Trends in Sea Cucumber Faecal Production across Species, Size, and Location on the Great Barrier Reef

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Background Information

• **Corals provide a variety of ecosystem services** (e.g. aesthetic appreciation, cultural values [Bellwood *et al.*, 2004]).

• **Climate change and CO_2 emissions harm corals via ocean acidification** as hydrogen ions react with CO_3^{2-} molecules, preventing them from forming $CaCO_3$ with Ca^{2+} (Feely *et al.*, 2009). **Less $CaCO_3$ is available for corals**, reducing their ability to form $CaCO_3$-based structures/grow (Cohen & Holcomb, 2009).

• **Sea cucumbers can digest substrate containing $CaCO_3$ and excrete the molecule in their faeces**, increasing its availability in the environment and **facilitating coral growth** (Schneider *et al.*, 2011). Sea cucumbers also **excrete NH_3, which, combined with $CaCO_3$, raises the water's total alkalinity** (Schneider *et al.*, 2011).

• **Queensland's sea cucumber fishery** is regulated to be ecologically sustainable (Department of Environment and Energy, 2018). These regulations have been **criticized as not being proactive** in maintaining population sizes and for **not being based in science**; decisions behind which species to focus harvesting on did not consider their ecological roles, life histories, or baseline population sizes (Ericksson & Byrne, 2015).

Figure 1. A market stall in Ho Chi Minh, Vietnam, selling dried sea cucumbers (among other marine animals and wares). Cucumbers are a delicacy in Southeast Asia, with thousands of tonnes of them exported to the region each year. Queensland's cucumber fishery regulates total annual catches to around 360 tonnes. Photo by Selina Ward.

Objective/Methods

Objective: To **identify ecologically important cucumbers based on the metric of faecal production**. Faecal production was quantified by collecting faeces from surveyed cucumber individuals and determining their mass. Cucumbers with high faecal production should not be harvested as that would reduce the amount of benefits being provided to reefs. Three cucumber parameters are examined: species *(Holothuria atra, H. edulis, H. leucospilota, Stichopus chloronotus, S. variegatus* were found), size, and location (inshore, midshore, offshore) on Heron Reef.

