FISHStory Length Analysis: Development of King Mackerel Length Distribution from Historic Photographs

For October 2020 SSC Meeting

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Background

Historic photos from the for-hire recreational fishery are an untapped source of potential biological data for years prior to dedicated catch monitoring programs. FISHstory, the SAFMC's second citizen science pilot project, is developing a standardized protocol for archiving and analyzing historic photos from the 1940s to 1970s from a for-hire fleet based in Florida to document the beginnings of the South Atlantic for-hire fishery and collect data on catch and length composition prior to when dedicated fishery dependent surveys began.

Information in historical photos provides insight into the species composition of the catches and the size of fish that were encountered during a critical period in the development of offshore recreational fishing in the South Atlantic. While most stock assessments of South Atlantic species assume fish stocks were virtually unexploited through the 1950's when consistent monitoring of the commercial fishery began, and only lightly exploited through the 1970's when recreational monitoring began, there is very little information on overall catch or size composition to evaluate these assumptions.

Few fishery-dependent surveys were in existence prior to the 1970s; those that existed were limited in scope and lacked comprehensiveness and continuity. Monitoring of the recreational headboat fishery began in the 1970's in the South Atlantic, and monitoring of private and charter boat fishing began in the early 1980's. To account for the lack of information from the period, stock assessment scientists currently rely on species ratios and measurements from other sectors (i.e., commercial fisheries) as proxies; alternately, modern landings trends are regressed back in time to recreate historical landings. Analyzing historic photos from the for-hire fishery provide a unique opportunity to test these assumptions.

The for-hire fishery (charter and headboats) in the South Atlantic is part of the recreational sector where hired vessels take paying anglers on board their vessels to fish for targeted species. The for-hire fleets have a long-standing tradition of bringing the day's catch back to the dock and displaying fish on a hanging leaderboard with the largest fish hanging on the board and smaller fish displayed in buckets or on the dock underneath the display board. Photos of this nature, while not typically incorporated into current data collection programs, have the potential to provide quantifiable species and length composition data at a point in time when fishery dependent surveys of the for-hire fleet did not exist (McClenachan, 2009). The information in the photographs covers the nascent period of the recreational for-hire marine sport fishing sector along Florida's East Coast, which is widely regarded as a data-poor period for all finfish stock assessments, regardless of species, in the U.S. South Atlantic.

Project Overview

The FISHstory project will develop standardized protocols for compiling, analyzing, and archiving historic for-hire fishing photos in the South Atlantic. Photos for this pilot project were provided by Rusty Hudson and are from his family's fishing fleet in Daytona Beach, FL from the 1940s to 1970s. While the initial geographic scope of the FISHstory project is small, the image analysis methods have a high likelihood of scalability and transferability to multiple agency partners or other regions. If successful, the protocols and techniques developed through this pilot project could be applied to photos from other locations throughout the region. If the crowdsourcing approach is successful, this method could be developed

into a standardized protocol for historic image analysis and shared with other agencies to allow them to analyze other for-hire fleets within the South Atlantic region and even to other regions and other fishery sectors with an archive of historic photos. Fishermen from other locations in the South Atlantic have reached out to Council staff indicating they have similar photos that could be used to expand the project in the future as funding allows.

The FISHstory project has three primary components:

- Digitizing and archiving historic fishing photos
- Analyzing historic photos to estimate for-hire catch composition and effort using crowdsourcing
- Developing a method to estimate length distributions from historic photos

The first component of the pilot project, digitizing and archiving photos, is complete. Over 1300 historic photos have been digitized and archived to date. A photo index was developed to accompany the photos which documents corresponding metadata including date, vessel name, captain, port city, and state.

The initial classification of photos to estimate for-hire catch composition is being done through the online crowdsourcing platform, Zooniverse. The FISHstory project built in Zooniverse trains volunteers to identify and count the fish and people in the photos. The project includes an online tutorial and training materials, so that volunteers who may not be very familiar with fish identification can participate in the project. Within the project, each photo is classified by multiple volunteers. When there is disagreement among volunteers, a Validation Team, comprised of fishermen and scientists will verify species identifications and counts. The FISHstory project launched in Zooniverse in May 2020 and as of September 25, 2020 – just under 1,400 volunteers have participated in the project making over 23,800 classifications. Preliminary analysis of the Zooniverse data is underway and the Validation Team will begin photo verification in the upcoming months.

