Length-weight relationship and condition factor of ethanol-preserved contemporary and museum *Spratelloides delicatulus*

# Introduction

The purpose of this study is to report the length-weight relationship and condition factor of Philippines *Spratelloides delicatulus* (blue sprat; Spratelloididae) from ethanol-preserved museum and contemporary specimens. Additionally, the effect of ethanol preservation on contemporary samples is investigated to establish a correction factor for length-weight relationship and condition factor between fresh and after 1 month of ethanol preservation.

Body condition is a key indicator of health at the individual or population level, since it is closely related to important fitness variables, such as growth, reproduction, behavior, and survival.

The collections of the *Albatross* expeditions in the Philippine islands from 1907 to 1910 represent a huge opportunity to study morphological variation between species that may have become less accessible in the modern day. Understanding the effects preservation has on the reported LWR and condition factor will determine the viability of using these collections to measure change in ecological productivity, determine morphological relationships, and describe characteristics of species that are data-deficient. It is understood that the shrinkage of preserved specimens is variable and determined by a number of factors, meaning correction factors may only be applicable to individuals from that same collection. While using preservation corrections is less ideal than determining these measurements from fresh specimens, access to large sample sizes of commercially unvalued or vulnerable species presents an opportunity to collect valuable morphological data via museum collections that should not be overlooked. This project is meant to capture a snapshot of the condition factor of these fish at the time of capture as it is influenced by multiple factors for throughout the year.

# Methods

## Museum (USS Albatross) Collection (n = 124)

Specimens were collected by the USS Albatross during the Albatross Philippine Expedition from 1907 to 1910. Specimens were fixed and preserved in ethanol, without being fixed in formalin. Specimens were collected from four locations:

Mapun Island, Tawi-Tawi, Philippines (USNM 138978). (n = 38). Date: January 8, 1909. Collection Method: 130-ft seine. Depth 1 m. Daily Surface Water Temp Range: 80-82 F

Jamelo Cove, Batangas, Philippines (USNM 138979). (n = 28). Date: July 13, 1908. Collection Method: Seine. Depth ?. Daily Surface Water Temp Range: 82-87 F

Sacol Island, Zamboanga, Philippines (USNM 150772). (n = 26). Date: September 8, 1909. Collection Method: Dip net, electric light. Depth ?, but probably surface. Daily Surface Water Temp Range: 80-84 F

Mansalay, Oriental Mindoro, Philippines (USNM 138969). (n = 32). Date: June 4, 1908. Collection Method: 150 ft seine. Depth 2-3 m. Daily Surface Water Temp Range: 81-85 F

Collection Method:

Mansalay & Jamelo were collected with a 150' seine. Cagayan de Jolo with a 130' seine. Sacol with an electric light and dip net. This makes sense with the size of the specimens from Sacol, which might need to be removed from the dataset.

Sea Surface Temperature (SST):

Surface water temperature can be identified from the ship’s logbooks. SST measurements are taken every hour for 24 hours a day. It's difficult to identify the time of capture, so this project uses the daily temperature range on the date of capture as a proxy to the temperature.

Cagayan de Jolo (1/8/1909): 80-82 F

Jamelo (7/13/1908): 82-87 F

Mansalay 6/4/1908): 81-85 F

Sacol (9/8/1909): 80-84 F

Sampling:

The species selected for study were based on the availability of lots used in the Carpenter Lab for an unpublished PIRE temporal genomics project. From that, species were selected based on the availability of length-weight studies for comparison. Individual specimens were taken out of the ethanol preservation solution. The mouth and gill cavities were drained, then the specimens were dried using Kimtech wipes. Individual specimens were removed from a preservation solution of approximately 70% ethanol one fish at a time. The mouth and gill cavities were drained, and specimens were pat dry using Kimtech wipes. Individuals who had their abdominal cavities cut were drained and gently squeezed to remove excess ethanol. The standard and total lengths (mm) were taken using calipers and mass (g) was measured using an analytical balance. This process was kept consistently within 1-3 minutes, during which time additional ethanol also evaporated. After measurements were taken, the samples were transferred to another jar of 70% ethanol until the lot was completed.

Calculations:

This uses the observed standard length and weight data in the equation: *W=aL^b.* Fulton's Condition Factor (cf) is calculated from the observed standard length and weight: cf=100(W/SL^3), where a cf of 1 indicates a "normal" fish, >1 is relatively more fit, <1 is relatively less fit. Le Cren's Relative Condition Factor (Kn) *Kn=W/aL^b* first requires the calculation of the constants a & b from the length-weight relationship equation, where *a* represents the relationship between length and weight and *b* represents allometry with regard to SL and TL. The product of this equation is similar to Fulton's condition factor but determines condition with relation to the average weight of fish sampled rather than an ideal weight. The denominator in this equation is the expected fish weight at a given length. So, this is the ratio of the observed to the theoretically expected weight for a given length.

