Weight conversion ratios for five commercially important sea cucumber species from the Great Barrier Reef

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Background

Queensland's Sea Cucumber Fishery (East Coast) is a multi-species fishery targeting primary and secondary sea cucumber species including Black Teatfish (*Holothuria whitmaei*), White Teatfish *(Holothuria fuscogilva*), Prickly Redfish (*Thelenota ananas*), Amberfish, (*Thelenota anax*), and Golden Sandfish (*Holothuria lessoni*) in the Great Barrier Reef Marine Park and adjacent east coast waters. Sea cucumbers differ markedly in size, shape, body wall thickness, and the way they are commercially processed — all factors that influence how live weight translates to processed weight (Skewes et al., 2004; Purcell et al., 2009; Ngaluafe and Lee, 2013; Prescott et al., 2015).

Several species-specific processing stages are used to produce a marketable product from live sea cucumbers, which may include gutting, salting, boiling, drying and freezing (Skewes et al., 2004; Purcell et al., 2009; Ngaluafe and Lee, 2013). Each processing stage results in significant weight reduction in the product, with the final processed product representing only a proportion of the original live weight of the animal (Purcell et al., 2009; Ngaluafe and Lee, 2013). Consequently, the relationship between live and processed weight is a critical consideration when interpreting catch records, estimating biomass, and comparing fishery-dependent and fishery-independent data (Purcell et al., 2009; Department of Agriculture and Fisheries, 2021; Department of Climate Change, Energy, the Environment and Water, 2024).

Introduction

Fishery-independent surveys undertaken by Fishwell record density and biomass of sea cucumbers in live weight (for example, Koopman and Knuckey, 2021). Survey data provide important information on relative abundance, size structure and live biomass, and can be used to support stock assessments and assess fishery performance. However, management arrangements, including Total Allowable Commercial Catches (TACCs), are determined using processed weights (Department of Agriculture and Fisheries, 2021; Department of Climate Change, Energy, the Environment and Water, 2024). This creates a requirement for robust and species-specific conversion ratios to translate live survey weights into processed-weight equivalents and, conversely, to interpret processed catches in terms of original live biomass (Skewes et al., 2004; Purcell et al., 2009; Ngaluafe and Lee, 2013).

Accurate conversion ratios of processed sea cucumber weight to original whole weights are required to meet Condition 7 of the 2024 Wildlife Trade Operation (WTO) approval under the *Environment Protection and Biodiversity Conservation Act 1999* (Department of Climate Change, Energy, the Environment and Water, 2024). This condition states:

> *By 1 July 2026, the Queensland Department of Primary Industries must:*
>
> a) *establish accurate ratios for converting between all processed and unprocessed forms of CITES-listed prickly redfish (Thelenota ananas), CITES-listed amberfish (Thelenota anax), CITES-listed black teatfish (Holothuria whitmaei) and CITES-listed white teatfish (Holothuria fuscogilva) used in the Queensland Sea Cucumber Fishery (East Coast). Conversion ratios should be consistent across Commonwealth and Queensland managed fisheries where*

appropriate. Precautionary proxy conversion ratios can be adopted from other fisheries or jurisdictions until more accurate conversion ratios can be established.

b) *publish information to clarify what specific product form and associated conversion ratios the catch limits and catch-based harvest strategy triggers are based on.*

Differences in processing methods, the proportion of weight retained after processing, and differences in body weight, size, body wall thickness, internal water retention, and gut contents all underscore the importance of species-specific weight conversion ratios (Skewes et al., 2004; Purcell et al., 2009; Ngaluafe and Lee, 2013; Prescott et al., 2015). The use of inaccurate conversion factors could result in inaccurate estimates of product loss, processed yield or biomass removal (Purcell et al., 2009; Ngaluafe and Lee, 2013; Department of Agriculture and Fisheries, 2021; Department of Climate Change, Energy, the Environment and Water, 2024).

This report presents live–to–processed weight conversion ratios for five commercially important sea cucumber species from the Great Barrier Reef: Black Teatfish (*Holothuria whitmaei*), White Teatfish (*Holothuria fuscogilva*), Prickly Redfish (*Thelenota ananas*), Amberfish (*Thelenota anax*) and Golden Sandfish (*Holothuria lessoni*). For each species, live weight was compared with processed weights at different stages, including gutted, boiled (for Golden Sandfish only) and dried product forms.

Objectives

1. Collect sea cucumber samples and weigh them at each stage of the standard commercial processing procedure.
2. Provide reports to the Queensland Department of Primary Industries to meet WTO condition 7.

