JMP Academic Case Study 065

Microplastics

Chi-square test, Kruskal-Wallis test

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Key ideas

This case study guides students through the process of using descriptive statistics, nonparametric hypothesis testing, and correlation analysis to interpret real-world ecological data. Students will summarize skewed data, compare groups with small samples, and evaluate associations among variables.

Background

Plastic pollution has become a global environmental crisis, threatening marine and terrestrial ecosystems, wildlife, and humans. Microplastics, defined as plastic particles less than 5 mm in diameter, are generated from the degradation of larger plastic debris. Once in the environment, these particles persist and accumulate, entering the food web through both direct and indirect ingestion. For consumers of these microplastics, especially top predators, the risk of contamination is high due to their position in the trophic chain and the potential for bioaccumulation and biomagnification. Check out this video for an in-depth look at how pervasive the plastic problem is.

For example, there is strong evidence for microplastic accumulation in fish, making species such as seals, dolphins, sharks, and humans vulnerable to the negative health consequences associated with contamination. Several studies, including one on the critically endangered Mediterranean monk seal (Monachus monachus), confirmed the presence of these pollutants.

Bottlenose dolphins (Tursiops truncatus), iconic and highly intelligent marine mammals, are another bioindicator species that can provide important insights into the health of marine environments. Recent research has revealed that bottlenose and other species of dolphins are ingesting microplastics, likely through contaminated prey or direct ingestion in the water column. In this case study, we explore microplastic ingestion in bottlenose dolphins stranded along the coastlines of the United States.

The task

We use data on the presence of microplastics in stranded individuals to analyze the amount of microplastics found, evaluate the differences in age and sex class, and characterize the frequency of different microplastic types and polymer compositions.

For the purposes of this case study, we focus on bottlenose dolphins. We use dolphin necropsy data to:

- Describe the abundance and types of microplastics ingested.
- Compare counts across age and sex classes using nonparametric methods.
- Evaluate correlations between dolphin size or gut content mass and microplastic abundance.
- Visualize the distribution of microplastic types and colors.

The data **Microplastic-data.jmp**

The variables in the data set include:

- **Region** (Atlantic, Gulf, NW Pacific)
- **Latitude**
- **Longitude**
- **Species** (Tt, Pp)

- **Sex** (Male, Female).
- **AgeClass** (Adult, Non-Adult)
- **Animal Length**
- **Microplastic Type** (Fiber, Fragment, Tirewear).
- **Microplastic color** (black, white_clear, other)
- **Total Microplastic Count** (corrected for blanks).
- **ContentWeight** (weight of microplastic in grams)

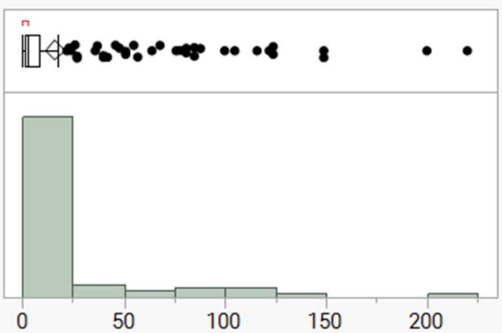
Analysis

We start by filtering the data table to include only bottlenose dolphins; we then generate summary statistics of the total microplastic counts. Exhibit 1 shows a histogram of the total counts per dolphin. We can see that although most individuals had fewer than 25 particles, some had substantially higher numbers, creating a right-skewed distribution. Next, we compare groups within the sample using box plots (Exhibit 2). These plots highlight how microplastic counts vary between males and females and across age classes, making it easy to see differences in median values and the spread of the data. Finally, we explore potential spatial patterns by mapping stranding locations along the coast (Exhibit 3). This visualization helps us investigate whether dolphins from certain regions appear more heavily contaminated than others. Together, these initial descriptive approaches provide a foundation for identifying patterns and variation in the bottlenose dolphin sample.