The results generated by this project were then compared to past length-weight studies using data from the Fishbase database. Duplicate studies and those which were deemed “Doubtful” by fishbase editors were removed, and then a *b* vs. log10*a* figure was recreated to include this study and compare the length-weight parameters of different studies in different localities. Measurements were initially written by hand before being transferred to Microsoft Excel spreadsheets. Calculations were completed using R v.4.3.1, as well as the pacman, dplyr, readxl, ggplot2, rfishbase, rlang, nls2, and patchwork packages.

## Contemporary Collection (n = 124)

Samples were collected from Olympia Island, North Bais Bay, Negros Oriental, Philippines (n = 124). Fish were purchased from local fisherman between June 2-12, 2023. Fresh measurements were taken by John Paul Sullera and Rabbi Montegrejo (Negros Oriental State University). Specimens were fixed and preserved in 70% ethanol. Measurements were taken again 1 month after fresh measurements.

## Data Analysis

Length-weight Relationship, where W is the expected weight based on the actual standard length (L).

Equation 1. W=aL^b.

Fulton's Condition Factor, for comparison to an ideal weight

Equation 2. K=100(W/SL^3).

Le Cren's Relative Condition Factor, for comparison to the average weight. Where W is weight, L is standard length.

K\_n = W/aL^n.

A map of philippines with colorful dots and numbers

Description automatically generated

Figure #. (S\_delicatulus\_Albatross\_Locations.png)

# Results

## Museum (USS Albatross) Collection

A graph with a line and dots

Description automatically generated

Figure #. (S\_delicatulus\_LWR\_SL.png). The length-weight relationship of museum *Spratelloides delicatulus* specimens collected in 1908 and 1909 from Mapun Island, Hamilo Cove, Sacol Island, and Mansalay (n = 124). Standard length is reported in cm and mass in g.

A graph of a line

Description automatically generated

Figure #. (S\_delicatulus\_log10a\_b). The log10*a* and *b* values from the length-weight relationship of *Spratelloides delicatulus* calculated from three different locations.

A graph with a line and dots

Description automatically generated

Figure #. (S\_delicatulus\_lm.png). A linear regression of the log 10 mass and standard length of museum *Spratelloides delicatulus* (n = 124).

A graph with black dots and a line

Description automatically generated

Figure #. (S\_delicatulus\_kn.png). The relative condition factor and standard length of museum *Spratelloides delicatulus*.

## Fulton’s Condition Factor from Museum Collection

A graph of different colored lines

Description automatically generated

Figure #. (S\_delicatulus\_cfvSL\_byLocality\_95CI.png) S delicatulus linear regression of condition factor by site.

A chart with colorful rectangles

Description automatically generated

Figure #. (S\_delicatulus\_boxplot\_cf\_byLocality.png) S. delicatulus condition factor by site.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table #. Kruskal-Wallis with Dunn Test and Bonferroni for Fulton's Condition Factor (cf). | | | | |
| Comparison | Z-value | Unadjusted p-value | Adjusted p-value | Significance |
| Cagayan\_de\_Jolo - Jamelo\_Cove\_Luzon | -6.6224 | < 0.0001 | < 0.0001 | \*\*\* |
| Cagayan\_de\_Jolo - Mansalay\_Mindoro | -4.626 | < 0.0001 | < 0.0001 | \*\*\* |
| Jamelo\_Cove\_Luzon - Mansalay\_Mindoro | 2.0847 | 0.0185 | 0.1113 |  |
| Cagayan\_de\_Jolo - Sacol\_Island\_Zamboanga | 2.7417 | 0.0031 | 0.0183 | \* |
| Jamelo\_Cove\_Luzon - Sacol\_Island\_Zamboanga | 8.6182 | < 0.0001 | < 0.0001 | \*\*\* |
| Mansalay\_Mindoro - Sacol\_Island\_Zamboanga | 6.8466 | < 0.0001 | < 0.0001 | \*\*\* |

## Le Cren’s Relative Condition Factor from Museum Collection

A graph of different colored lines

Description automatically generated

Figure #. (S\_delicatulus\_KnvSL\_byLocality\_95CI.png) S delicatulus linear regression of relative condition factor by site.