The third step is developing a length distribution for fish caught in the for-hire fleet and is the focus of this working paper. Fish length is being estimated in the photos using the lumber in the leaderboards as a scale through the open-source software Image J. This pilot project is developing the protocol to measure fish and estimate length distributions from the historic photos and will pilot test these methods on one species, King Mackerel. Methods and preliminary results from the length analyses are detailed below. The SSC is asked to:

- Review the techniques to develop a length distribution from the photographs and discuss the techniques and potential improvements
- Provide feedback on methods to estimate error for the length distribution

Methods

Scalar Development

The scalar to estimate the length of fish from the photographs is crucial to ensure the resulting length distribution is precise and not biased. Six potential scalars (Appendix 1) were examined to estimate the length of boards of known size (n= 49). The scalars ranged in length from 2 7/16 inches to 81 inches. The scalars and boards of known length were photographed using a digital camera and uploaded for two

readers to record the length of the boards and scalars. The readers measured most of the scalars once per photograph. The exception was the 2x3 boards, which were measured three times per photograph and the average length was recorded. The 2x3 was measured more than once because this length could be estimated at different spots in the historic photographs in case the photograph was taken from an angle. Then the nearest scalar could be used to estimate length.

The boards and scalars were measured using ImageJ independently by the two readers. ImageJ reported the number of pixels for each measurement using the line measurement tool. The reader recorded the name of the scalar or board for each measurement. Based on the number of pixels per inch for each scalar, estimates of board length were developed for each board by scalar and reader.

Regressions using the lm package implemented in R were developed for each scalar, and the resulting R^2 and slope were used to select the appropriate scalar.

The most recent update to South Atlantic King Mackerel assessment binned lengths in 50 mm categories (SEDAR 2020). The board lengths were converted to the nearest inch measurement since the acceptable level of precision was 2-inch size bins (Note: will be changed to mm). The average of the 2x3 board scalar (proxy for 2x4 boards) was then tested to determine if differences were observed from the two primary readers. The resulting length estimates were compared using a Kolmogorov-Smirnov (tests the cumulative distribution of the data), pair-t test (tests if differences between observations is 0), and Wilcoxon paired rank sum test (test for independent samples) using the PairedData package implemented in R.

Comparison of Historical Photograph Length Estimates

A training set of photographs was used to compare length estimates among readers using randomly selected photographs in the dataset (see Appendix 2 for example photographs). The lengths from historical photographs were measured by five readers. There were more readers to estimate the lengths from historical photographs due to the number of photographs that needed to be analyzed. All readers were trained in a two-hour training session to learn the measuring process, reporting processing, and ensure accurate identification. Readers were provided a spreadsheet with variables to complete for each photograph and import from ImageJ for King Mackerel to ensure consistency in data entry fields. The dataset includes the scalar with the first three entries for a photograph reserved for scalar measurements, closest scalar for each fish measured, angle of photograph (yes or no), and total number of King Mackerel observed in the photograph.

The total number of lengths measured was compared among readers to check for outliers in number of King Mackerel measured. Readers selected which fish were King Mackerel and which King Mackerel could be measured. This first analysis helped to determine if additional training was necessary.

Lengths from the trained readers were estimated as described above. Line lengths in pixels were measured using ImageJ. Pixels were converted to inch measurements using the ratio of pixel number to scalar length (inches). Each photograph will be measured by at least two readers.

Slight differences in the number of fish measured occurred among readers. Therefore, a paired t test could not be performed on the length analysis. Anderson-Darling and Kolmogorov-Smirnov tests were used to test for significant differences among readers. Visual tests were also conducted using violin plots.

Accuracy of Length Estimates

The accuracy of lengths estimated from historic photographs were tested by estimating the height of an oil barrel and Phyllis Hudson, mate on one of the fishing vessels. The standard oil barrel height has been 34.5 inches since World War II[1]. Phyllis Hudson's height was 64 inches based on her military paperwork. Although the placement of these two known items were not on the leaderboard, the lengths were estimated to get a relative accuracy rate for objects with known heights.

Length Distribution and Error

The length samples were expanded by the ratio of the total number of King Mackerel counted in the photograph compared to the number measured by the reader. If all fish were measured, no expansion was used. The photographs were assumed to be a census of the fleet's trips; therefore, resampling was conducted at the photograph level. Fish lengths observed in the photograph were resampled based on the number of King Mackerel identified by one reader randomly selected. This set the number estimate lengths to estimate and allows for variability in length estimates from the different readers. King Mackerel lengths were counted for each one-inch length bins and summed across photographs. The resampling procedure was run 500 times to estimate the mean and standard error for each length bin.