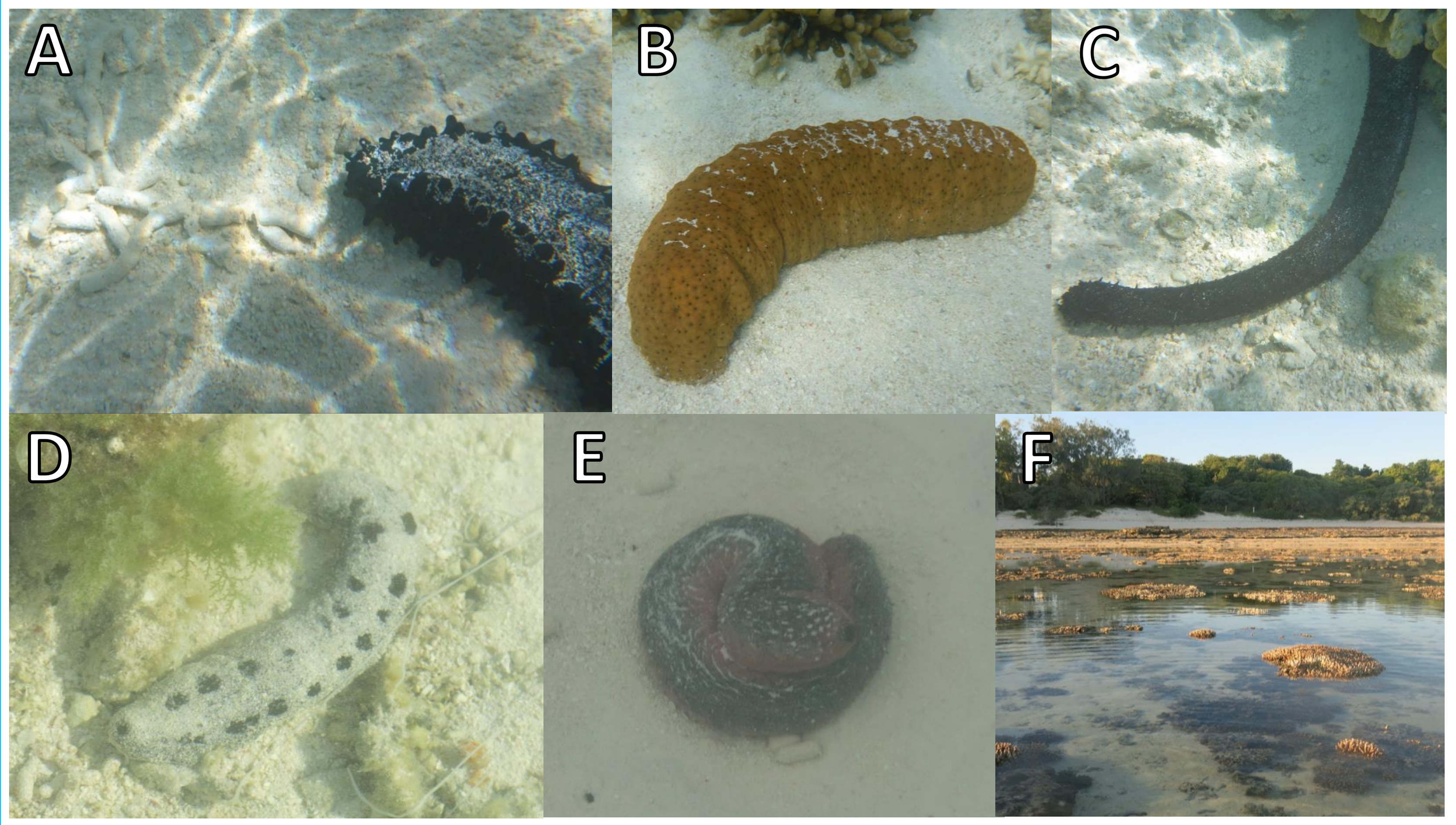

Figure 2. The five survey species: *Stichopus chloronotus* (A), *S. variegatus* (B), *Holothuria leucospilota* (C), *H. atra* (D), and *H. edulis* (E). Surveys consisted of collecting faeces from cucumbers on Heron Island's adjacent reef flats (F). Photos A-C by Tim Wu; Photos D-F by Selina Ward.

Q1: Are there any inter-species differences in faecal production?

Prediction: More faeces should be collected from larger species (i.e. *S. variegatus*) and less from smaller species (i.e. *S. chloronotus*).

