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Comparing Feeding Accuracy between High and Low Predation Trinidad Guppies

An Honors Thesis submitted in partial fulfillment of the requirements for Honors in

Biology

By Lydia Bonnell

Under the mentorship of Dr. Emily Kane

ABSTRACT

Efficient feeding accuracy could increase an organism's survival. Although local adaptation in Trinidad guppies is common, the effects on accuracy are unknown. Guppies were wild caught in 2015 and 2017, filmed while capturing prey. Accuracy wasn't different within samples but differed across samples, possibly due to the prey types used.

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Introduction:

All organisms have certain necessities for survival. Acquiring food, which requires the ability to find, seize, and handle a target, is one of these necessities.¹ Cheetahs hunting gazelles, hawks diving for mice, and orcas consuming squids are examples of prey capture. Similarly, fish capture prey in order to meet their nutritional needs; however, for some fish prey capture involves accounting for the unique way in which they acquire their prey, suction feeding. Trinidad guppies, *Poecilia reticulata*, are useful subjects of study since they not only utilize suction while feeding but they also have low and high predation populations.²

While successful prey capture in some animals may denote accuracy, this is not necessarily the case with other animals, including many fish.³ The distance from the mouth to the prey is not the only factor that must be accounted for in some fish. Many do not simply swim up to and snap their mouth shut on their prey; instead, they utilize suction to feed.³ They ingest a certain volume of water that must be accounted for in connection with their prey capture.³ Centrarchids feed by suctioning water into their mouths much like a mini-vacuum (Figure 1).⁴ The ingested volume of water (IVW), the

literal sphere of influence, is a result of the suction force which decreases with increasing distance from the mouth.⁴ The center of the IVW is the point of optimal accuracy since prey found at this point have little chance of escaping.³ Essentially, this is the point where the prey should be found.³ Accuracy is then determined by finding the distance the prey is from the ideal point (Figure 4, 5).³

This method mentioned above has been used to investigate accuracy in certain centrarchids - the bluegill sunfish, the largemouth bass, and the green sunfish.³ While this study did compared feeding accuracy between the centrarchids, it did not evaluate the effect predation may have on feeding accuracy.³

Studies of evolution-related topics commonly utilize guppies for many reasons, including the genetic differences that exist between populations.^{4,5} The most important characteristic of guppies for this specific research topic is the differences in predation between the Trinidad guppies.⁵

The Trinidad guppy populations are separated by natural boundaries, waterfalls. In some areas guppies face high levels of predation while guppies in other areas have relatively low threat of predation, resulting in resource scarcity due to high population density.⁵ The differing predation levels make the guppy populations likely to experience a tradeoff between predator avoidance and intraspecific competition for resources. Since greater accuracy could give guppies a selective advantage by allowing them to more accurately obtain food before either predators appear or another guppy tries to capture the same prey, Trinidad guppies an ideal model to bridge the gap in the research on the relationship between predation and feeding accuracy.

Although prey capture accuracy has yet to be studied in Trinidad guppies previous research has manipulated both predation level and food availability in guppies that had formerly not been subject to predators.⁴ When both food and predators were abundant, the guppies' amount of growth decreased.⁴ However, no conclusion was reached as to whether the decreased growth was the result of increased feeding caution due to risk of predation or because the predators were so large that the guppies' never outgrew their mouth size.⁴ While the amount of food available to the guppies was decreased, it had no measurable impact on the guppies.⁴ It was unknown whether more drastic decreases in food might change the results but it was apparent that predation influenced the guppies.⁴

Although many effects of predation in guppies have been investigated, such as the difference between the time allocated for feeding and reproduction, no study thus far has attempted to evaluate the effects of different levels of predation on feeding accuracy.⁵

Studies have shown that predation typically alters certain aspects and characteristics of Trinidad guppies.⁵ High predation has resulted in increased mortality rates, less vibrant coloration, a decrease in body mass, and changed behavior.^{4,5,6} More time is often spent on reproduction than feeding in high predation populations of guppies; therefore, it is logical to assume that capturing prey more accurately and efficiently would result in a selective advantage that would allow high predation guppies to spend less time feeding while acquiring the same amount of food.⁵

The aim of this study is to determine if a significant difference in feeding accuracy exists between the Trinidad guppy samples and if so which population is more accurate while feeding. The null hypothesis would state that feeding accuracy would not

differ between the two guppy populations. Based on previous studies though, the overall hypothesis is that high predation guppies will display greater feeding accuracy than low predation guppies. Alternatively, there is the possibility that low predation guppies will significantly differ from high predation guppies by having a higher degree of feeding accuracy, giving them an advantage.

Efficient feeding accuracy could give an organism, including Trinidad guppies, a selective advantage, increasing the probability of survival. It is important to be able to anticipate the characteristics that may be favorable or expected under various circumstances. I intend to use Trinidad guppies from high predation and low predation areas to establish whether there is a difference in feeding accuracy between the two populations. This will be accomplished through methods similar to those utilized in the research on centrarchids.² Thus, I am examining whether the differing predation levels in a guppy's original habitat affect its level of feeding accuracy.