Methods

Onboard measurements

Following in-situ collection of sea cucumbers by commercial divers, animals were transferred to the dory and held in seawater-filled fish bins until they were processed on the main vessel (see Appendix 1, Table 5 for all sample collection locations). Onboard the main vessel, animals were taken out of the water and, following Skewes et al. (2004), left for five minutes before being weighed to record live weights using a Rapala Tournament balance (±10 g) (Rapala VMC Corporation, Minnetonka, MN, USA). Skewes et al. (2004) found that some animals could lose up to 25% of their body weight in the first 5 minutes and up to 30% after 60 minutes, and that there was considerable variability between individuals. They therefore recommended allowing at least five minutes after an individual sea cucumber wastaken from the water before weighing, to provide a more reliable live-weight measure. Draining for five minutes has been used in other studies, including one for Golden Sandfish (see Djenidi et al., 2024). During collection, or during the five-minute period out of the water, some samples eviscerated and expelled internal organs. Where this occurred, it was recorded on the datasheets. Where possible, the expelled internal organs were retained and weighed together with the animal to provide the most representative live weight; otherwise, data from those animals were excluded from calculations that included live weight. The number of animals collected compared to the number of animals used in calculations involving live weight are shown in Table 1.

Tagging and processed measurements

Animals were gutted in accordance with standard commercial processing practices. After gutting, animals were shaken dry and weighed. Animals were double-tagged with different coloured and labelled tags, and different coloured zip ties, with colours and tag numbers recorded. The combined weight of the zip ties and tags was then subtracted from subsequent weight measurements where required.

Animals were then processed in accordance with standard commercial procedures. Individual species processing procedures are described below.

Processing

Teatfish, Amberfish, and Prickly Redfish

Black Teatfish, White Teatfish, Amberfish, and Prickly Redfish underwent the same commercial processing procedure, including gutting (the gills of Teatfish remained intact, whereas Amberfish and Prickly Redfish gills were removed). Once gutted, all product was salted and stored in fish bins onboard.

On delivery to Seafresh, the usual commercial processing factory in Cairns, samples were washed as per normal processing standards. After washing, the total salted weight of each species (Black Teatfish, White Teatfish, Amberfish, and Prickly Redfish) were weighed, because individual weights were not able to be measured. This is the stage and product form where accurate weights are recorded for quota deduction.

Prickly Redfish and Amberfish were then dried for approximately 14 days (±2 days) after capture. Teatfish were dried for approximately 10 days (±2 days). All animals were dried in drying rooms set to between 40–45°C.

Following drying, each sample was then weighed again. Final measurements were recorded using the more accurate A&D SJ-30KWP digital waterproof scales, due to the substantially reduced weight of the dried product and the more suitable, controlled environmental conditions (i.e. not on the mothership, where wave motion is an issue).

Golden Sandfish

Golden Sandfish were processed onboard, consistent with commercial processing practices. Animals were gutted and then boiled for 30 minutes; samples were left to cool, weighed, and then frozen.

On delivery to Seafresh, product was steamed for 30 minutes at 90°C, then left to dry for approximately 14 days (±2 days). As above, all animals were dried in drying rooms set to between 40–45°C and, following drying, weighed again using A&D SJ-30KWP digital waterproof scales.

Sample Sizes

Previous conversion-ratio studies for similar species have typically used sample sizes of 5–51 animals per species (e.g. Purcell et al., 2009; Skewes et al., 2004). We aimed to collect up to 50 Amberfish and Prickly Redfish, and up to 100 Golden Sandfish, Black Teatfish and White Teatfish, for this study.

Collections and handling of all species other than Golden Sandfish were conducted in line with Queensland Fisheries general fisheries permit number 277064 and Great Barrier Reef Marine Park Authority Permit G51200.1. Golden Sandfish were taken under the commercial fishing vessel's permit and were deducted from the Total Allowable Commercial Catch (TACC). Collection numbers, locations and species were recorded for reporting and traceability.

Permits authorized the take and possession of:

- Black Teatfish — 100 total, maximum 50 per location
- White Teatfish — 100 total, maximum 50 per location
- Prickly Redfish — 50 total (10 per reef)
- Amberfish — 50 total (10 per reef)
- Golden Sandfish – Taken under quota

Disposal of Samples

After final dried weights were recorded, a disposal protocol was followed in accordance with the permit conditions. This included removing all samples from the premises (Seafresh) and disposing of them at Portsmith Transfer Station. Disposal was well documented photographically throughout the whole process to provide evidence of destruction. Receipts from Portsmith Transfer Station were also kept.

Data analysis

All data analyses were undertaken in R (R Core Team, 2025).