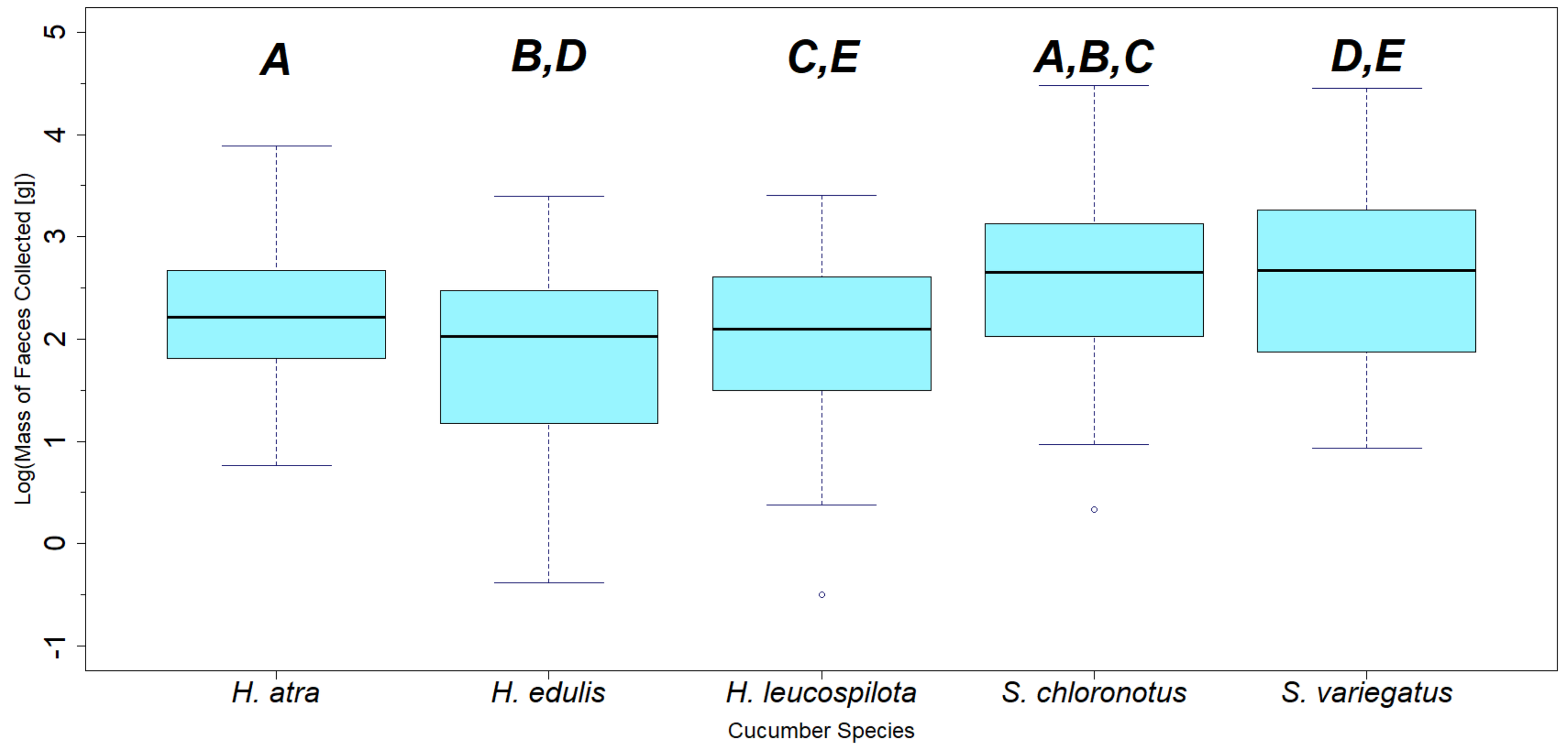

Figure 3. Boxplot illustrating the relationship between cucumber species surveyed on Heron Reef and their associated logs of collected faecal mass. An ANOVA (p-value = 2.5e-5) suggests a significant statistical relationship. A post-hoc pairwise comparison (Tukey's test) was performed; species with similar letters have significant differences, as indicated by the Tukey's test.

Key results: *S. chloronotus* has the most faecal mass (significantly different to all Holothurians) followed by *S. variegatus* (significantly different to two Holothurians). *H. leucospilota* has significantly lower faecal mass than the *Stichopus* species.

Q2A: Is there a relationship between length and volume?

Prediction: There should be a positive relationship between length and volume.