The panorama of evolutionary history is the repetition of stories describing the manner in which one species or one subset of a species adapted to its environment more effectively than another. Charles Darwin is attributed with naming this process "natural selection;" not uncommonly the most skilled organism triumphs over the less skilled. The effectiveness of Trinidad guppies at preying on their food source is a factor in determining whether they survive. They must be able to meet their nutritional needs while also avoiding predation when necessary; therefore, Trinidad guppies are an ideal model to analyze whether there is a relationship between predation and feeding accuracy exists due to their varying predation levels.

Methods:

The guppies, *Poecilia reticulata*, used were collected from Trinidad in 2015 and 2017 and filmed in Colorado and Georgia respectively (Figure 2). Each guppy was placed in its own tank with a recirculating system so that the water was shared. All tanks were identical. Each guppy received the same amount of food and was on a 12:12 light:dark cycle.

Each fish was recorded multiple times with a Edgertronic SC1 camera at 500 fps while consuming plankton collected from a local pond and while having a 1 cm grid in the tank. The grid was later used to calibrate the videos. In order to have optimal lighting to see the tiny prey, two IR lights were placed on the top of the tank while filming the Georgia (2017) sample while visible light was used in the Colorado (2015) sample. The best video for each fish was selected based on the clarity of the video and angle of the fish while approaching and consuming its prey. Ideally, the fish will be positioned perpendicular to the camera (lateral view). This was to minimize error that would occur if the fish were angled while the video was taken. An angled video would require the z plane to be accounted for and a second camera above or below the fish to be utilized. Only one camera was deployed for this study.

Version 1.5.5.8 of ProAnalyst - made by Xcitex Inc. in Woburn, MA - was utilized in each frame of a video to place five points: prey position, upper jaw, lower jaw, center of mass, and tail (Figure 3). The x and y coordinates for each point were exported to an Excel file. Matlab was used next to smooth the raw data because of the constraints of digitizing the videos such as placing the five points on the pixels in the ProAnalyst

program.^{2,8} It also was utilized to calculate velocity and peak gape from the data in the ProAnalyst Excel sheets. The 95% of maximum gape was generally used for the peak gape since guppies tend to keep their mouths open for an extended period of time when capturing prey. A 100% peak gape in the middle of a guppy keeping its mouth open would incorrectly make it seem like the guppy opened its mouth at a much slower velocity. Due to this fact, using the 95% peak gap is a common method.^{2,8} These Matlab calculations were used to yield values for accuracy. This was accomplished by inserting peak gape and velocity into regression equations. The result was the approximate length and height of the suction volume. The center of the IVW was the intersection of these lines (Figure 4, 5). Since center of the IVW was determined, the distance between the prey and the center of the volume was able to be determined (Figure 4). The accuracy values for the high predation guppies and the accuracy values for the low predation guppies was evaluated by a ANOVA through the JMP program (Table 1, 2, 3, and 4). The ANOVA was also done for velocity at peak gape and peak gape since this gives insight as to what may cause a difference in accuracy.

The independent variable that was focused on was the level of predation found in the guppies' natural habitat, high or low. The dependent variable was the feeding accuracy value for each fish which was required while determining the swim velocity and gape of mouth first. The Georgia sample consisted of 26 guppies while the Colorado sample included 45. The addition of these guppies filmed in Colorado provided replication in the research.

Results:

The guppies used in this study approached their prey at a slow speed which ranged from 2.27 to 4.42, opened their mouth between 0.116 cm to 0.241 cm, and sucked in water while attempting to capture prey (Table 1). The standard error for peak gape was 0.0327 to 0.00717. The mean ram at peak gape ranged from 2.27 to 4.42 while its standard error was from 0.288 to 0.897. The sample sizes ranged from 4 to 14 individual guppies. While filming the guppies to collect this data it could be easily seen that the guppies used suction to pull in prey and water around it (Figure 1). The results of this study exhibited that the method of estimating accuracy using kinematics of swim speed and mouth size could be successfully applied to guppies (Figure 4, 5).²

At the outset of this study the major aim was to see whether the level of predation (high versus low) affects accuracy. Within the Georgia sample of guppies there was no significant difference in accuracy based solely on predation (Table 2, Figure 6C). The same conclusion was found for accuracy within the Colorado sample (Table 3, Figure 6C). Although there were no differences in accuracy within samples, there could be differences in the shape or size of the ingested volume. Height to length ratio and IVW volume did not differ based on predation within the Georgia sample (Table 2, Figure 6A, Figure 6B). IVW size did significantly diverge - YALP is shown to be much lower than the others which contributed to the significant difference - within the Colorado sample while height to length ratio did not show a difference (Table 3, Figure 6A, Figure 6B). Despite a lack of differences within samples, when the data was compared across GA and CO samples, accuracy significantly differed across them (Table 4, Figures 7C). North

Colorado guppies were shown to have a high mean and much smaller range in comparison (Table 1, Figure 7C). The West Colorado group had a larger range than that of its northern counterpart as well as a lower sample. Both North and West Colorado had higher means and smaller ranges than that of East sample analyzed in Georgia. The West sample analyzed in Georgia had a similar range to the East sample analyzed in Georgia group and a mean between the two Colorado groups. This is true with IVW and height to length ratio as well.