Results

Scalar Development

- 48 boards lengths and six scalars were measured for a set of test photographs.
- The average 2X3 board scalar had a slope closest to 1 (**Table 1**), indicating little bias in estimating length.
- The largest scalar had the lowest standard error for the slope indicating it had the highest accuracy.
- The larger scalars (41- and 81-inch boards) tended to have slopes closer to 1 and smaller standard error.
- The average width of a 2X4 or 2X6 board is the easiest to measure in the historic photographs along with having a reference for the board width. Other scalars would need to be based on other pieces of information that might not be available or expanded from the 2X4 or 2X6 measurements.
- The average 2X3 board (proxy for 2X4 and 2X6 board) was selected as the preferred scalar due to the ease of measurement, proximity of the regression slope closest to 1, and visually seemed to match best with the true length (**Figure 1**).
- Differences in length estimates (scalar = 2X3 board) were not detected among readers based on the results of Kolmogorov-Smirnov, paired t, Wilcoxon paired rank sum tests (**Table 2**).
- The percent of lengths within two inches was highest with the two largest scalars but the average scalar from the 2X3 board was third (**Table 3**). The three scalars were within 2 inches for greater than 95% of the length measurements.

[1] https://en.wikipedia.org/wiki/Drum_(container)

Table 1. Results of regression analysis comparing true length with predicted length estimated using different scalars. Slope is the resulting slope parameter from the regression with intercept set at 0. SE is the standard error of the slope estimate and Adj R2 is the adjusted R^2 for the regression.

Scalar	True Length (inches)	Slope	SE	Adj R2	Slope Rank	SE Rank
Avg 2x3	2 7/16	0.99288	0.0023	0.9995	1	5
Letter H	3	0.9382	0.0038	0.9984	7	7
SAFMC Logo	5 7/8	0.95737	0.0021	0.9995	5	3
FISHstory Logo	8 1/2	0.95303	0.0022	0.9995	6	4
Wood Vertical	11	0.95765	0.0032	0.9989	4	6
Wood Horizontal*	41	0.97463	0.002	0.9998	3	2
White Board	81	0.97839	0.0016	0.9997	2	1

*Only one analyst measured this scalar

Table 2. Comparison of length estimates (scalar = 2X3 board) for the two primary readers using three different statistical test: Kolmogorov-Smirnov, paired t, and Wilcoxon rank sum tests.

Test	Statistic	p-value
Kolmogorov-Smirnov	.08333	0.9969
Paired T Test	-1.9716	0.05456
Wilcoxon Rank Sum (paired)	88	0.05557

Table 3. Comparison of percent of estimated length measurements within 2 inches of the true length measures for each scalar. Length in inches is in parentheses.

Error from True Length	Avg 2X3 (2 7/16)	Letter H (3)	SAFMC Logo (5 7/8)	FISHstory Logo (8 ½)	Wood Vertical (11)	Wood Horizontal (41)*	White Board (81)
< 2 inches	96%	66%	74%	78%	71%	100%	99%

