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Change in Length and Weight of *Holothuria mexicana* Sea Cucumber During Processing

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ABSTRACT

Knowing the conversion ratio of processed sea cucumbers is important in determining the amount harvested from the wild. In Belize, the sea cucumber fishery was opened from 2009-2016. Estimating the amount harvested from the wild was especially difficult since sea cucumbers were exported semi-processed or dried. Dry weights were used to estimate the catch, yet the total allowable catch (TAC) was set based on wet weight. In this study, sea cucumbers were collected monthly for eight months and processed. The largest and heaviest individuals came from Marine Protected Areas (MPAs) and were found during the reproductive months. On average individuals lost about 54% of their total length and 84% of their body weight. The majority (87%) of all the processed sea cucumbers were of inferior quality. Sea cucumber exporters and fishers need more training in sea cucumber processing.

INTRODUCTION

Countries that recently created or are about to create a sea cucumber fishery have much to learn about the commercial aspects of the fishery, including the market, prices, commercial policies, marketing and quality of the product. Such information was needed in Belize before permitting a sea cucumber fishery. The sea cucumber fishery in Belize was formally opened from 2009-2016 although sea cucumbers had been fished in the previous 20 years [1]. Although a total allowable catch (TAC) based on wet weight was set annually, there was no mechanism in place to determine how much catch was extracted from the wild by sea cucumber fishers. This was primarily because sea cucumbers were exported semi-processed or dried and these export data were used as a total to estimate the TAC, yet the TAC was set based on wet weight.[1] Data on the weights of processed sea cucumbers for export or results of studies that use fishery-dependent surveys are obtained with great difficulty and errors as they can be in various processing stages at the time such information is obtained.[2]

The processing of sea cucumbers has a major influence on price [3],[4], especially for sea cucumber exporters. Any fault in the process risks the quality of the end product.[5] The commercial value of a species is determined by the size and the thickness of the body wall [6], and the species itself.[7] While the dry weight to wet weight conversion ratios of processed sea cucumbers have been studied for various species in New Caledonia [6],[2], Tonga [8], and Madagascar [9], to our knowledge no such study exists in Latin America or the Caribbean for the harvested species *Holothuria mexicana*. At the request of the Belize Fisheries Department (BFD), this study was completed with the aim of providing a conversion ratio for each processing stage, especially for semi-

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processed and dry sea cucumbers, the two export stages. These results can be useful to determine the amounts harvested from the wild and to monitor the TAC.

METHODOLOGY

Around 28-30 *H. mexicana* individuals were collected monthly from February to September 2015 during a study that looked at the reproductive cycle of *H. mexicana*.[10] This resulted in a total of 232 individuals. Collection sites were all in Southern Belize (Fig. 1).

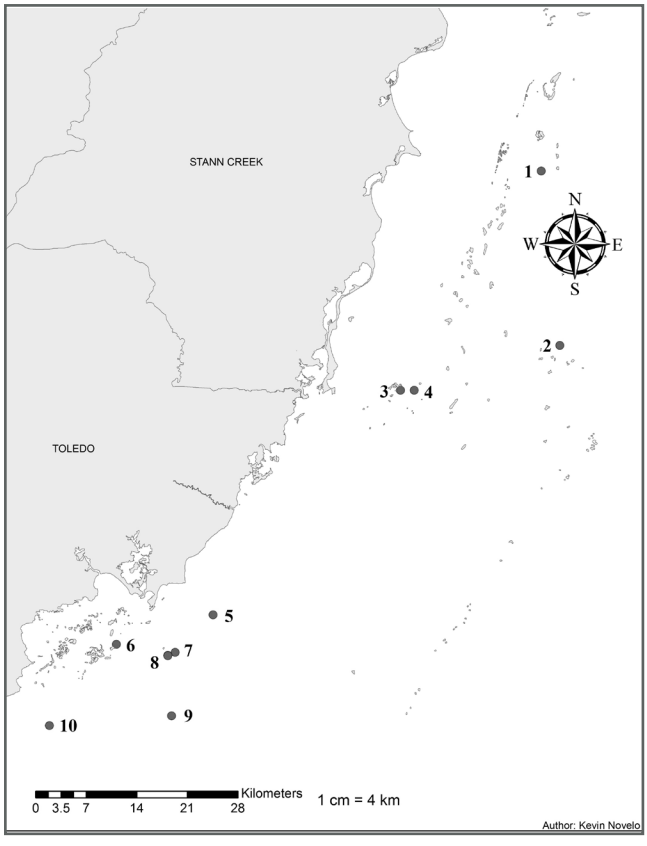

Figure 1. Sea cucumber collection sites in southern Belize including 1 Tobacco; 2 Gladden; 3 & 4 West Laughing Bird; 5 Tarpon and Abalone; 6 The Range; 7 & 8 Snake Cayes; 9 Southeast PHMR; 10 Southwest PHMR. All