Discussion:

At the outset of this study the question posed was whether accuracy is affected by predation level. The data from this study shows that there was no evidence of a significant difference in accuracy between high and low predation guppies (Table 2, 3). Similar research that utilized centrarchids capturing evasive and non-evasive prey concluded that *M. salmoides* was more accurate in obtaining evasive prey while *L. macrochirus* captured non-evasive prey more accurately.² Other research that compared aspects - ram speed, gape, cranial elevation, IVW and jaw protrusion - of suction feeding between marine and freshwater sticklebacks, ultimately concluding that the marine variety had greater values for all of the aforementioned characteristics.⁸ Although the main focus of this study, accuracy, did not significantly differ within the guppy samples, IVW within the Colorado sample did significantly differ (Table 3). Local adaptation - when populations within a species become better suited to environments with different characteristics - is likely affecting the guppies' IVW as a whole rather than just predation, one characteristic of their complex environment.⁹ This indicates that the differences

between the two populations is much more complicated than originally hypothesized. There is the possibility that this sample produced their suction volume differently. This could be influenced by a number of characteristics, including those analyzed in the stickleback research: ram speed, gape, cranial elevation, and jaw protrusion.⁸ The results of a study that investigates these factors in guppies could help determine exactly what kind of prey these guppies are best suited to consume.

All of the significant data across the Colorado and Georgia samples points to two possible explanations: a drainage effect or differences in prey type (Table 4, Figure 7, Figure 8). The Colorado sample contained the North and West drainages while the Georgia sample consisted of the East and West drainages (Figures 7). Differences between the drainages could have resulted in a drainage effect, causing the significant differences between accuracy, IVW, and height to length ratio. These differences could be but are not limited to visibility and flow speed in the water.⁸ Alternatively, prey type could have caused the differences.⁸ Both the prey for the guppies filmed in Colorado and that of Georgia were wild caught from specific ponds - whose plankton content could have differed - in those respective states. Both the centrarchid and stickleback research suggests that prey type, evasive versus nonevasive, influences aspects of suction feeding.^{2,8} The guppies could have responded to the different types of plankton differently. Copepods are much better at detecting and responding to water movement and have a much better escape response that helps them jump farther and faster than daphnia. We believe that copepods were in high concentration in the Colorado pond while daphnia were abundant in the Georgia pond. This could have led to the significant

differences seen or, more likely, both drainage effect and prey type are influencing the outcome simultaneously. In addition, it is known that plankton are not frequently in a guppy's normal palate in the wild. They typically eat noninvasive prey such as algae off of rocks, making them not suited to ideally capture plankton as a species.

Guppies have become a prime research organism for evolutionary change. Many of their characteristics - color diversity, lifespan, body size, and DNA variation to name a few - have been researched in the past.⁵ Since the peak gape differed across the guppy samples, there is a possibility of morphological differences which should be investigated in future research.⁸

Figures & Tables:

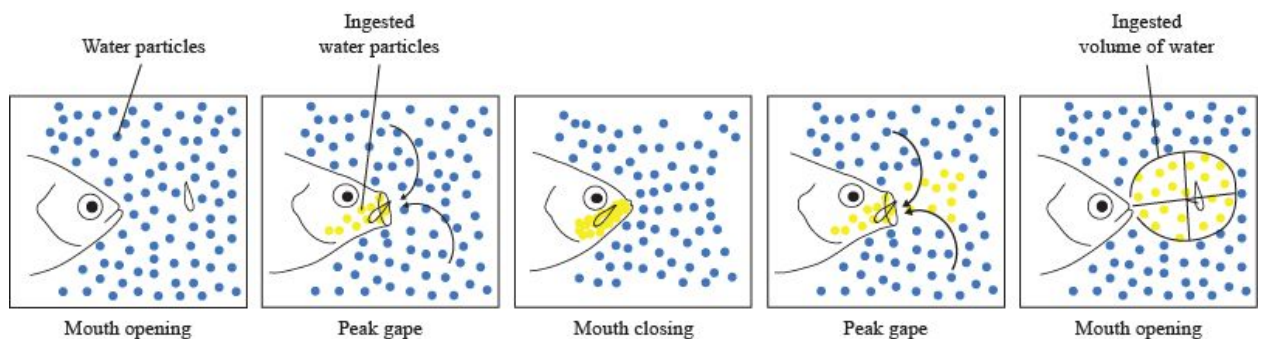


Figure 1. Visual explanation of IVW calculation. The blue dots generally represent water while the yellow dots identify the water particles that are suctioned into the fish during prey capture.

