4	4	4	4	73	100					
Coral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
Crayfish and Rocklobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.00	0.00000	0.0000	
East Coast Pearl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
Marine Aquarium Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
Eel Fishery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0		0.00000	0.0000	
Sea Cucumber Fishery (East Coast)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					0.00000		1
Trochus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0.00	0.00000		1
Coral Reef Finfish	1	1	1	1	3	1	1	0	2	2	0	2	2	2	0	0	1	3	2	2	0	2	29	39.73	1	222.21	0.00836	0.3321	
Deep Water Finfish	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	1	3	0	2	0	2	14	19.18	1	0.37	0.00001	0.0003	
East Coast Spanish Mackerel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	2		0.00000	0.0000	
Gulf of Carpentaria Line	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	1	3	0	2	0	2	14	19.18	1	18.51	0.00070	0.0134	
Rocky Reef Finfish	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	1	3	0	2	0	2	14	19.18	1	14.95	0.00056	0.0108	
East Coast Inshore Finfish Fishery	1	1	1	1	3	2	2	0	2	2	0	2	2	2	0	0	1	3	0	2	0	2	29	39.73	2	280.51	0.01055	0.0000	
Gulf of Carpentaria Inshore Finfish	1	1	1	1	3	2	2	0	2	2	0	2	2	2	0	0	1	3	0	2	0	2	29	39.73	2	99.58	0.00375	0.1488	
Blue Swimmer Crab	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	1	3	0	2	0	2	14	19.18	1	44.12	0.00166	0.0318	
Mud Crabs	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	1	3	0	2	0	2	14	19.18	1	404.45	0.01522	0.2918	
Spanner Crabs	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	1	3	0	2	0	2	14	19.18	1	253.96	0.00955	0.1832	
East Coast Otter Trawl	4	3	3	2	3	2	2	0	2	2	0	2	2	2	0	0	1	3	2	2	0	2	39	53.42	3	25064.70	0.94302	50.3805	
Gulf of Carpentaria Developmental F	0	0	0	0	0	0	0	0	0	0	2	2	2	2	0	0	1	3	0	2	0	2	16	21.92	1	119.88	0.00451	0.0989	
River and Inshore Beam Trawl	1	1	1	1	3	2	2	0	2	2	0	2	2	2	0	0	1	3	2	2	0	2	31	42.47	2	55.95	0.00211	0.0894	
																					totals:					26579.19	1.00000		
																					average score:		17.13	23.47	1.27			51.58103	
1 - assumes zero discards and no need to quantify discards and therefore a quality metric is not applicable																													

Appendix 6 - Spreadsheet used to score Queensland's data on SOCI interactions according to the US Tier Classification system.

	Adequacy of Bycatch Data																Quality of the Bycatch Estimate					TOTAL	% score		
	Observer Data										Industry Data	Supplementary Data					Database /IT	Analytical Approach								
	Longevity of Observer Data	Sampling Frame	Sampling Design of Vessels	Sampling Design of Trips	Sampling Design of Hauls	Spatial Coverage	Temporal Coverage	Vessel-Selection Bias	Observer Bias	Data Quality Control	Score	Data available as expansion factors for unobserved components	Data available for stratification	Data available for imputation	Data available for model covariates	Industry data verified	Score	Assumptions Identified, Tested, and Appropriate	Peer Reviewed / Published Design	Peer Reviewed / Published Analytical Approach	Statistical Bias of Estimators	Measures of Uncertainty			Tier:	Note
Maximum Scores	5	3	4	4	4	2	2	2	2	5	2	2	2	2	2	2	2	10	4	4	4	4	73	100		
Coral	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0				1
Crayfish and Rocklobster	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
East Coast Pearl	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0				1
Marine Aquarium Fish	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0				1
Eel Fishery	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
Sea Cucumber Fishery (Ea	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0				1
Trochus	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0				1
Coral Reef Finfish	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
Deep Water Finfish	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
East Coast Spanish Mack	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
Gulf of Carpentaria Line	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
Rocky Reef Finfish	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
East Coast Inshore Finfisl	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
Gulf of Carpentaria Insho	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
Blue Swimmer Crab	2	2	1	1	1	1	1	0	0	2	2	0	0	0	0	0	1	0	0	0	0	0	14	19.18	1	
Mud Crabs	2	2	1	1	1	1	1	0	0	2	2	0	0	0	0	0	1	0	0	0	0	0	14	19.18	1	
Spanner Crabs	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
East Coast Otter Trawl	3	2	3	2	3	2	2	0	2	2	2	2	0	0	0	0	1	1	2	2	0	2	33	45.21	2	
Gulf of Carpentaria Devel	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
River and Inshore Beam T	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	3	4.11	1	
																					totals:					
																					average score:		6.47	8.86	1.07	
1 - assumes zero interactions and no need to quantify them so a quality metric is not applicable																										

Appendix 7 – Spreadsheet used to score the Northern Territory's general discard data according to the US Tier Classification system.