Conversion factors were calculated in three different ways:

- the mean of live-to-gutted, live-to-boiled and live-to-dried weights calculated for each specimen (i.e. live_to_gutted_weight = gutted_weight_kg / live_weight_kg, live_to_boiled_weight = boiled_weight_kg / live_weight_kg, and live_to_dried_weight = dried_weight_kg / live_weight_kg); and
- fitting a linear model by robust regression using the MASS (Venables and Ripley, 2002) function rlm() in R via the MM-estimation method (Yohai, 1987), which minimises the influence of outliers. In line with Skewes et al. (2004), the intercept was constrained through the origin.

- for salted weight, individual animals were not able to be weighed, and so the total weight of salted product was calculated as total_salted_weight / total_live_weight.

Results

Golden Sandfish, White Teatfish, Black Teatfish, Amberfish, and Prickly Redfish were caught from various locations across the Great Barrier Reef region. Figures 1 to 5 illustrate the capture locations for each species.

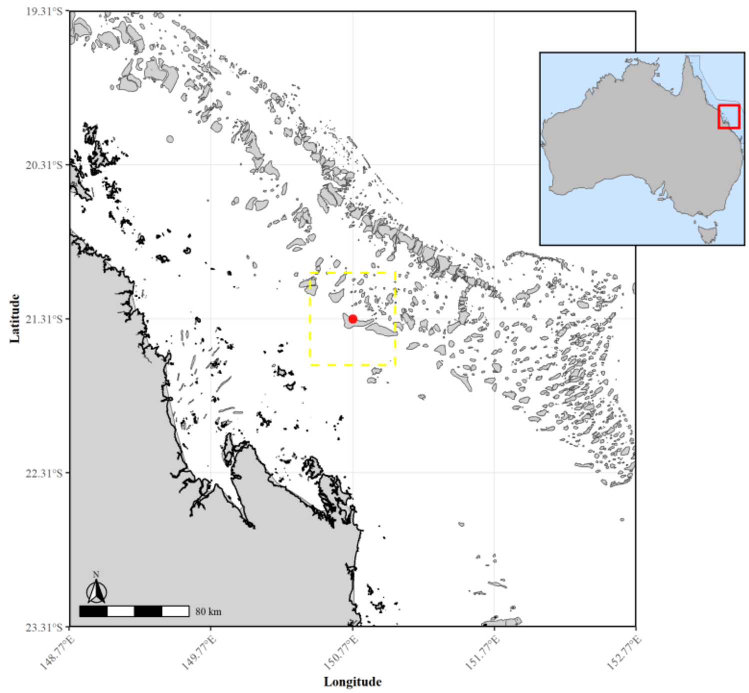

Figure 1. Map of Golden Sandfish capture sites.

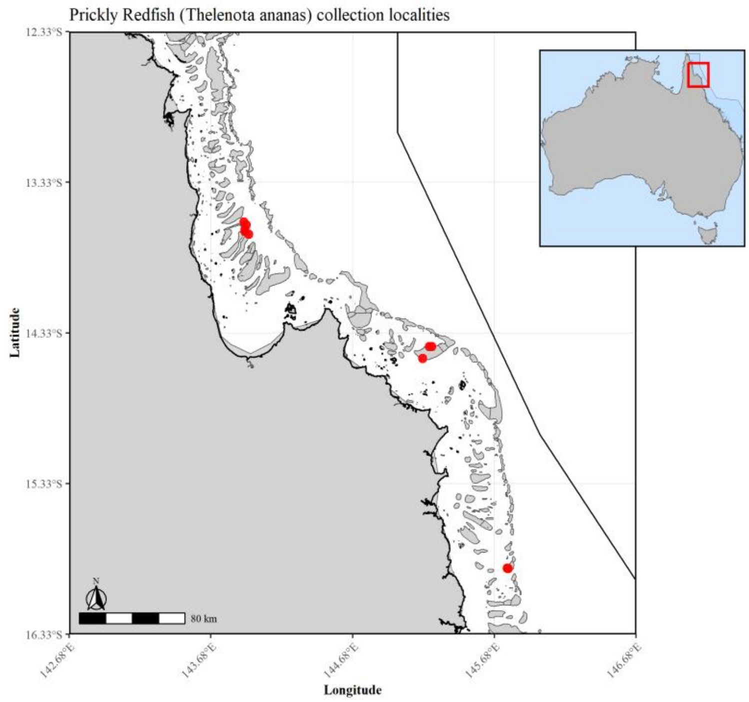

Figure 2. Map of Prickly Redfish capture sites.