A graph with colored squares and black lines

Description automatically generated

Figure #. (S\_delicatulus\_boxplot\_Kn\_byLocality.png) S. delicatulus relative condition factor by site.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table #. Kruskal-Wallis with Dunn Test and Bonferroni for Le Cren's Relative Condition Factor (Kn) | | | | |
| Comparison | Z-value | Unadjusted p-value | Adjusted p-value | Significance |
| Cagayan\_de\_Jolo - Jamelo\_Cove\_Luzon | -7.7356 | < 0.0001 | < 0.0001 | \*\*\* |
| Cagayan\_de\_Jolo - Mansalay\_Mindoro | -5.3399 | < 0.0001 | < 0.0001 | \*\*\* |
| Jamelo\_Cove\_Luzon - Mansalay\_Mindoro | 2.4942 | 0.0063 | 0.0379 |  |
| Cagayan\_de\_Jolo - Sacol\_Island\_Zamboanga | 0.3114 | 0.3778 | 1 |  |
| Jamelo\_Cove\_Luzon - Sacol\_Island\_Zamboanga | 7.365 | < 0.0001 | < 0.0001 | \*\*\* |
| Mansalay\_Mindoro - Sacol\_Island\_Zamboanga | 5.1526 | < 0.0001 | < 0.0001 | \*\*\* |

## Contemporary - Figures

A graph with a line and dots

Description automatically generated

Figure #. (S\_delicatulus\_LWR\_SL\_2\_fresh.png). The length-weight relationship of freshly caught contemporary *Spratelloides delicatulus* specimens collected in 2023 from Bais Bay (n = 124). Standard length is reported in cm and mass in g.

A graph with a line

Description automatically generated

Figure #. (S\_delicatulus\_log10a\_b\_fresh.png). The log10*a* and *b* values from the length-weight relationship of freshly caught contemporary *Spratelloides delicatulus* and those from three other studies.

A graph with a line and dots

Description automatically generated

Figure #. (S\_delicatulus\_lm\_fresh.png). A linear regression of the log 10 mass and standard length of freshly caught contemporary *Spratelloides delicatulus* from Bais Bay, Philippines (n = 124).

A graph with black dots and a blue line

Description automatically generated

Figure #. (S\_delicatulus\_kn\_fresh.png). The relative condition factor and standard length of freshly caught, contemporary *Spratelloides delicatulus*.

## Matching – Figures

A graph with colored dots and lines

Description automatically generated

A graph of a graph

Description automatically generated

Figure #. (S\_delicatulus\_shrink.png). The length-weight relationship of freshly caught contemporary (n = 124), 1 month preserved contemporary (n = 124), and 115 year old museum (n = 124) *Spratelloides delicatulus* specimens. Standard length is reported in cm and mass in g.

A graph with black dots and blue line

Description automatically generated

Figure #. (S\_delicatulus\_LWR\_SL\_matching.png).

A graph with black dots and blue line

Description automatically generated

Figure #. (S\_delicatulus\_LWR\_SL\_2\_matching.png).

A graph with a line

Description automatically generated

Figure #. (S\_delicatulus\_log10a\_b\_matching.png).

A graph with a line drawn on it

Description automatically generated

Figure #. (S\_delicatulus\_log10a\_b\_comparison.png). The log10*a* and *b* values from the length-weight relationship of freshly caught contemporary (n = 124), 1 month preserved contemporary (n = 124), and 115 year old museum (n = 124), and those from other studies as reported by fishbase (fb-world).

A graph with black dots and a blue line

Description automatically generated

Figure #. (S\_delicatulus\_lm\_matching.png).

A graph with black dots and a line

Description automatically generated

Figure #. (S\_delicatulus\_kn\_matching.png).

## One Month – Figures

A graph of a graph with black dots

Description automatically generated

Figure #. (S\_delicatulus\_LWR\_SL\_month.png).

A graph with a line and a line

Description automatically generated with medium confidence

Figure #. (S\_delicatulus\_LWR\_SL\_2\_month.png).

A graph with a line drawn on it

Description automatically generated

Figure #. (S\_delicatulus\_log10a\_b\_month.png).

A graph of a graph with black dots

Description automatically generated

Figure #. (S\_delicatulus\_lm\_month.png).

A graph of a graph of a number of dots

Description automatically generated with medium confidence

Figure #. (S\_delicatulus\_kn\_month.png).

# Discussion

Latitudinal effect on condition factor

"Temperature and Growth in Fish" - Reviews in Fish Biology and Fisheries

"Seasonal and Latitudinal Variations in Fish Condition" - Journal of Fish Biology

"Genetic and Environmental Influences on Fish Condition Factor" - Marine Ecology Progress Series

Counterintuitive effect of fishing pressure on condition factor