All individuals were processed through 10 stages (Table 1 and Fig. 2). In all stages, all individuals were treated similarly to the way that fishermen and sea cucumber exporters treat them for processing and export. All individuals were processed at a sea cucumber processing plant in the Boom Road in the Belize District. Each stage was coded (Table 1). Each individual was collected, total length (1L) measured in situ (Fig. 2A), eviscerated and then weighed (Fig. 2 B, C, D). Total weight and total length were regarded as the weight and length of the drained body wall plus the drained viscera and drained gonads (1W) which were weighed separately (Fig. 2 C). The length (2L) and weight of the body wall (2W) were also recorded. All individuals were individually labelled, transported to the laboratory at the University of Belize and frozen (Fig. 2 E).

This is similar to what fishermen do after they land their sea cucumber catch in late evenings and there is no exporter available to purchase their catch. The following day, all individuals frozen lengths (3L) and weights (3W) were taken, corresponding to when fishers sell frozen sea cucumbers). Subsequently, all individuals were thawed (Fig. 2 F), measured (4L) and weighed (4W) again. Sea cucumbers were then boiled (Fig. 2 G) for an hour and cooled; measured (5L) and weighed (5W); placed in containers with brine (Fig. 2 H) and left for 2 days after which they were measured (6L) and weighed (6L) again. Some exporters dry freeze and export them at this semi-processed stage.

The sea cucumbers were then sun-dried for 8 days (Fig. 2 I), measured (7L) and weighed again (7W). At the end of the eight days, the individuals were re-boiled for 1 hour (Fig. 2 J), measured (8W) and weighed (8W) again. They were then sun-dried again; lengths and weights taken at day 15 (9L and 9W; Fig. 2 K) and day 30 (10L and 10W; Fig. 2 L). At day thirty of sun drying, the specimens were considered to be fully dried (bêche-de-mer) Some exporters export them at this stage.

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Table 1. H. mexicana bêche-de-mer processing stage names and codes

Stage	Code (Weight)	Code (Length)
Total Weight	1W	1L
Body Wall Weight	2W	2L
Frozen Weight	3W	3L
Thawed	4W	4L
1st Boil (Semi-Processed)	5W	5L
2 days brine	6W	6L
8 days sun dry	7W	7L
2nd boil	8W	8L
15 days sun dry	9W	9L
30 days sun dry	10W	10L

Fig 2. A Obtaining total length in situ; B Evisceration; C Gonads drained and weighed separately; D Weighing body wall; E Tagged and bagged sea cucumbers for freezing; F Thawing; G First boil; H Brining; I Sun drying; J Second boil; K Sun drying for 15 days; L Sun drying after 30 days (bêche-de-mer).

RESULTS AND DISCUSSION

Length and Weight Lost

For this study, the initial mean total length per month ranged from 20.9 – 36.9 cm and varied across sites (ANOVA: $P < 0.001$), similar to the mean total length obtained for the reproductive study which varied across sites and habitats.[10] The initial mean total weight per month ranged from 354 g – 841g and varied across sites and habitats. These heavy individuals had a moderate correlation to the range of large individuals (scatterplot, R^2=0.58); not all individuals that were heavy were large. During processing, all individuals decreased in length in all stages, except 6L when they were slightly hydrated after the second boil (Table 2).

Table 2. Mean Length (cm) for each processing stage by month

Month	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L
Feb	21	19	19	16	13	13	12	13	11	11
Mar	23	22	21	21	18	17	16	17	15	14
Apr	27	25	26	17	14	13	11	12	11	10
May	28	27	27	21	17	17	14	15	13	13
Jun	28	26	24	20	17	18	16	16	14	13
Jul	27	26	24	22	16	17	15	15	13	12
Aug	37	35	34	24	18	19	17	17	14	13
Sep	30	29	28	23	18	17	16	16	14	13
Avg	28	26	25	20	16	16	15	15	13	12

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In stage 2W, the mean weight did not change after individuals were thawed except for the month of February that shows a decrease in mean weight (Table 3) which may have been due to loss in water after individuals were thawed. In all subsequent stages, individuals decreased in weight, except in 6W when they were slightly hydrated after the second boil (Table 3).

