Change in weight of sea cucumbers during processing: Ten common commercial species in Tonga

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Abstract

Accurately estimating the weight of live sea cucumber from the weight of dried beche-de-mer is important for national fisheries data, for standardising data collected from surveys or export records, and for informing management decisions and regulating fisheries quotas. Different sea cucumber species lose different proportions of their body weight through processing, so conversion ratios are best calculated on a species-by-species basis. This study measured the proportional change in weight of ten sea cucumber species in Tonga over the various stages of processing. The aim of the study was to fill knowledge gaps by providing conversion ratios for species for which no relevant data exist, such as *Actinopyga lecanora*, *Bohadschia argus*, *B. similis*, *B. vitiensis* and *Holothuria coluber*. For other species studied, the conversion ratios were compared with the ratios calculated in previous studies, with this study generally producing higher conversion ratios (i.e. less weight lost through processing). We discuss the possible reasons for this discrepancy, the implications for fisheries management in Tonga, and the need for further studies.

Introduction

Sometimes, weight data for sea cucumbers are available for only one stage of processing, whether this be the pre-processing stage (fresh weight), an intermediate processing stage or, more commonly, the fully processed dried product (beche-de-mer). Conversion ratios allow weight data to be compared using a common unit for analysis. If accurate conversion rates are available for a particular species, the processed weight can be used in order to estimate the weight (and numbers, if average weights are available) of fresh sea cucumbers that were processed.

Some previous studies have determined the average change in weight from whole, unprocessed sea cucumbers to dried beche-de-mer for several common tropical species (Conand 1990; Skewes et al. 2004; Purcell et al. 2009; Lavitra et al. 2009). However, there are still knowledge gaps for some commercial species, several of which have been addressed in this study.

In addition to differences between species, the conversion rates for the same species may vary, depending on country/location/environment, and also on the processing standards and methods used. To date, no sea cucumber weight conversion studies have been carried out in Tonga. Comparing the ratios obtained in this study to those reported in previous studies will help the Tongan Fisheries Department to decide whether the ratios currently being used for catch calculations are appropriate to Tonga.

Methods

The methods followed were based on the methods used by Purcell et al. (2009), with some variations. Length conversion information was not considered in this study, as it is not as relevant as weight conversion information for commercial export calculations in Tonga.

The study was conducted in Uiha on the island of Felemea, in the Ha'apai group of islands in Tonga. Sea cucumbers were collected by local fishers and brought to shore in tubs. A sample size of twenty-five individuals was weighed for each species, with the exception of *Thelenota ananas* (prickly redfish), with only 14 individuals recorded, and *Actinopyga* sp. (affinity *flammea*) with only two individuals recorded.

The sea cucumbers were allowed to drain for one minute before being weighed to the nearest 10 g in a plastic bag on a digital hanging scale. They were

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then gutted (although some had already excreted their viscera) in the standard manner for the processor, and were weighed again. Tags were attached by piercing the body wall and attaching numbered labels on plastic zip-ties.

The sea cucumbers were 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. After salting, they were re-weighed, and then sundried for several weeks before being weighed a final time. The dry weight was recorded at the Fisheries Department in Nuku'alofa, Tongatapu. Figure 1 illustrates some of the stages of processing.

There were some exceptions to the above methods. *Bohadschia marmorata* (chalkfish) were collected by Fisheries staff in Tongatapu and taken to a different processor. Unlike the samples of the other species which were of commercial size, the *B. marmorata* were undersize. One consequence of this was that, once dried, many samples did not register on the hanging scale (i.e. were under 10 g), and so an electronic balance was used to record these weights. Salting is not part of the standard processing method for this species, so this stage was omitted. In addition, the *B. marmorata* in this study were oven-dried, not sun dried, due to a difference in the processing methods of the two processors and the facilities available for this study.

During weighing of the dry product (final stage), some species, the white teatfish and stonefish, were found to be rock-hard. All the other species were quite soft and dry.

Results

This study provided estimates of conversion ratios for ten species (Table 1). The proportion of weight lost at each stage of processing was calculated for each individual separately. These percentages were averaged to give the conversion ratios. This allowed standard errors to be calculated both for the mean weight and for the average percentage of fresh/whole weight represented at each stage.

Although data are provided for each stage of processing, the most relevant conversion ratio for

Figure 1. (A) Sea cucumbers brought to shore in tubs; (B) *Actinopyga* sp. (affinity *flammea*); (C) tagging of *Holothuria fuscogilva*; (D) weighing and recording; (E) boiling stage; (F) salting stage; (G) tagged samples; (H) dried product; (I) standard sun-drying procedure.