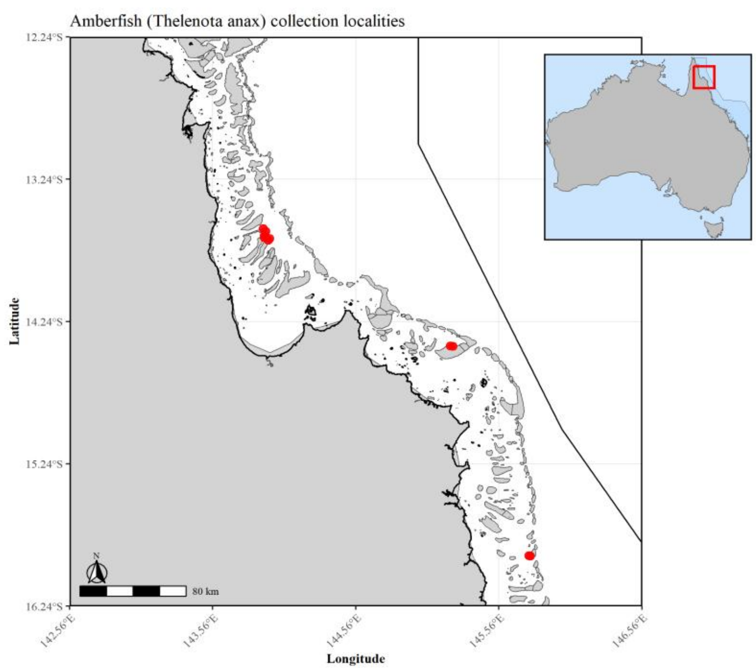

Figure 3. Map of Amberfish capture sites.

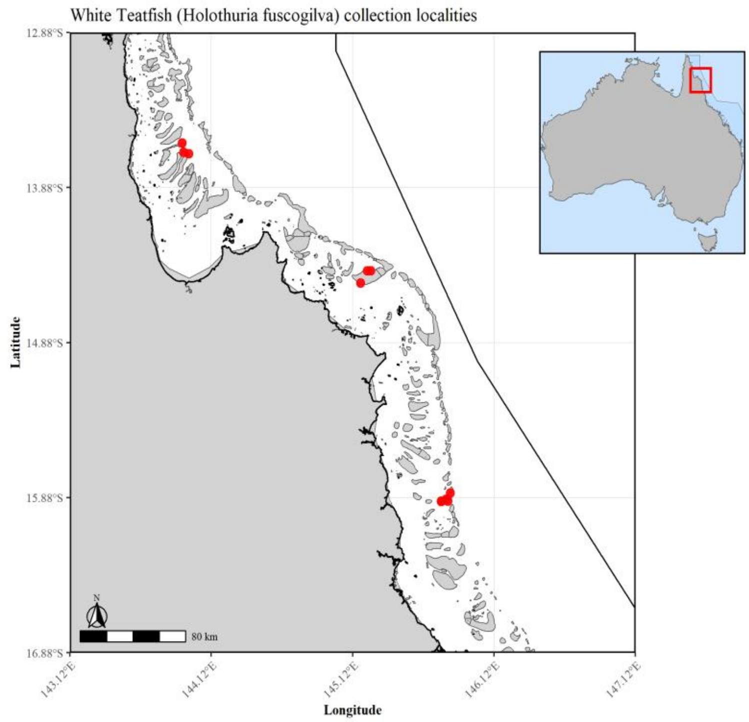

Figure 4. Map of White Teatfish capture sites.