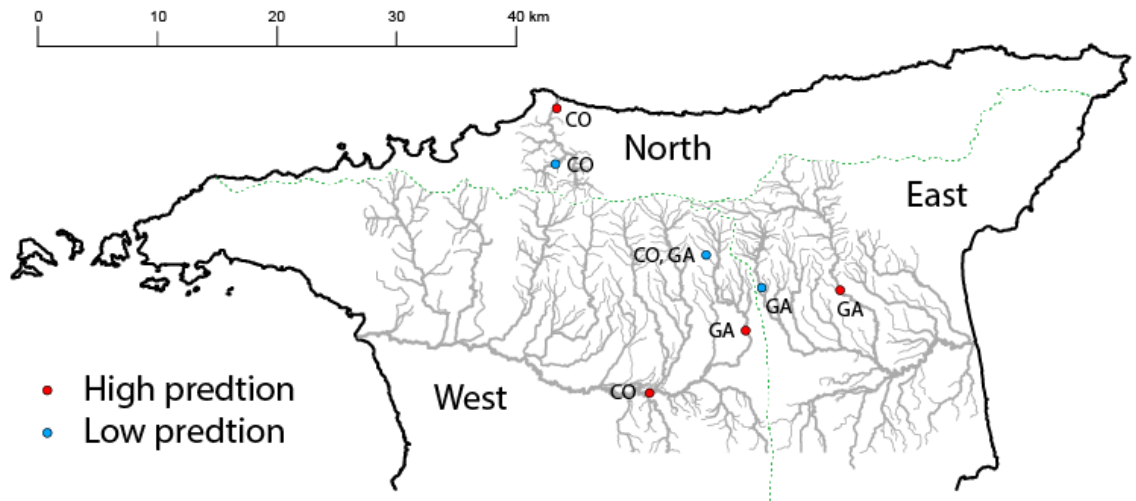


Figure 2. The photo made by E. Kane above displays the locations that the guppies were collected from in 2015 and 2017.

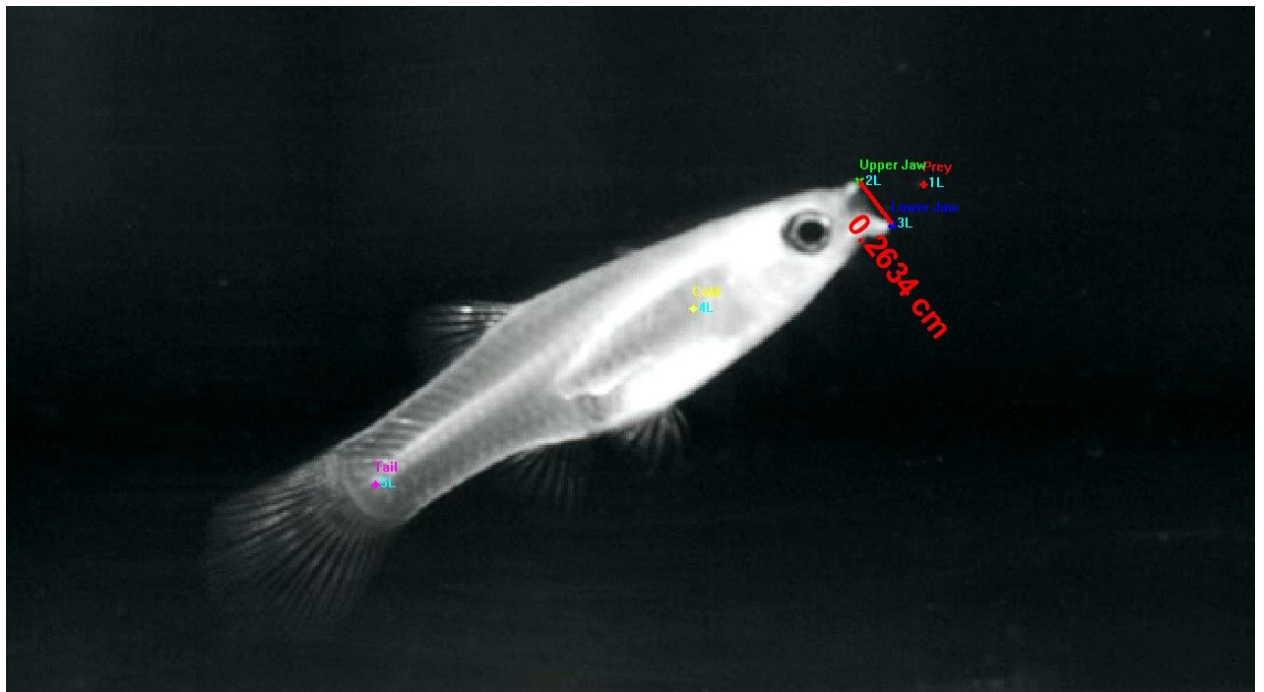


Figure 3. A representative frame taken at maximum gape (QDLP 064 trial 06) showing labeled kinematic points.