*Only one analyst measured this scalar

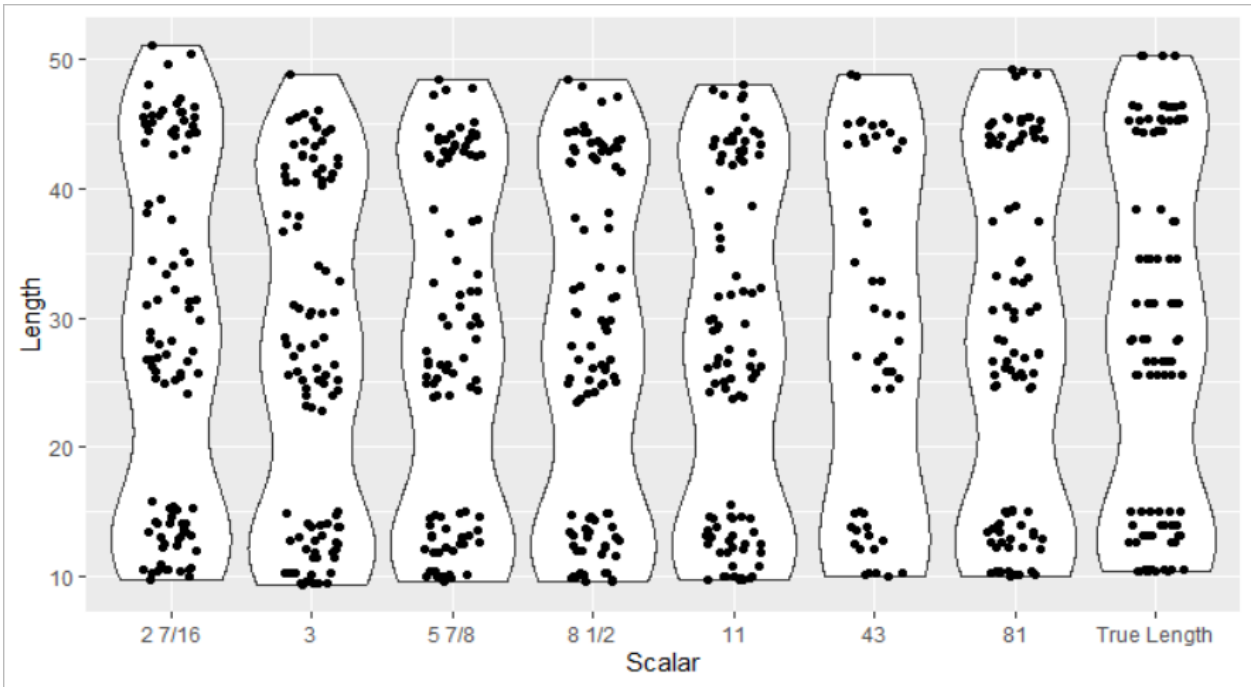

Figure 1. Distribution of board lengths estimated from different scalars compared with the true length.

Comparison of Historical Photograph Length Estimates

- Significant differences were not observed among four of the five readers (**Table 4**, **Figure 2**).
- Analyst 3 was significantly different from three readers.

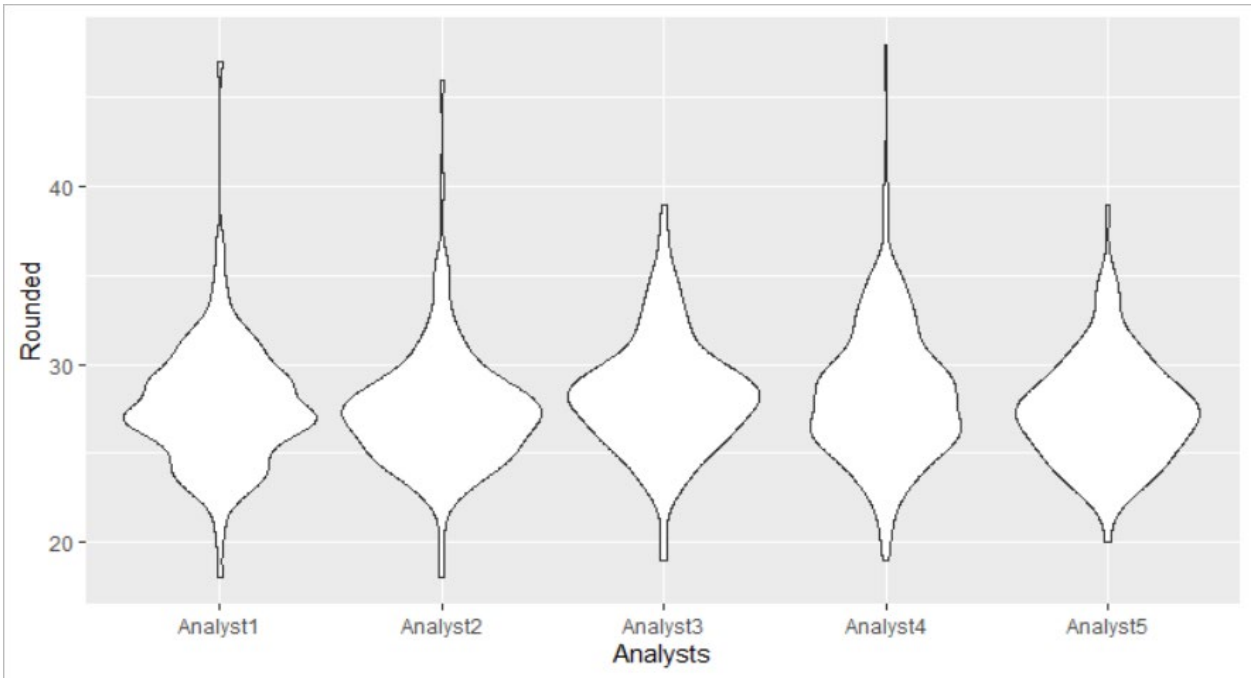

Figure 2. Violin density plots for the lengths estimate for the training dataset.

Table 4. P-values for the Komolgorov-Smirnov (left of diagonal) and Anderson-Darling tests (right of diagonal) used to compare the historical photographs length estimates by the different readers. Yellow indicates significant differences.