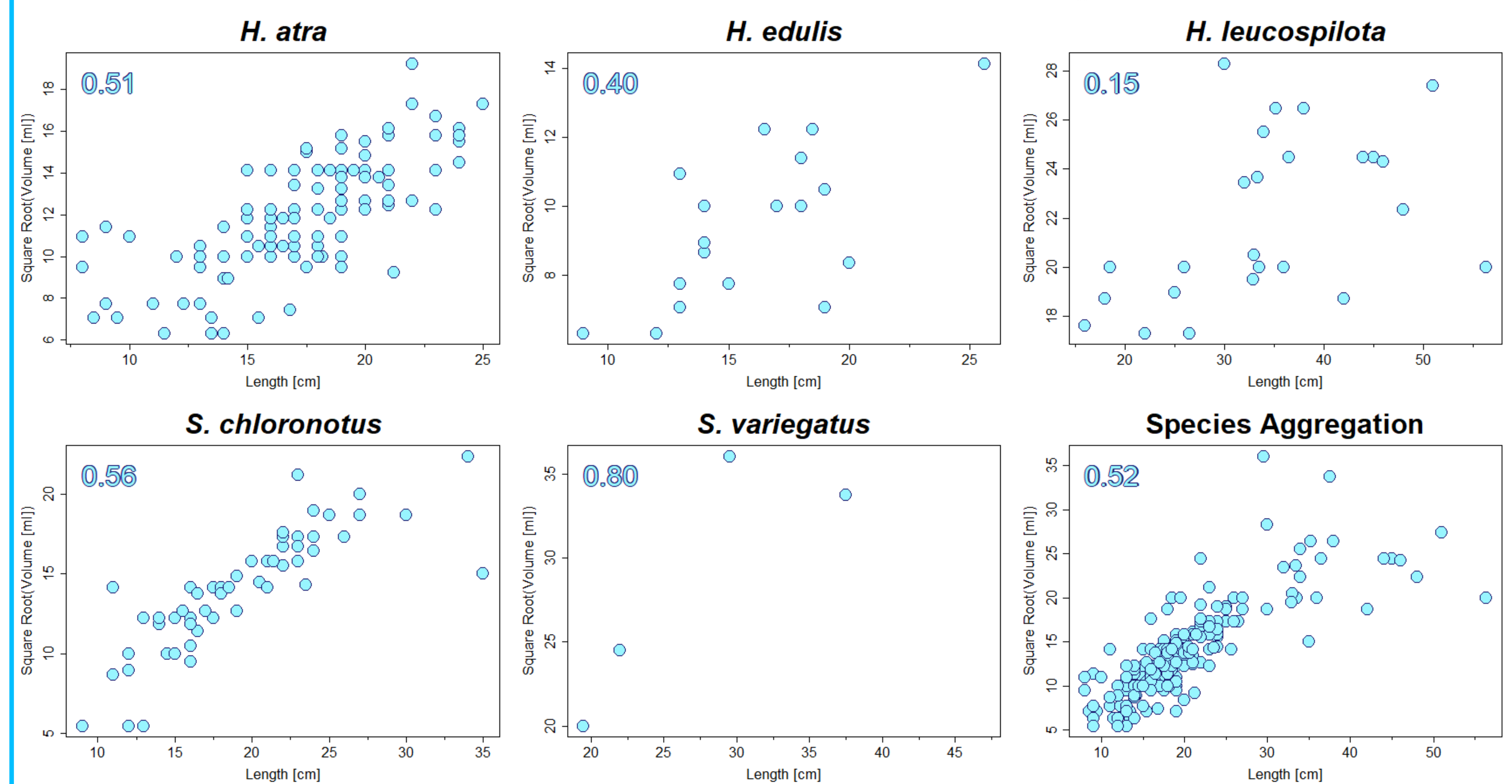

Figure 4. Six graphs (one for each species surveyed on Heron Reef and one aggregating all species) plotting the square root of an individual cucumber's volume against their length. The regression coefficient of each graph's associated linear regressions are also shown. ANOVAs for *H. atra*, *H. edulis*, *H. leucospilota*, *S. chloronotus*, and the aggregation indicate a significant relationship (p-value = <2.2e-16, 2.5e-4, 1.5e-2, 4.3e-16, and <2.2e-16 respectively). The ANOVA for *S. variegatus* does not suggest a significant relationship (p-value = 0.15).

Key results: Statistically significant positive relationships are strongest in *H. atra* and *S. chloronotus*; only *S. variegatus*' relationship is not significant. The relationship is weaker for *H. leucospilota*.

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Q2B: Is there a relationship between size and faecal production?

Prediction: There should not be a relationship between size and amount of faeces collected, regardless of the metric used (length or volume).

Table 1. Regression coefficients of a linear model where cucumber length or volume and the log of faecal weight are the explanatory and response variable respectively. For each parameter , five models pertain to each species surveyed on Heron Reef ; the sixth one pertains to an aggregation of all species. Associated p-values are also listed.

Species	Regression coefficient of Log(Mass of Faeces Collected [g]) as a function of…	
	Length [cm]	Volume [ml]
H. atra	0.02 | p-value = 0.19	0.00 | p-value = 0.96
H. edulis	0.07 | p-value = 0.17	0.01 | p-value = 0.19
H. leucospilota	0.00 | p-value = 0.77	0.00 | p-value = 0.22
S. chloronotous	0.03 | p-value = 0.15	0.00 | p-value = 0.22
S. variegatus	0.01 | p-value = 0.62	0.00 | p-value = 0.13
Aggregation	0.01 | p-value = 0.06	0.00 | p-value = 0.70

Key results: There is no relationship between size and faecal mass.

Q3: Is there a difference in faecal production between cucumbers found in different zones of the reef?

Prediction: There should a positive relationship between distance from the shore and amount of faeces collected.