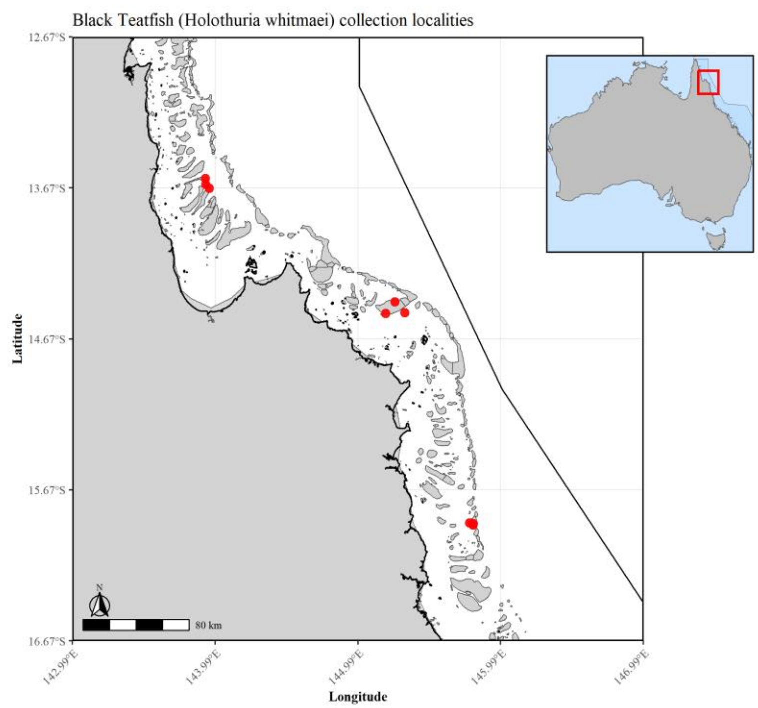

Figure 5. Map of Black Teatfish capture sites.

The number of samples collected for each species, number of live weights used in calculations, together with the mean weight and range of weights for each processing phase (live weight, gutted weight, boiled weight and dried weight), are shown in Table 1. Boiled weight was recorded only for Golden Sandfish because no other species required boiling during processing. Mean live weights varied from 4.996 kg for Amberfish to 1.698 kg for Golden Sandfish.

Table 1. Weight Summary by Species

Mean and range of live, gutted, boiled weights and dried (kg)

Species	n (collected)	n (live)	Live weight (kg)		Gutted weight (kg)		Boiled weight (kg)		Dried weight (kg)	
			Mean	Range	Mean	Range	Mean	Range	Mean	Range
Amberfish	50	35	4.996	2.150 – 7.800	3.195	1.303 – 5.763		NA – NA	0.300	0.097 – 0.667
Black Teatfish	100	89	1.828	1.050 – 3.350	1.272	0.586 – 1.946		NA – NA	0.341	0.076 – 0.531
Golden Sandfish	102	88	1.698	0.630 – 3.350	0.928	0.376 – 1.416	0.377	0.116 – 0.676	0.110	0.027 – 0.192
Prickly Redfish	50	50	3.897	2.250 – 6.200	2.328	1.156 – 3.636		NA – NA	0.251	0.130 – 0.449
White Teatfish	100	98	2.937	1.750 – 4.770	1.821	1.156 – 2.766		NA – NA	0.470	0.200 – 0.785

Table 2 summarises the number of samples for each species (number of live weights included) and the associated conversion ratios, including mean and robust MM-estimates and the range for each processing phase (live-to-gutted, live-to-boiled and live-to-dried). For each species, mean and robust MM-estimate conversion ratios were similar, indicating that the conversion estimates were not strongly influenced by outliers. Live-to-dried ratios showed substantial weight loss across all species. Live-to-gutted ratios were highest for Black Teatfish and lowest for Golden Sandfish. Only mean live to salted ratios are shown because this was calculated from the sum of landed catch for White Teatfish, Black Teatfish, Amberfish, and Prickly Redfish because they were calculated from total landed weights.

Table 2. Live – Processed Conversion Ratios by Species

Mean, robust MM-estimate (), and range of live→gutted, live→salted (boiled) and live→dried ratios (unitless)

Species	n (live)	Live → Gutted ratio			Live → Salted ratio**			Live → Dried ratio		
		Mean	Robust	Range	Mean	Robust	Range	Mean	Robust	Range
Amberfish	35	0.653	0.641	0.452 – 0.935	0.469	NA	NA	0.060	0.059	0.028 – 0.102
Black Teatfish	89	0.705	0.697	0.497 – 0.955	0.528	NA	NA	0.190	0.191	0.130 – 0.272
Prickly Redfish	50	0.607	0.598	0.406 – 0.799	0.396	NA	NA	0.065	0.064	0.044 – 0.120
White Teatfish	98	0.630	0.622	0.456 – 0.838	0.457	NA	NA	0.162	0.160	0.097 – 0.220
					Live → Boiled ratio**					
					Mean	Robust	Range			
Golden Sandfish	88	0.568	0.556	0.310 – 0.840	0.226	0.219	0.129 – 0.343	0.065	0.065	0.031 – 0.096

** processed form when weighed for quota deduction and harvest strategy trigger reporting

Figure 6 illustrates the robust regression relationships between live weight (x-axis) and processed weight (y-axis) for each species.

- Fitted lines were forced through the origin, with the slope representing the robust live-to-processed conversion ratio for each product form.
- The blue regression line shows the live-to-gutted relationship.
- The purple regression line shows the live-to-dried relationship.
- The red regression line represents the live-to-boiled relationship (Golden Sandfish only).