Exhibit 1 Histogram, box plot, summary statistics of microplastic counts

Distributions Student Edition

Total MP Count



Quantiles

100.0%	maximum	220
99.5%		218.4
97.5%		124
90.0%		55.8
75.0%	quartile	8
50.0%	median	3
25.0%	quartile	1
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

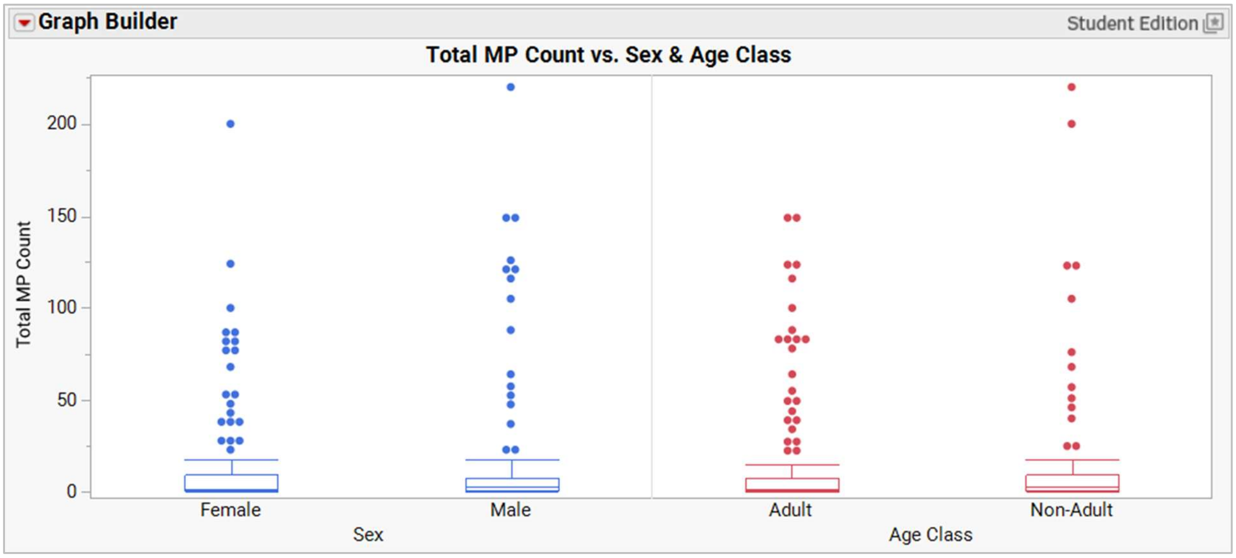
Summary Statistics

Mean	16.125581
Std Dev	34.844354
Std Err Mean	2.3763652
Upper 95% Mean	20.809662
Lower 95% Mean	11.441501
N	215
N Missing	0

(Analyze > Distribution. Select Total MP Count as the Y variable. Click OK. Select Stack option from the top red triangle.)

This histogram displays the frequency distribution of total microplastic counts across bottlenose dolphins. The skewed shape indicates that while many dolphins have relatively low counts, a few individuals ingested far higher numbers of particles. It also shows descriptive statistics, including the mean, median, standard deviation, and interquartile range of total counts. The gap between the mean and median reflects the right-skewed distribution observed in the histogram, where a few individuals had higher numbers of particles.

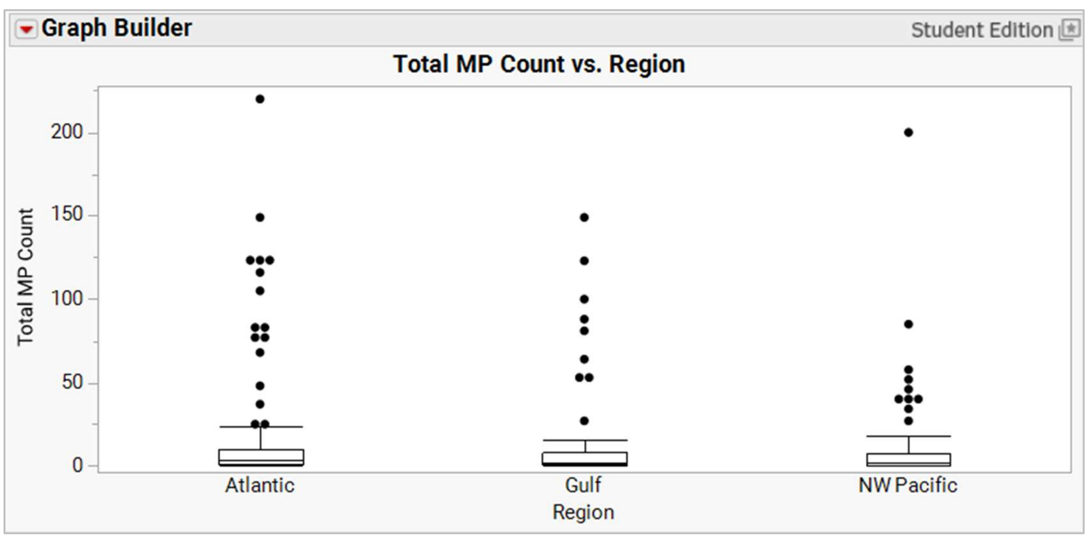
Exhibit 2   Box plots by sex and age class



(Comparative box plots: Graph > Graph Builder. Place Total MP Count on the Y axis and Sex on the X. Select the box plot icon in the graph palette.)