Tonga fisheries is the fresh-to-dry ratio, as most exports are in the form of dried beche-de-mer, and it is this final dried product that is weighed. However, knowing the ratio for each stage may be useful in some circumstances, such as a quantity of illegally caught sea cucumbers being discovered during the intermediate stages of processing.

Across all species, the sea cucumbers lost an average of 30% of their initial body weight when they were gutted, a further 24% of initial weight during salting, and another 34% of initial weight during the drying stage, leaving an average of 12% of the initial weight remaining at the end of the process. There was a fair degree of variation of weight loss percentages between species, with the wet-to-dry recovery rate ranging between 5% and 20% for different species (see Table 1).

Note that some specimens had already excreted their viscera when the initial fresh measurements were taken; this is likely to have affected the conversion ratios (see Table 2). Also, it should be noted that sample sizes were smaller for *Thelenota ananas* (14 animals) and *Actinopyga* sp. (two animals), so the conversion rates produced may not be as reliable for these species.

Different species varied in the proportion of weight lost at each stage of processing, as illustrated in Figure 2. The initial weight loss proportion is affected by the fact that in many cases the viscera had already been excreted before gutting (Table 2). In these cases the weight loss in the gutting stage mainly represents water loss.

Table 1. Mean body weight in g (± standard error), and mean percentage of initial whole fresh weight (± standard error), across the different stages of processing.
Wet-to-dry conversion ratios are in bold.

Species and sample sizes (n)		Whole fresh	Gutted	Salted	Dried
Stonefish	Mean weight (g)	652.0 (± 39.8)	583.0 (± 21.3)	425.0 (± 14.7)	107.6 (± 19.2)
Actinopyga lecanora (25)	% of fresh weight	100.0 (± 0.0)	92.2 (± 2.4)	67.7 (± 2.1)	**17.2** (± 0.6)
Deepwater (DW) blackfish	Mean weight (g)	554.0 (± 23.1)	521.0 (± 20.5)	368.0 (± 15.0)	110.8 (± 5.7)
A. palauensis (25)	% of fresh weight	100.0 (± 0.0)	94.3 (± 0.7)	66.6 (± 0.9)	**19.9** (± 0.4)
Leopardfish	Mean weight (g)	647.0 (± 60.8)	476.0 (± 25.1)	370.0 (± 21.5)	86.4 (±6.2)
Bohadschia argus (25)	% of fresh weight	100.0 (± 0.0)	80.4 (± 3.8)	54.4 (± 5.1)	**14.3** (± 0.7)
Brown sandfish	Mean weight (g)	583.2 (± 34.8)	428.4 (± 13.0)	357.2 (± 10.8)	67.6 (±3.0)
B. vitiensis (25)	% of fresh weight	100.0 (± 0.0)	77.4 (± 3.4)	65.0 (± 3.2)	**12.2** (± 0.7)
Lollyfish	Mean weight (g)	507.6 (± 26.6)	204.8 (± 11.7)	120.0 (± 7.1)	30.8 (± 2.2)
Holothuria atra (25)	% of fresh weight	100.0 (± 0.0)	40.7 (± 1.5)	23.7 (± 0.8)	**6.0** (± 0.3)
Snakefish	Mean weight (g)	444.0 (± 24.2)	192.0 (± 9.3)	103.2 (± 6.3)	29.2 (±2.0)
H. coluber (25)	% of fresh weight	100.0 (± 0.0)	44.5 (± 1.9)	24.3 (± 1.7)	**6.7** (± 0.4)
White teatfish	Mean weight (g)	2091.0 (± 125.8)	1601.0 (± 66.2)	1241.0 (± 51.6)	384.4 (± 23.3)
H. fuscogilva (25)	% of fresh weight	100.0 (± 0.0)	79.8 (± 2.9)	61.7 (± 2.2)	**18.6** (± 1.0)
Prickly redfish	Mean weight (g)	2901.0 (± 502.9)	2179.0 (± 318.7)	1396.0 (± 222.3)	133.6 (± 23.6)
Thelenota ananas (14)	% of fresh weight	100.0 (± 0.0)	80.9 (± 4.8)	50.1 (± 3.1)	**5.1** (± 0.7)
***Actinopyga* sp.**	Mean weight (g)	1775.0 (± 565)	1155.0 (± 105.0)	760.0 (± 30.0)	205.0 (± 15.0)
Affinity *flammea* (2)	% of fresh weight	100.0 (± 0.0)	70.3 (± 16.5)	47.1 (± 13.3)	**12.5** (± 3.2)
Chalkfish	Mean weight (g)	115.6 (± 2.9)	80.8 (± 3.4)	20.4 (± 1.5)	7.2 (± 0.4)
B. marmorata (25)	% of fresh weight	100.0 (± 0.0)	69.7 (± 2.2)	17.8 (± 1.3)	**6.3** (± 0.3)

Table 2. Status of each species at the time of initial weighing (fresh stage).