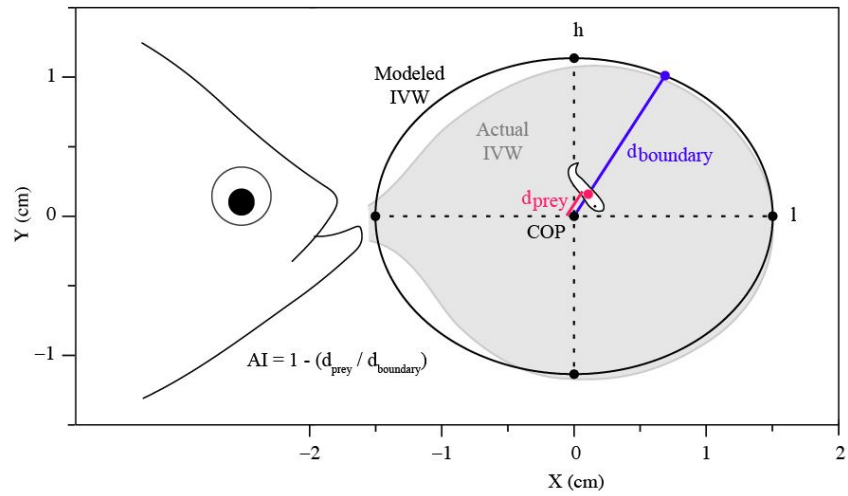


Figure 4. A visual display of a IVW along with the center of the IVW (COP) and position of the prey which was made by E. Kane.

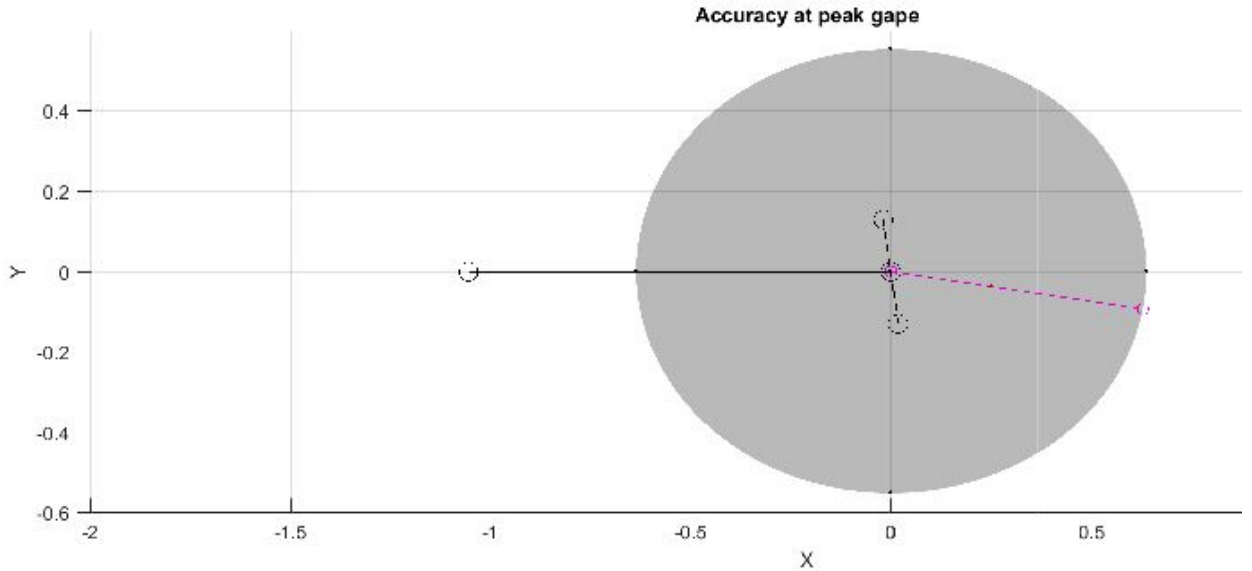


Figure 5. Visual representation of the estimated ingested volume of water - the grey area - and accuracy calculation. The center of the circle - the point that has both a black and magenta circle around it - represents the ideal point for prey to be. This is the point of

perfect accuracy. The dashed magenta circle shows where the prey actually was while the dashed line is the distance between the prey and point of ideal accuracy. The black line indicates the position of the predator (guppy). The line goes from the CoM on the guppy to the center of the open mouth.

Table 1. The mean and standard error values for kinematic traits.