Table 3. Mean Weight (g) for each Processing Stage by Month

Month	1W	2W	3W	4W	5W	6W	7W	8W	9W	10W
Feb	360	257	260	246	116	103	108	121	79	76
Mar	581	433	435	407	206	182	191	254	138	134
Apr	354	264	268	233	116	105	108	142	79	75
May	807	626	628	595	279	259	165	209	133	92
Jun	688	529	530	525	291	256	173	185	109	91
Jul	589	451	452	436	220	204	137	139	83	72
Aug	841	665	667	459	244	277	199	200	118	99
Sep	615	476	479	342	186	214	149	151	89	75

The average total length of individuals decreased by 5% (Figure 3, 2L) and weight by 24% (Figure 4, 2W) after evisceration. After freezing, the total length decreased by 8% (Figure 3, 3L) and weight by 24% (Figure 4, 3W). Following the 1st boil, the total length decreased by 39% (Figure 3, 5L) and weight by 66% (Figure 4, 5W). After the final stage of sun drying for 30 days, the total length of individuals decreased by 54% (Figure 3, 10L) and weight by 84% (Figure 4, 10W).

Fishermen usually sell fresh or frozen catch based on weight and not by number of individuals or length. While a difference was observed between the wet weight and the frozen weight, this difference was small (0.4%) and thus would not affect the price to fishers for their frozen catch when compared to their fresh catch.

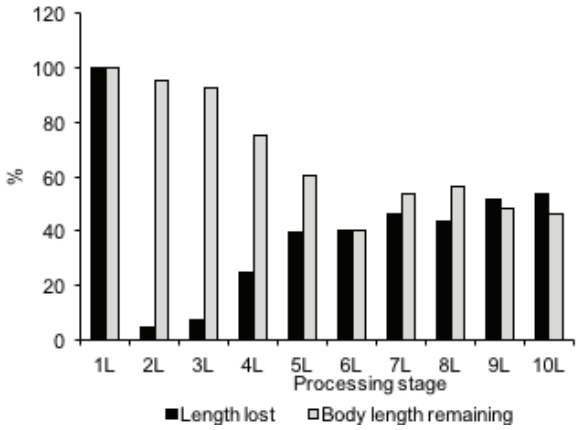

Figure 3. Percent water lost and body length in each H. mexicana processing stage

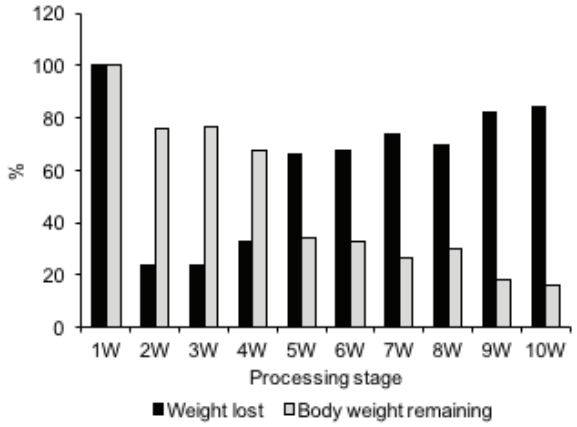

Figure 4. Percent water lost and body weight in each H. mexicana processing stage

Conversion ratio

From the data derived at various processing stages conversion ratios for each stage based on length (Table 4) and weight (Table 5) were calculated from the average data for all months.

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Table 4. Percent change in length of Holothuria mexicana after each processing stage.

	1L	2L	3L	2L	1L	2L	1L	2L	1L	2L
Mean	28	26	25	20	16	16	15	15	13	12
Conversion Ratio	N/A	94.9	92.2	74.1	59.6	59.1	53	55.4	47.1	45.3

Table 5. Percent change in weight of Holothuria mexicana after each processing stage.

	1L	2L	3L	2L	1L	2L	1L	2L	1L	2L
Mean	605	26	25	20	16	16	15	15	13	12
Conversion Ratio	N/A	94.9	92.2	74.1	59.6	59.1	53	55.4	47.1	45.3

*The conversion ratio was derived by dividing the mean length from the current stage by the original total weight or total length and multiplying the quotient by 100.