These box plots compare microplastic counts across male and female dolphins (left) and across adult and non-adult age classes (right). The plots reveal both the median levels and variability of microplastic ingestion by group.

Exhibit 3   Comparative box plots by region



(Comparative box plots: Graph > Graph Builder. Place Total MP Count on the Y axis and Region on the X. Select the box plot icon in the graph palette.)

These box plots compare total microplastic counts across three geographic regions where bottlenose dolphin samples were collected (Atlantic, Gulf, and NW Pacific). The plots can show whether dolphins from different regions have variation in microplastic ingestion, possibly due to differences in prey or pollution sources.

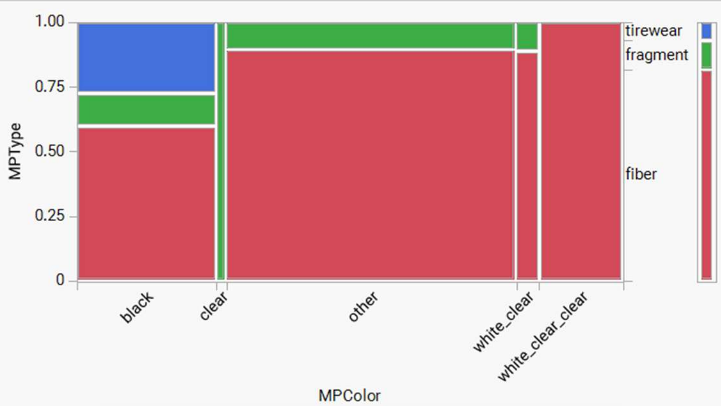
Microplastic characteristics

The data set includes variables describing the type and color of recovered particles. To better understand how microplastic characteristics influence total mass, we can examine color (black, clear/white, other) and type (fiber, fragment, tirewear) on total microplastic weight. This comparison could explain whether certain types of plastics contribute disproportionately to overall weight and whether that contribution varies by color category. Because both variables are categorical, we can test whether the distribution of one variable depends on the categories of the other. In this case, whether the type of microplastic is independent of or associated with its color category. The contingency analysis (Exhibit 4) revealed a significant association between microplastic type and color ($\chi^2 = 84.43$, $p < 0.0001$). Black particles were more likely to be fragments or tirewear, while white/clear and other-colored particles were predominantly fibers. This pattern suggests that color may serve as a proxy for particle source, with darker microplastics representing distinct origins such as tirewear or industrial debris.

Exhibit 4 Contingency analysis

Contingency Analysis of MPType By MPColor — Student Edition

Mosaic Plot



Tests

N	DF	-LogLike	RSquare (U)
215	8	35.511491	0.2779

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	71.023	<.0001*
Pearson	84.435	<.0001*

Warning: 20% of cells have expected count less than 5, ChiSquare suspect.

Contingency Table

MPColor	Count / Total % / Col % / Row %	fiber	fragment	tirewear	Total
black	Count	33	7	15	55
	Total %	15.35	3.26	6.98	25.58
	Col %	18.75	29.17	100.00	
	Row %	60.00	12.73	27.27	
clear	Count	0	4	0	4
	Total %	0.00	1.86	0.00	1.86
	Col %	0.00	16.67	0.00	
	Row %	0.00	100.00	0.00	
other	Count	102	12	0	114
	Total %	47.44	5.58	0.00	53.02
	Col %	57.95	50.00	0.00	
	Row %	89.47	10.53	0.00	
white_clear	Count	8	1	0	9
	Total %	3.72	0.47	0.00	4.19
	Col %	4.55	4.17	0.00	
	Row %	88.89	11.11	0.00	
white_clear_clear	Count	33	0	0	33
	Total %	15.35	0.00	0.00	15.35
	Col %	18.75	0.00	0.00	
	Row %	100.00	0.00	0.00	
Total	Count	176	24	15	215
	Total %	81.86	11.16	6.98	