All still had viscera	Some had excreted viscera	Most had excreted viscera	All had excreted viscera	Unknown status
Chalkfish	Leopardfish	Stonefish	Deepwater blackfish	*Actinopyga* sp.
Lollyfish	Prickly redfish	Brown sandfish		
Snakefish	White teatfish			

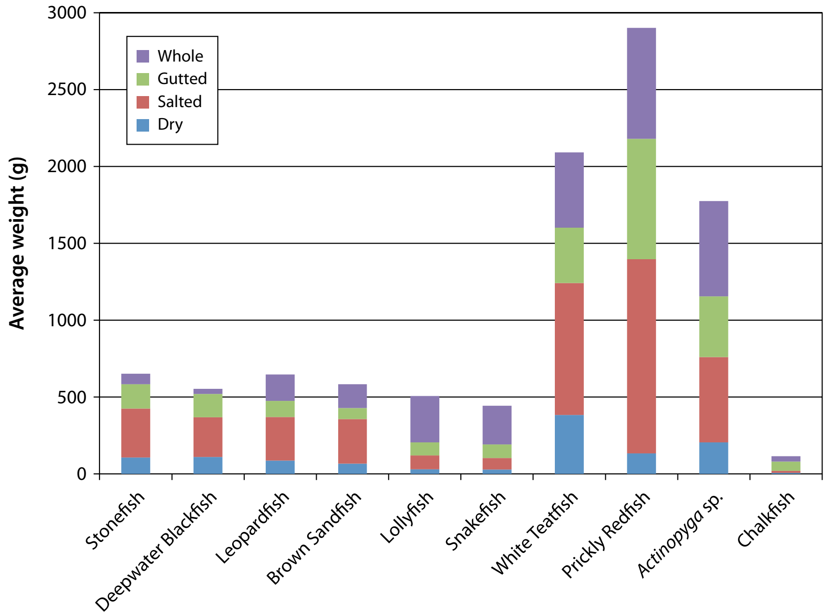

Figure 2. Average weight (g) of each species at different stages of processing.

Discussion

As expected, different sea cucumber species showed marked difference in weight loss through processing. Therefore, as other authors have noted, it is highly recommended that calculations are carried out on a species-by-species basis for the most accurate estimates of weight.

The species that lost the highest percentage of body weight in this study were lollyfish, snakefish, chalkfish and prickly redfish. This may indicate naturally higher water content, but it is also likely to be influenced by the fact that lollyfish, snakefish and chalkfish were the three species that had retained their viscera for the initial weighing, and some prickly redfish had also retained their viscera. This would have resulted in a higher initial fresh weight, making the end/dry weight a smaller proportion compared to species that were initially weighed without their viscera.

The data for chalkfish may also be influenced by other factors. The samples collected were not representative of the common size for commercial harvest, which may have a different percentage of weight loss. In addition, this species was oven-dried, while all other species in this study were sun-dried. This could also contribute to the larger weight loss.

The species that lost the lowest percentage of body weight were stonefish, deepwater blackfish and white teatfish. From observations during this study, these species seemed to have the thickest body wall, which would help explain the lower weight loss. In addition, the samples for these species all contained some individuals that had lost their viscera prior to initial weighing: some white teatfish, most stonefish and all deepwater blackfish.

In addition, in previous research, these species were boiled and dried a second and third time, as part of the processing method to improve the quality. These activities were mostly carried out by the processors as indicated in a survey documented by Purcell et al. (2012) under PARDI/ACIAR sea cucumber project. However, in this study, these species were not boiled and dried a second and third time and it was found, through observation, that a few samples, especially of stonefish and white teatfish, were rock-hard during the final weighing of the dry product. These factors may all contribute to the higher conversion ratios resulting from this study, as shown in Table 3, which provides a compilation of the fresh-to-dry conversion ratios for many sea cucumber species as calculated in previous studies.

Conversion ratios for *Actinopyga flammea* and *Bohadschia marmorata* have not been determined in previous studies, nor were there any conversion ratios for these species recommended for use by the Secretariat of the Pacific Community (SPC). *Actinopyga* sp. is not a common commercial species in Tonga. To our knowledge, conversion ratios for stonefish, leopardfish, brown sandfish and snakefish have not been determined in previous studies, but ratios have been recommended by SPC. It is unclear on which data or studies these recommendations are based. Our calculated conversion ratios for these species were at least double the ratios recommended for use by SPC. Ratios from previous studies and SPC ratios were available for deepwater blackfish, white teatfish, lollyfish and prickly redfish. We calculated a much higher ratio for deepwater blackfish and for white teatfish than previous studies and the SPC recommended ratios, but our ratios for lollyfish and prickly redfish are much closer to the results of previous studies and/or SPC ratios.