These robust estimates were derived using MM-estimation and reduce the influence of outliers compared with simple mean ratios. Across all species, gutted weight showed a strong positive relationship with live weight, while dried weight represented a much smaller proportion of live weight. For Golden Sandfish, boiled weight was also included and showed an intermediate relationship between gutted and dried product forms.

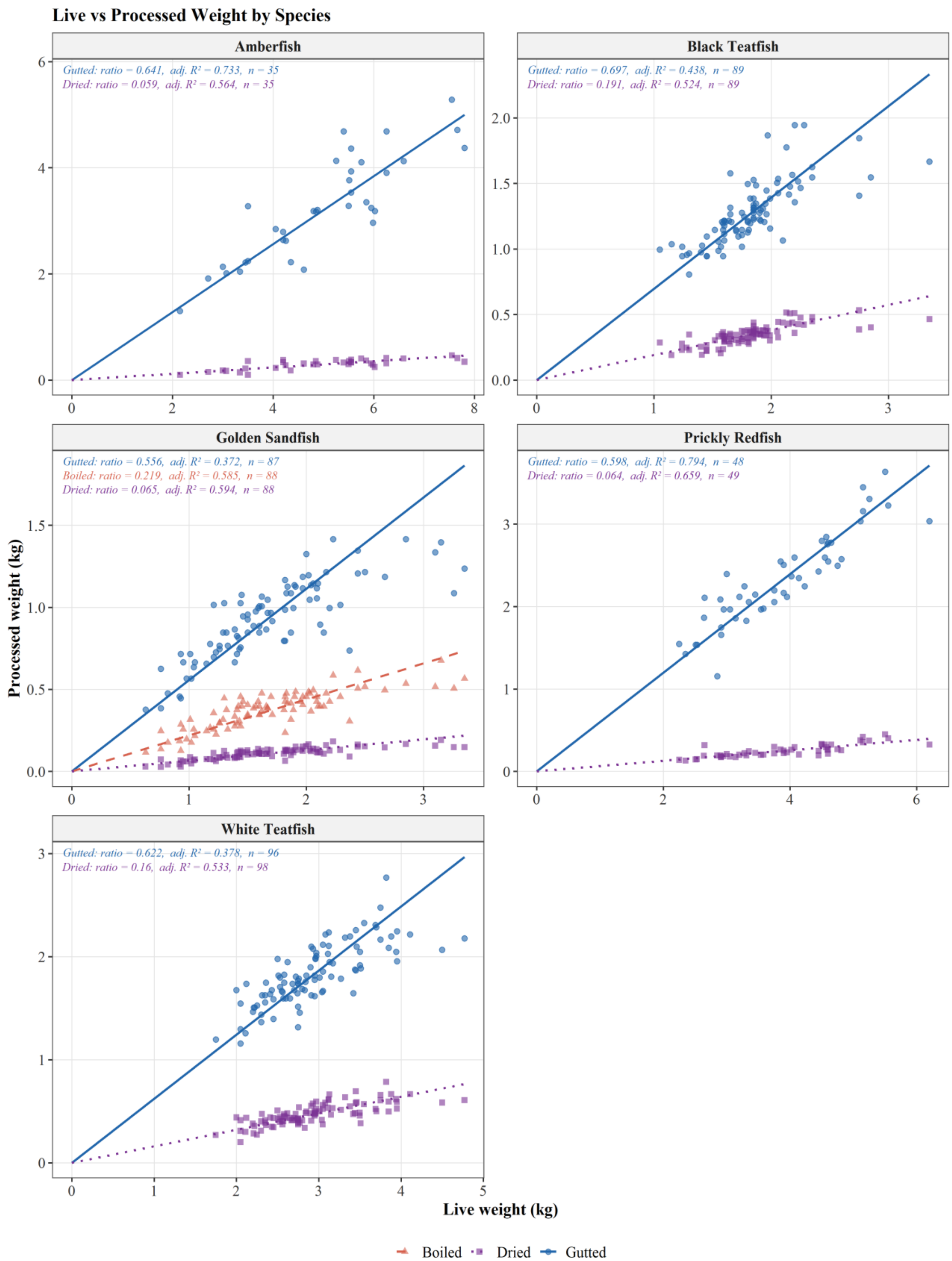

Figure 6. Relationship Between Live and Processed Weight by Species

Discussion

The results provide weight conversion ratios for five key sea cucumber species, as required for WTO condition 7.