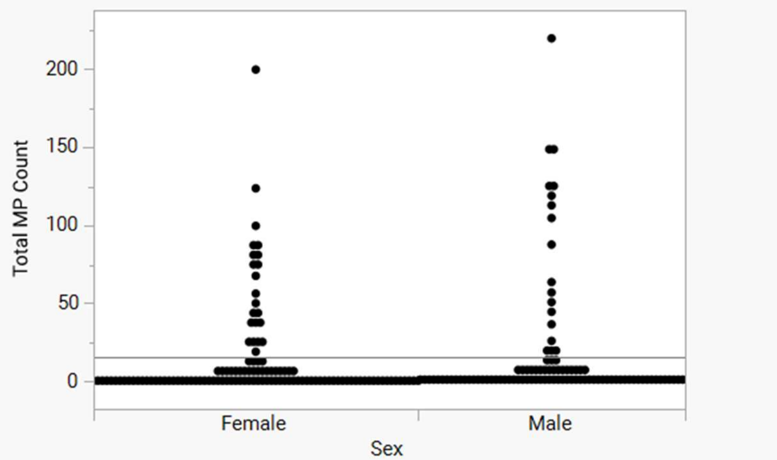
(Analyze > Fit Y by X. Place MPType to the Y, Response role; place MPColor to the X, Factor role. Click OK.)

Group comparisons with nonparametric tests

Because the data set is small and the counts are not normally distributed, we need to use nonparametric methods to compare groups. Exhibit 5 presents the results of a Wilcoxon rank sum test comparing males and females. Since the box plots from Exhibit 2 suggest differences in median counts, this test allows us to evaluate whether these differences are statistically significant.

Exhibit 5 Kruskal-Wallis tests by sex

Oneway Analysis of Total MP Count By Sex Student Edition



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Female	118	12284.5	12744.0	104.106	-1.020
Male	97	10935.5	10476.0	112.737	1.020

Wilcoxon Two-Sample Test, Normal Approximation

S	Z	Prob>Z	Prob>|Z|
10935.5	1.02040	0.1538	0.3075

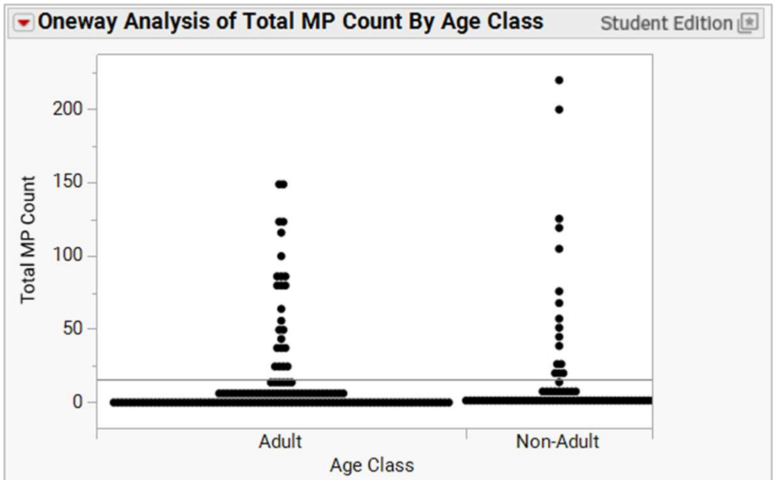
Kruskal-Wallis Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.0435	1	0.3070

(To perform these tests, go to Analyze > Fit Y by X. Place Total MP Count in the Y, Response role; place Sex in the X, Factor role. Select Nonparametric > Wilcoxon Test or Nonparametric > Kruskal-Wallis Test under the red triangle.)

Next, Exhibit 6 shows a Kruskal-Wallis test across age classes (adult, non-adult). This analysis reveals whether age groups differ in their levels of microplastic ingestion.

Exhibit 6 Kruskal-Wallis tests by age class



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Adult	143	15398.5	15444.0	107.682	-0.105
Non-Adult	72	7821.50	7776.00	108.632	0.105

Wilcoxon Two-Sample Test, Normal Approximation

S	Z	Prob>Z	Prob>|Z|
7821.5	0.10548	0.4580	0.9160

Kruskal-Wallis Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.0114	1	0.9151

(To perform these tests, go to Analyze > Fit Y by X. Place Total MP Count in the Y, Response role; place Age Class in the X, Factor role. Select Nonparametric > Wilcoxon Test or Nonparametric > Kruskal-Wallis Test under the red triangle.)