Sample	Direction	Predation	Sample Size	Mean of Peak Gape (cm)	Standard Error for Peak Gape (cm)	Mean Ram at Peak Gape (cm/s)	Standard Error for Ram at Peak Gape (cm/s)
CO	North	Low	5	0.178	0.00949	4.42	0.897
CO	North	High	14	0.116	0.00717	2.42	0.323
CO	West	Low	13	0.192	0.0154	3.26	0.288
CO	West	High	13	0.190	0.0105	4.41	0.439
GA	East	Low	10	0.241	0.00920	3.36	0.300
GA	East	High	5	0.196	0.0200	3.36	0.7607
GA	West	Low	4	0.196	0.0327	2.27	0.351
GA	West	High	7	0.191	0.0135	2.29	0.415

Table 2. Statistics within the Georgia sample of Trinidad guppies.

	Response Variable	Ingested Volume	Height to Length Ratio	Accuracy	Peak Gape	Ram at Peak Gape
ANOVA	F _{3,22}	3.4113	1.5108	0.3119	2.7652	1.8998
	P	0.0353*	0.2395	0.8166	0.066	0.1591
Direction	F ₁	5.1317	0.1058	0.4238	2.0883	5.2174
	P	0.0337*	0.748	0.5218	0.1625	0.0324*
Predation	F ₁	1.4708	1.8722	0.137	2.2104	0.0007
	P	0.2381	0.185	0.7148	0.1513	0.9799
Direction*Predation	F ₁	0.6845	1.4811	0.5137	1.4306	0.0002
	P	0.4169	0.2365	0.4811	0.2444	0.9879
Significant value *						
ANOVA = analysis of variance						

Table 3. Statistics within the Colorado sample of Trinidad guppies.

	Response Variable	Ingested Volume	Height to Length Ratio	Accuracy	Peak Gape	Ram at Peak Gape
ANOVA	F _{3,41}	9.2181	7.5706	2.7791	10.8764	5.5537
	P	<.0001*	0.0004*	0.0531	<.0001*	0.0027*
Direction	F ₁	6.4443	9.478	2.0897	11.3632	0.8744
	P	0.015*	0.0037*	0.1559	0.0016*	0.3552
Predation	F ₁	4.1963	5.5257	0.9272	6.0858	0.8749
	P	0.047*	0.6975	0.3412	0.0179*	0.3551
Direction*Predation	F ₁	9.6303	0.6975	3.0124	5.3477	12.0847
	P	0.0035*	0.4085	0.0901	0.0258*	0.0012*
Significant value *						
ANOVA = analysis of variance						

Table 4. Statistics across the Georgia and Colorado samples of Trinidad guppies.

	Response Variable	Ingested Volume	Height to Length Ratio	Accuracy	Peak Gape	Ram at Peak Gape
ANOVA	$F_{3,67}$	8.5078	15.8155	6.3497	14.4992	3.647
	P	<.0001*	<.0001*	0.0007*	<.0001*	0.0169*
Sample	F_1	4.5483	34.509	15.3986	20.4657	2.6899
	P	0.0366*	<.0001*	0.0002*	<.0001*	0.1057
Direction [Sample]	F_2	10.6007	7.536	1.9468	12.137	4.1575
	P	0.0001*	0.0011*	0.1507	<.0001*	0.0199*
Significant value *						
ANOVA = analysis of variance						