The results of this study align reasonably well with previous reports on sea cucumber conversion ratios (Tables 3, 4 and 5). The results provide species-specific conversion ratios for animals obtained from the Great Barrier Reef, which are useful for comparing live survey biomass estimates with processed catch weights under WTO conditions (Skewes et al., 2004). Species-specific conversion ratios help bridge the gap between live biomass surveys and processed product weights, improving the accuracy of TACC requirements, biomass estimation, product recovery calculations, and compliance reporting. Weight loss during processing varied among species, resulting in clear differences in the conversion ratios outlined in Table 2. Black Teatfish and White Teatfish retained proportionally more weight after drying than Amberfish, Prickly Redfish, and Golden Sandfish (Prescott et al., 2015). These differences are likely influenced by body size, body wall thickness, water retention, and other species-specific characteristics (Prescott et al., 2015). This highlights the importance of species-specific conversion ratios, as applying a generic conversion factor across the fishery could lead to inaccurate biomass estimates and TACC decisions.

Table 3. Live to gutted conversion ratios compared to other studies

Species	This study	Skewes et al. (2004)	Derived from Purcell et al. (2009)	Various studies reported in Plagányi et al. (2019) and Murphy et al. (2021)
Amberfish	0.641			
Black Teatfish	0.697	0.633	0.642	0.677
Golden Sandfish	0.556		0.645	
Prickly Redfish	0.598	0.496		0.667
White Teatfish	0.622	0.500		0.627

Table 3 demonstrates that the conversion ratios from live to gutted animals in this study were generally similar to those outlined in previous studies. This supports the use of the ratios generated in this report, as they were broadly consistent with existing published values. For example, Black Teatfish had a ratio of 0.697 in this report, which aligns with the ratio of 0.633 reported by Skewes et al. (2004) and 0.642 derived from Purcell et al. (2009). White Teatfish were also very similar to previous estimates. This study recorded a ratio of 0.622, compared with 0.627 reported in Plagányi et al. (2019) and Murphy et al. (2021). Prickly Redfish also fell within the range of previous studies, with this study recording 0.598, compared with 0.496 from Skewes et al. (2004) and 0.667 from other studies.

Table 4. Live to salted conversion ratios compared to other studies

Species	This study	Derived from Purcell et al. (2009)	Derived from Ngaluafe and Lee (2013)	Various studies reported in Plagányi et al. (2019) and Murphy et al. (2021)
Amberfish	0.470			
Black Teatfish	0.531	0.529		0.529
Prickly Redfish	0.397		0.481	0.481
White Teatfish	0.459		0.593	0.593

Comparisons of live to salted weights are shown in Table 4. The conversion factor for Black Teatfish is consistent with those reported by Purcell *et al*. (2009) and subsequently used by Plagányi *et al*. (2019) and Murphy *et al*. (2021). However, the conversion factors for Prickly Redfish and White Teatfish are lower than those used in Plagányi *et al*. (2019) and Murphy *et al*. (2021) and in Ngaluafe and Lee (2013). although Plagányi *et al*. (2019) and Murphy *et al*. (2021) attribute their Prickly Redfish and White Teatfish conversion factors to Purcell *et al*. (2009), that study does not in fact include these species. The figures they cite appear to originate from Ngaluafe and Lee (2013), which does report conversion ratios for both species. Differences in conversion factors likely reflect processing methodology —with Ngaluafe and Lee (2013) describing their processing as "*boiled, and then salted for a minimum of three days, with the time of each stage varying for different species according to the standard method of the processor*". They do not report the duration of the salting period for each species.

Table 5. Live to dried conversion ratios compared to other studies

Species	This study	Skewes et al. (2004)	Derived from Purcell et al. (2009)	Derived from Ngaluafe and Lee (2013)	Various studies reported in Plagányi et al. (2019) and Murphy et al. (2021)
Amberfish	0.059				
Black Teatfish	0.191		0.116		0.108
Golden Sandfish	0.065		0.098		0.098
Prickly Redfish	0.064	0.067		0.051	0.055
White Teatfish	0.160			0.186	0.137

Table 5 outlines broadly comparable ratios with previous studies, although some differences were observed. Prickly Redfish showed very close agreement between ratios, with this study recording a ratio of 0.064, compared with 0.067 reported by Skewes et al. (2004), 0.051 derived from Ngaluafe and Lee (2013), and 0.055 reported in studies summarised by Plagányi *et al*. (2019) and Murphy *et al*. (2021). White Teatfish was also reasonably close to previous estimates. This study recorded a live to dried ratio of 0.160, compared with 0.186 derived from Ngaluafe and Lee (2013) and 0.137 from other studies reported by Plagányi *et al*. (2019) and Murphy *et al*. (2021). Golden Sandfish recorded a lower ratio in this study (0.065) compared with 0.098 derived from Purcell *et al*. (2009) and other reported studies. This difference may be partly due to processing methods, as sandfish in some previous studies were salted and dried, whereas in this study they were boiled and dried.