Summary

Statistical insights

Our analysis of bottlenose dolphins demonstrated that microplastic ingestion is both widespread and variable across individuals. Descriptive statistics (Exhibit 2) confirmed a right-skewed distribution, with most dolphins ingesting relatively few particles and a handful showing much higher counts. Nonparametric comparisons (Exhibits 5 and 6) tested whether ingestion levels differ by sex or age class, allowing us to evaluate potential demographic differences despite small sample sizes and skewed data. Contingency analysis (Exhibit 4) suggested color and type are not independent. Since certain colors are more likely to be associated with certain types (for example, black = tirewear, white/clear = fibers), any differences we find in total microplastic count or weight by color could partly be due to type differences and vice versa. Together, these results illustrate the utility of nonparametric methods when dealing with small and nonnormally distributed data sets.

Implications

These results suggest bottlenose dolphins are an important indicator of marine ecosystem health. The predominance of fibers among recovered particles points to textiles and wastewater as likely sources of contamination (Ahmad et al. [2025]). The presence of microplastics in dolphins across age classes and sexes suggests that exposure is pervasive and not limited to demographic groups. Because bottlenose dolphins are apex predators and share environments with humans, these results also highlight the potential for microplastic contamination in the broader food web, including species directly consumed by people.

JMP features and hints

The Distribution platform generates summary statistics and histograms for exploring skewed data. The Fit Y by X platform supports nonparametric hypothesis testing, including the Wilcoxon rank sum and Kruskal-Wallis tests for group comparisons and Contingency Analysis when comparing frequencies or proportions. The Multivariate Methods platform allows for correlation analyses, including Kendall's Tau, which is well-suited for ordinal or non-normally distributed data. Graph Builder provides a suite of flexible options for visualizing histograms, box plots, and geographic maps of strandings. Combining these tools integrates exploratory visualization with appropriate statistical methods.

Exercises

1. The histogram in Exhibit 1 showed the distribution of total microplastic counts for bottlenose dolphins. Using this as a guide, create the same histogram for long-beaked dolphins (Pp). Is the distribution similarly skewed, or does it differ? What do the mean and median values indicate about the most appropriate measure of central tendency for this species?

2. The analysis in Exhibit 4 compared microplastic counts between male and female bottlenose dolphins and used a Wilcoxon rank sum test to evaluate differences. Replicate this analysis for long-beaked dolphins. Do the results show a statistically significant difference between sexes? If the p-value is below 0.05, what would this suggest about differences in microplastic counts between males and females? To explore possible reasons for such a difference, you may also consider examining whether microplastic counts vary across geographic regions (different water bodies), since regional variation in prey availability could drive dietary differences. (Hint: *JMP steps:* Go to Analyze > Fit Y by X. Place *Total Microplastic Count* in the Y, Response role; place *Water Body* (or State/Region, depending on the column label in your data) in the X, Factor role. Under the red triangle menu, select Nonparametric > Kruskal-Wallis Test to assess whether counts differ significantly across regions.

3. Exhibit 3 displayed box plots of microplastic counts across adult and nonadult bottlenose dolphins and tested for differences with a Kruskal-Wallis test. Repeat this analysis for long-beaked dolphins. Do ingestion levels vary significantly by age class? Which age class shows greater variability, as indicated by the width of the box and the length of the whiskers?

4. Exhibit 4 presented the results of a contingency analysis exploring whether the frequency of color and type were related. Perform the same analysis for long-beaked dolphins and then the entire data set. Which microplastic type is most common overall? Which color category dominates? What might these patterns suggest about the primary sources of microplastic exposure?

5. Drawing on your results, propose one ecological explanation for variation in microplastic ingestion among long-beaked and bottlenose dolphins. Consider factors such as prey choice, habitat use, or feeding strategies.

6. Do the two species show similar or different distributions of microplastic counts? Are sex- and age-related patterns consistent across species? Which species appears more heavily impacted and what might this suggest about their foraging ecology? Summarize your comparison in a short paragraph, highlighting both statistical differences and ecological insights.