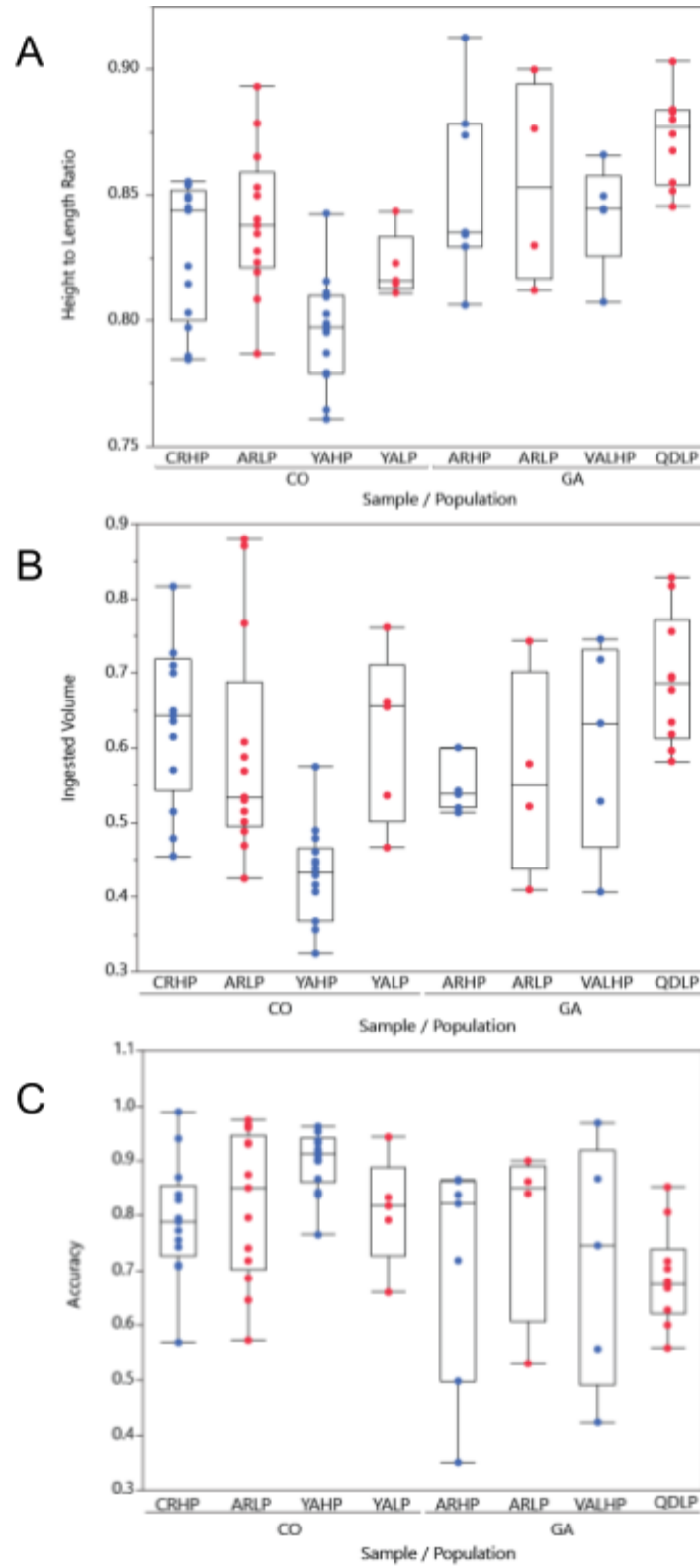


Figure 6. Height to length ratio, ingested volume, and accuracy for each population.