	General Discards Information Quality																	Quality of the Bycatch Estimate					TOTAL	% score					
	Observer Data										Industry Data	Supplementary Data						Database /IT	Analytical Approach											
Method	Longevity of Observer Data	Sampling Frame	Sampling Design of Vessels	Sampling Design of Trips	Sampling Design of Hauls	Spatial Coverage	Temporal Coverage	Vessel-Selection Bias	Observer Bias	Data Quality Control	Score	Data available as expansion factors for unobserved components	Data available for stratification	Data available for imputation	Data available for model covariates	Industry data verified	Score	Assumptions Identified, Tested, and Appropriate	Peer Reviewed / Published Design	Peer Reviewed / Published Analytical Approach	Statistical Bias of Estimators	Measures of Uncertainty			Tier:	Total Discards (t)	Prop of total discards	% score weighted by estimated discards	Note
Maximum Scores:	5	3	4	4	4	2	2	2	2	5	2	2	2	2	2	2	2	10	4	4	4	4	73	100					
Demersal	5	2	2	2	2	2	2	2	2	3	2	2	2	2	0	0	2	3	0	2	0	2	41	56.16	2	393.23	0.46029	25.85	
Timor Reef	5	2	2	2	2	2	2	2	2	3	2	2	2	2	0	0	2	3	0	2	0	2	41	56.16	2	75.39	0.08824	4.96	
Barramundi	5	2	2	2	2	2	2	2	2	3	2	2	2	2	0	0	2	3	0	2	0	2	41	56.16	2	228.83	0.26785	15.04	
Offshore Net and Li	5	2	2	2	2	2	2	2	2	3	2	2	2	2	0	0	2	3	0	2	0	2	41	56.16	2	112.73	0.13196	7.41	
Spanish Mackerel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	2.74	1			0.00	
Mud Crab	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	3	0	2	0	2	13	17.81	1	33.40	0.03910	0.70	
Coastal line	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	3	0	2	0	2	13	17.81	1	10.63	0.01244	0.22	
Trepang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0.00	0.00000		1
Restricted Bait	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0.00	0.00000		1
Aquarium Display	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0.00	0.00000		1
Coastal net	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	3	0	2	0	2	13	17.81	1	0.10	0.00011	0.00	
																					totals:					854.30	1.00000		
																					average score:		25.63	35.10	1.50			54.18	
1 - assumes zero discards and no need to quantify discards and therefore a quality metric is not applicable																													

Appendix 8 - Spreadsheet used to score the Northern Territory's data on TEPs interactions according to the US Tier Classification system.

	TEP Species Information Quality																	Quality of the Bycatch Estimate					TOTAL	% score		
	Observer Data										Industry Data	Supplementary Data						Database /IT	Analytical Approach								
Fishery	Longevity of Observer Data	Sampling Frame	Sampling Design of Vessels	Sampling Design of Trips	Sampling Design of Hauls	Spatial Coverage	Temporal Coverage	Vessel-Selection Bias	Observer Bias	Data Quality Control	Score	Data available as expansion factors for unobserved components	Data available for stratification	Data available for imputation	Data available for model covariates	Industry data verified	Score	Assumptions Identified, Tested, and Appropriate	Peer Reviewed / Published Design	Peer Reviewed / Published Analytical Approach	Statistical Bias of Estimators	Measures of Uncertainty			Tier:	Note
Maximum Scores:	5	3	4	4	4	2	2	2	2	5	2	2	2	2	2	2	2	10	4	4	4	4	73	100		
Demersal	5	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	2	0	0	0	0	0	11	15.07	1	
Timor Reef	5	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	2	0	0	0	0	0	11	15.07	1	
Barramundi	5	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	2	0	0	0	0	0	11	15.07	1	
Offshore Net and Line	5	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	2	0	0	0	0	0	11	15.07	1	
Spanish Mackerel	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	4	5.48	1	
Mud Crab	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	4	5.48	1	
Coastal line	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	4	5.48	1	
Trepang	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0				1
Restricted Bait	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0				1
Aquarium Display	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0				1
Coastal net	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	4	5.48	1	
																					totals:					
																					average score:		7.50	10.27	1.00	
1 - assumes zero interactions and no need to quantify them so a quality metric is not applicable																										