Weight relationship with spawning months

While fishers suggested that *H. mexicana* body wall weight (2W) seemed to increase during spawning months, there are no studies that look at such correlation. It is noted [1] that there was a positive relationship between total length and total weight for all individuals, regardless of where they were collected relative to marine protected areas. In this study, the results of random scatter of the body wall length-weight (2L and 2W) relationship by month showed that the residuals didn't contradict the linear assumption; suggesting that most of heavy individuals were normally larger and were not heavy because they were in their reproductive season. Although some of the shorter individuals (~32 cm) were among the heaviest (~800 g). Individuals were heavier (1W) during the reproductive months because their gonads were heavier [11]. The total wet weight (1W) and body wall weight (2W) of individuals varied significantly among months (ANOVA: $p < 0.001$). The heaviest individuals (total wet weight) were found in the months of May (avg. 807 g) and August (avg. 841 g). Relatively heavy individuals were also found in March (avg. 581 g), June (avg. 688 g), July (avg. 589 g) and September (avg. 615 g) (Tukey SD, $P < 0.05$); all these months correspond with the reproductive months of *H. mexicana* in Belize [10]. Peak spawning months were from April - May and July - August [10].

Bêche-de-mer quality

Bêche-de-mer quality requirements are widely accepted as processed sea cucumbers that are larger in size (12 cm and above), clean and free from sand or dirt or white salty deposits, have a straight cylindrical form, are dark in colour (instead of light in colour), have no odour and are thoroughly dry [12] . Based on these criteria, the results of this study, yielded (as guided by the sea cucumber exporter) only 13% of individuals with good bêche-de-mer quality (Figure 5 A, B, C and D). Bêche-de-mer quality is a direct result of its processing, not based on the individual sea cucumber characteristics (except large size and dark colour which are favoured). Although these were considered to have "good" quality, they were still not of the highest quality. For instance, they had visible layers of salt and mud on the surface and the incision made for evisceration was visible (Figure 5 B). The majority (87%) of the individuals processed had inferior quality (Figure 5 E, F, G and H). These individuals had either one or more than one inferior quality features such as having a layer of mud, too much salt, had a large cavity or had irregular shape. Although the size is the major factor in attaining

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These quality features were affected in various ways. For instance, each fisher had a way of gutting sea cucumbers. This was usually dependent on whether a small or a large incision for evisceration was the easiest evisceration method for them or based on the incision type the exporters asked them to do. Some sea cucumber fishers would make a small incision on the ventral body and others would make one large incision on the ventral body (Figure 5 F). Others would make two small incisions on both anterior and posterior ends of the ventral body (Figure 5 D), During processing, if not set to dry on a flat surface the sea cucumbers will not acquire the desired flat shape (Figure 5 E and G). Knowing the percent of salt needed to dehydrate is important so that large amounts of salt don't accumulate on the surface. All these factors play a role on the amount of money that the exporters are offered. Exporters expressed their preference for exporting semi-processed sea cucumbers since the market demanded high-quality sea cucumbers they weren't able to provide. The reason for the price difference is that Asian markets have an affinity for products that are visually appealing and that stay appealing after they are prepared.[13]

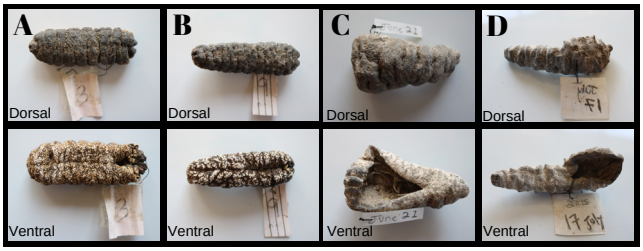

Figure 5. A, B, C, D Good quality Bêche-de-mer (A and C Dorsal; B and D Ventral); E, F, G, H Inferior quality bêche-de-mer (E and G Dorsal; F and H Ventral)

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CONCLUSIONS AND RECOMMENDATIONS

The percent of water lost during each processing stage can be very valuable when illegal processed sea cucumbers are seized to determine processed stage and wet weight. This information may also be useful for those countries that commercially harvest or plan to harvest *H. mexicana*. This study is the first to produce information for *Holothuria mexicana* from wet weight to bêche-de-mer. The results of this study were aimed to represent the average weight loss for this species during processing and to facilitate the management of this fishery. It is recommended that similar studies are completed for all months and body wall weight compared with reproductive months based on a larger sample size. Further replicate studies conducted at different locations around the coast of Belize would provide a more complete view of the populations of *Holothuria mexicana* in Belize. A sea cucumber guide that discusses sea cucumber biology, ecology, commercial value, processing and quality could prove useful to countries in this region. Training oriented to fishermen and exporters would benefit the industry by increasing the quality of semi-processed and dry sea cucumber.

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