Overall, it seems that some of the ratios calculated in this study were comparably large, i.e. not as much weight was lost over the processing stages. There are several possible reasons for this difference. The method of drying – natural sun-drying

Table 3. Compilation of Conversion Rates (CRs) in percent (%) of total whole/fresh weight – from wet to dry product.

Species	CRs calculated in previous studies*								CRs Tonga uses (on SPC advice)	CRs calculated in this study
	1	2	3	4	5	6	7	8		
Actinopyga sp. affinity *flammea*										12.5
A. mauritiana (Surf redfish)	6.7				4.9				5.5	
A. miliaris (Blackfish)		5.6			9.7		11.5		5.5	
A. echinites (Deepwater redfish)			11.2	3.0				10.5	5.5	
A. lecanora (Stonefish)									5.5	17.2
A. palauensis (Deepwater blackfish)								11.7	5.5	19.9
A. spinea (Burying blackfish)								7.3		
Bohadschia argus (Leopardfish)									4.0	14.3
B. similis (Chalkfish)										6.3
B. vitiensis (Brown sandfish)									4.0	12.2
Holothuria atra (Lollyfish)		2.6			7.7				3.0	6.0
H. coluber (Snakefish)									3.0	6.7
H. edulis (Pinkfish)									3.0	
H. fuscogilva (White teatfish)			7.6		9.8				8.0	18.6
H. fuscopunctata (Elephant trunkfish)					9.3	12.7			10.0	
H. lessoni (Golden sandfish)								9.8	5.0	
H. whitmaei (Black teatfish)		8.7	9.8		8.1			11.6	7.0	
H. scabra (Sandfish)				5.0			5.1		5.0	
Thelenota ananas (Prickly redfish)		3.0	4.6		5.6	8.0	6.7		5.0	5.1
T. anax (Amberfish)									5.5	
Stichopus chloronotus (Greenfish)					2.7				3.0	
S. herrmanni (Curryfish)								3.3	4.0	
S. horrens (Dragonfish)										
S. variegatus (Variegated/Curryfish)					3.9					

* Authors (note: studies 1–6 as compiled and listed by Skewes et al. 2004).
1 Zoutendyk (1989); **2** Harriot (1984); **3** Conand (1990); **4** Shelley (1981); **5** Vuki and Viala (1989); **6** Conand (1990); **7** Skewes et al. (2004); **8** Purcell et al. (2009).

(with the exception of chalkfish) possibly results in less water loss than oven-drying. There may also be a higher variation in weight loss for sun-drying, as the results are more environmentally-dependent. For example, the week leading up to the dry weighing in this study was very wet and humid in Tongatapu, which may have meant more moisture remained in the product than at the end of a sunny dry period. Unfortunately, most previous studies do not state the drying method used, which makes it difficult to evaluate the differences in ratios found. As previously discussed, the loss of viscera prior to initial weighing is also likely to make ratios larger.

Conclusions and recommendations

The findings of this study have implications for Tonga's export calculations and fisheries management, and managers may need to consider amending the SPC recommended ratios that are currently being used for more accurate calculations and reporting. The ratios calculated in this study are at least double the SPC recommended ratios, with the exception of the prickly redfish ratio.

If our findings do represent the average proportionate weight loss for the species studied within Tonga, then using the SPC rates for conversion (from dried to fresh product) would result in an overestimate of the weight (and numbers, based on the average weight of an individual animal) of freshly caught sea cucumbers. If resources permit it, it would be beneficial to replicate this study using a different location and processor, and to compare the results to the ratios determined in this study. Due to the large differences found between this project and previous studies for several species it would be beneficial to include some other common commercial species in Tonga that were not examined in this study, as they may vary significantly from the recommended ratios currently being used.

If further studies are carried out it is highly recommended that researchers collect their own samples so that sea cucumbers can be weighed fresh before they lose their viscera and excrete excessive water, or alternatively arrange with fishers for animals to be brought for weighing as soon as possible so they do not spend several hours in a warm crowded tub, increasing the chances of viscera loss. Further research into how widely processing methods vary within Tonga, especially with regard to drying methods, would be beneficial, as it may be the case that conversion ratios are significantly different for oven dried product and sun-dried product. A brief survey of the number of processors use oven drying method, for example, and any other potentially significant differences in processing methods and standards (number of weeks of sun-drying etc.), would contribute to a more accurate idea of the suitability of particular conversion ratios, and would be unlikely to require extensive time or resources to complete.

Other issues to consider for the improvement of this study as indicated by socio-economic survey results conducted by Purcell et al. (2012), include some of the high- and medium-value species (i.e. white and black teatfish, stonefish, surf redfish, etc.) had to be re-boiled and re-dried a second or third time in some stages to improve quality.

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