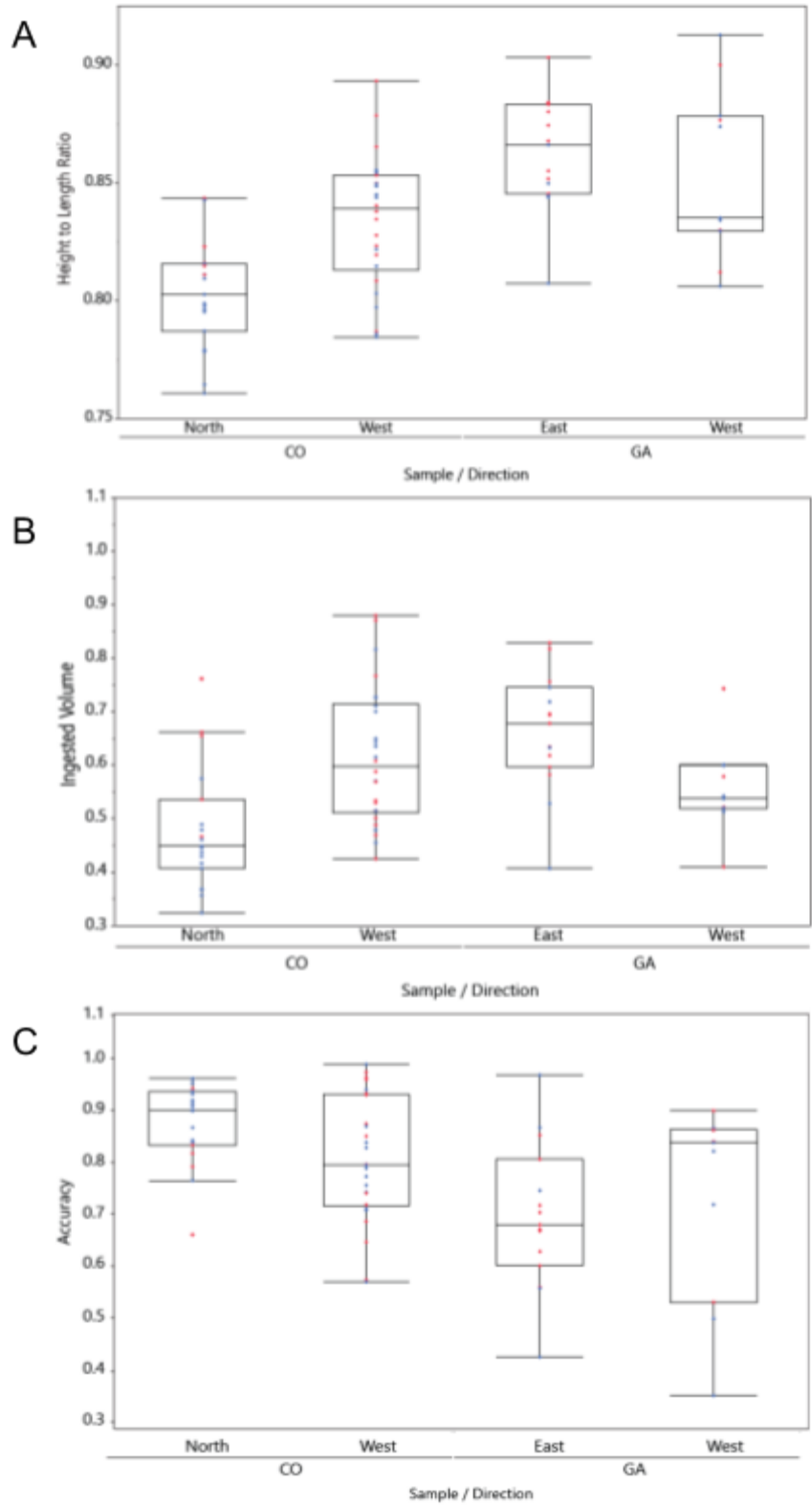


Figure 7. Height to length ratio, ingested volume, and accuracy plotted against direction.

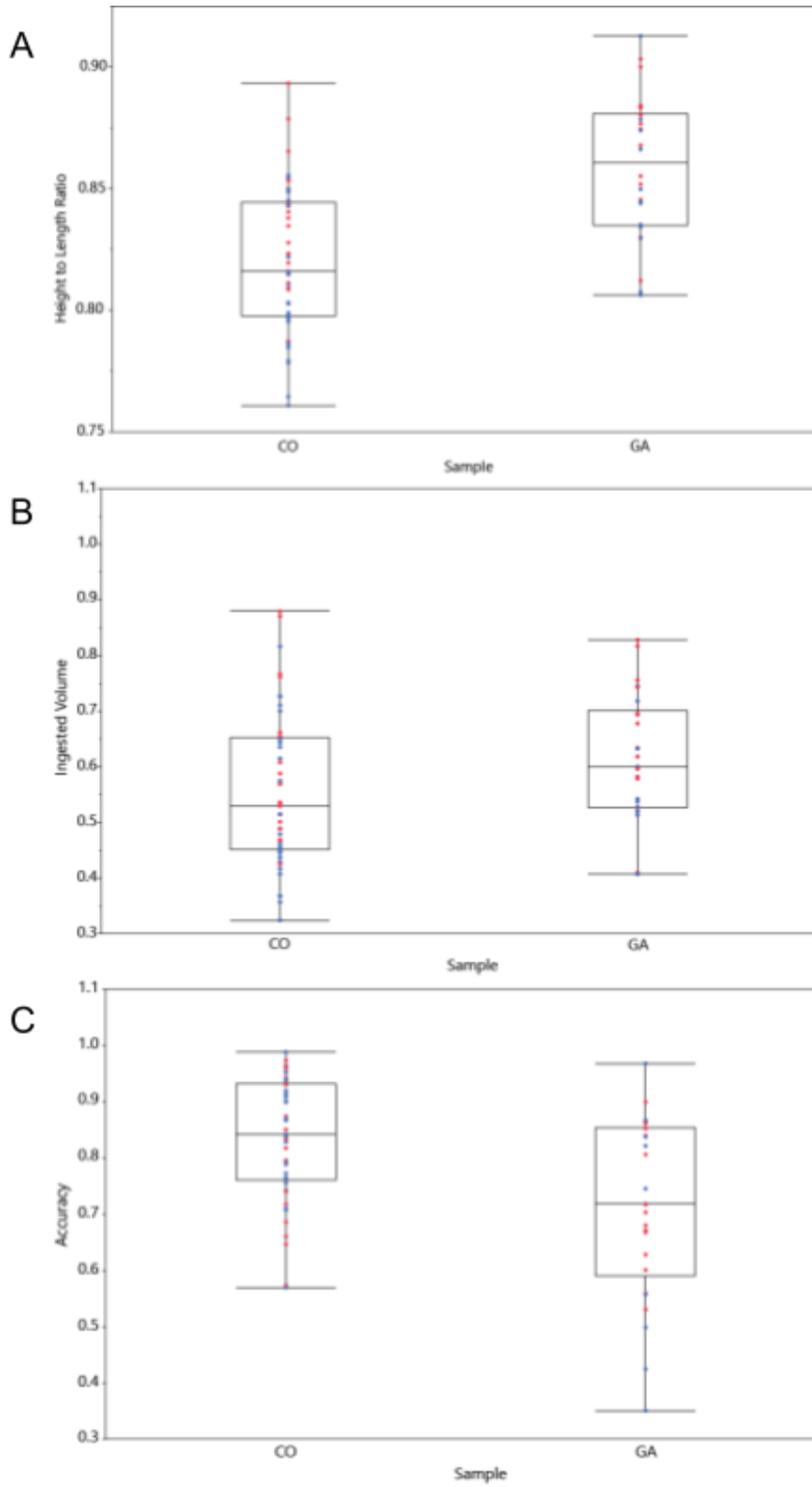


Figure 8. Height to length ratio, ingested volume, and accuracy versus sample.

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