Overall, differences between studies are expected because conversion ratios can be influenced by a range of factors, including collection location, animal condition, growth characteristics, handling methods, and processing techniques. Live-to-dried conversion ratios are particularly sensitive to differences in boiling, salting, drying methods, and final moisture content. The timing of live weight measurements following removal from the water may also influence results, because sea cucumbers can rapidly lose weight through water loss after collection (Skewes *et al*., 2004). Despite these sources of variation, the conversion ratios generated in this study were generally consistent with published values from other locations and provide reliable species-specific estimates for Queensland fisheries management and monitoring purposes.

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Cooperation and practical assistance from all parties was greatly appreciated.

Appendix 1

Table 6. Location and effort for each location where samples were collected.

Common name	Scientific name	Latitude	Longitude	Number taken
Amberfish	*Thelenota anax*	13º 35.425	143º 54.858	9
Amberfish	*Thelenota anax*	13º 36.531	143º 55.867	1
Amberfish	*Thelenota anax*	13º 38.235	143º 55.286	3
Amberfish	*Thelenota anax*	13º 39.091	143º 55.381	3
Amberfish	*Thelenota anax*	13º 39.606	143º 57.586	1
Amberfish	*Thelenota anax*	13º 40.229	143º 56.940	1
Amberfish	*Thelenota anax*	14º 24.898	145º 13.336	12
Amberfish	*Thelenota anax*	14º 24.950	145º 14.364	4
Amberfish	*Thelenota anax*	15º 53.210	145º 46.355	1
Amberfish	*Thelenota anax*	15º 53.408	145º 46.815	3
Amberfish	*Thelenota anax*	15º 50.909	145º 48.567	12
Black Teatfish	*Holothuria whitmaei*	13º 36.236	143º 55.292	14
Black Teatfish	*Holothuria whitmaei*	13º 38.615	143º 55.447	16
Black Teatfish	*Holothuria whitmaei*	13º 40.229	143º 56.940	21
Black Teatfish	*Holothuria whitmaei*	14º 25.285	145º 14.95	7
Black Teatfish	*Holothuria whitmaei*	14º 29.639	145º 19.077	5
Black Teatfish	*Holothuria whitmaei*	14º 29.858	145º 11.079	10
Black Teatfish	*Holothuria whitmaei*	15º 53.210	145º 46.355	1
Black Teatfish	*Holothuria whitmaei*	15º 53.452	145º 47.946	11
Black Teatfish	*Holothuria whitmaei*	15º 54.044	145º 47.813	15
Prickly Redfish	*Thelenota ananas*	13º 35.425	143º 54.858	2
Prickly Redfish	*Thelenota ananas*	13º 36.531	143º 55.867	9
Prickly Redfish	*Thelenota ananas*	13º 38.235	143º 55.286	6
Prickly Redfish	*Thelenota ananas*	13º 39.091	143º 55.381	1
Prickly Redfish	*Thelenota ananas*	13º 40.229	143º 56.940	4
Prickly Redfish	*Thelenota ananas*	14º 24.898	145º 13.336	1
Prickly Redfish	*Thelenota ananas*	14º 24.950	145º 14.364	14
Prickly Redfish	*Thelenota ananas*	14º 29.728	145º 10.518	4
Prickly Redfish	*Thelenota ananas*	15º 53.210	145º 46.355	6
Prickly Redfish	*Thelenota ananas*	15º 53.408	145º 46.815	3
White Teatfish	*Holothuria fuscogilva*	13º 35.425	143º 54.858	9
White Teatfish	*Holothuria fuscogilva*	13º 39.091	143º 55.381	5
White Teatfish	*Holothuria fuscogilva*	13º 39.606	143º 57.586	18
White Teatfish	*Holothuria fuscogilva*	14º 24.898	145º 13.336	10
White Teatfish	*Holothuria fuscogilva*	14º 24.953	145º 14.829	3
White Teatfish	*Holothuria fuscogilva*	14º 29.728	145º 10.518	4
White Teatfish	*Holothuria fuscogilva*	15º 50.909	145º 48.567	13
White Teatfish	*Holothuria fuscogilva*	15º 53.408	145º 46.815	4
White Teatfish	*Holothuria fuscogilva*	15º 54.116	145º 44.753	6
White Teatfish	*Holothuria fuscogilva*	15º 54.121	145º 47.562	5
White Teatfish	*Holothuria fuscogilva*	15º 54.302	145º 44.716	23