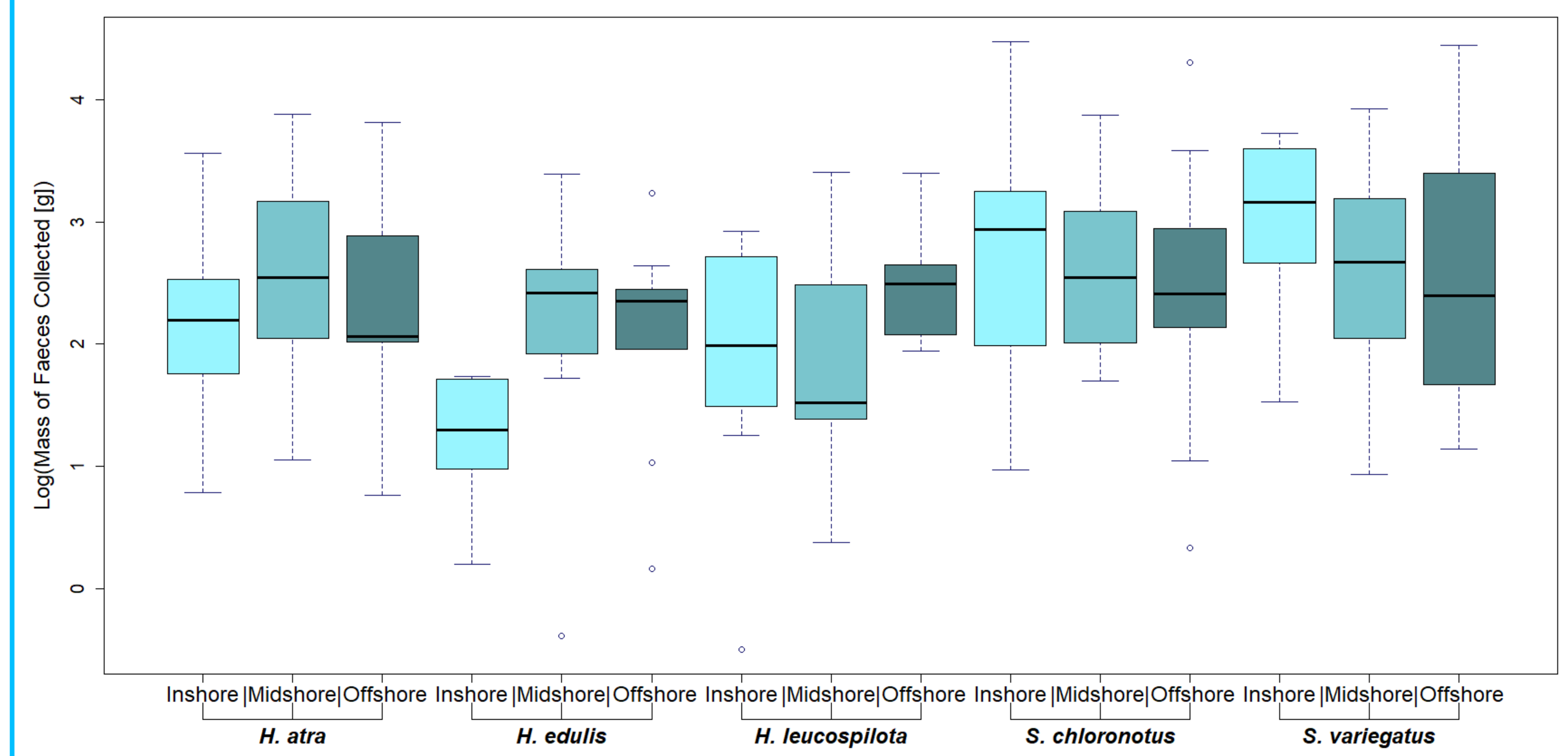

Figure 5. Box plots denoting the amount of faeces collected from cucumbers from five different surveyed species on Heron Reef at different distances from the shore.

Key results: Depending on the species, there are differing trends in faecal production across different reef zones, none of which show a positive relationship.

Conclusions

• Harvesters should not exploit *S. variegatus* or *S. chloronotus* as they appear to produce more faeces than other surveyed species and thus provide greater reef benefits. This goes against industry practices that focus harvests on *S. variegatus* (and *Actinopyga spinea*).

• As size is not related to faecal production, it should not be used as a metric for ecological importance and (by extension) suitability for harvest.

• The relationship between faecal production and location is species-dependent. Harvesters need to be aware of this relationship when fishing.

• Conclusions are limited by number of species surveyed and by how some cucumbers may have actually produced more faeces but the excrement was swept away elsewhere.

• Conclusions are limited and may be influenced by unevenness of sampling.