KS/AD Test	Analyst 1	Analyst 2	Analyst 3	Analyst 4	Analyst 5
Analyst 1	-	0.547	0.024	0.1119	0.995
Analyst 2	0.5445	-	0.0173	0.053	0.7945
Analyst 3	0.0302	0.0025	-	0.467	0.031
Analyst 4	0.2281	0.0568	0.5061	-	0.0956
Analyst 5	0.995	0.9495	0.0265	0.1436	-

Accuracy of Historical Photographs

Seventy-one percent of the oil barrel measurements (n=49) were within 2 inches of 34.5 inches and 62.5% of the measurement for Phyllis Hudson (n=8) were within 2 inches of 64 inches. Although the accuracy of these measurements was not great, the location of the oil barrels and Phyllis Hudson were often in front of the leaderboard or off to the side which can increase the error in the measurements. All measurements were within 5 inches.

Length Distribution and Error

- Since one reader was significantly different than the rest, resampling was used to incorporate the variation among readers.
- King Mackerel lengths ranged from 18- to 48-inches fork length (**Figure 3**).
- The number of lengths peaked between 26- and 29-inches fork length.
- Error was generally minor with standard error peaking in lengths with the highest number of fish measured.

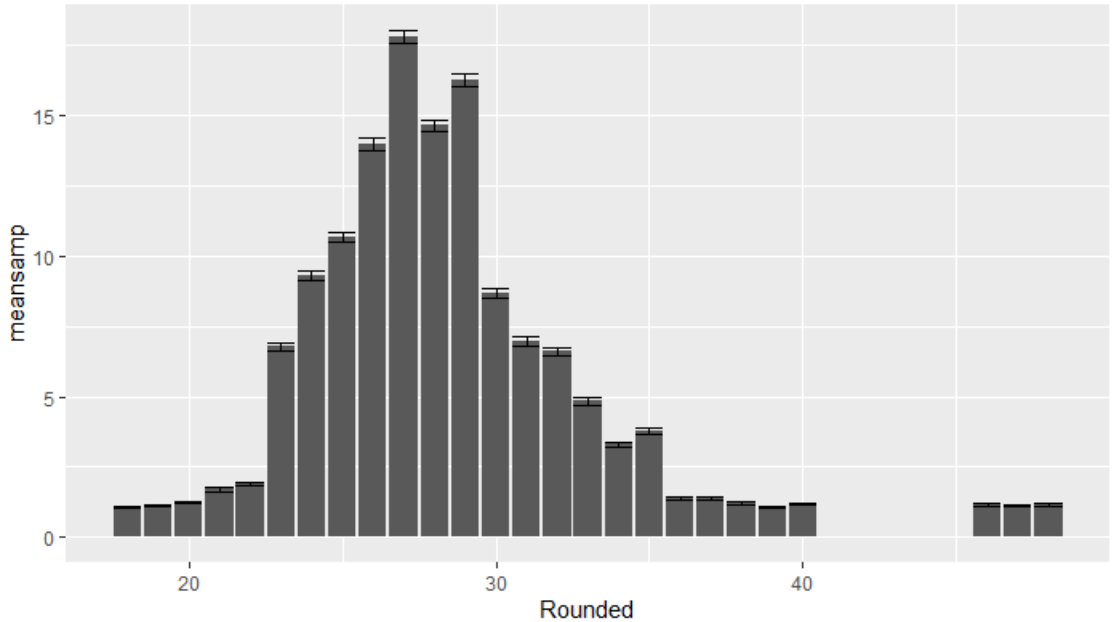

Figure 3. The mean of the resampled length distributions of King Mackerel from the training dataset (n=139 fish). The error bars represent standard error based on the resampling.

Discussion

Scalar Development

The average the of the 2X3 board was the selected as the preferred scalar for developing length estimates.

- The slope in the regression line was closest to 1 indicating minimal bias.
- Based on visual analysis, it best captured the full range of size distributions.
- Length estimates developed by the readers were not significantly different.
- Estimates from the readers were within 2 inches of actual size for 96% of the measured boards.

Length Distribution from Historical Photographs

Significant differences in length estimates were observed among readers. Since there were differences among readers, the reader lengths were resampled to capture potential differences in reader estimates.

The accuracy of objects with known size were estimated with some success. Although the lengths were not all within the 2-inch goal of measuring the oil barrel and Mrs. Hudson, both the oil barrel and Mrs. Hudson were in front of the leader board where the scalar was developed or off to the side where increased refraction could occur. Due to these issues, the accuracy of photographs within two inches seemed confirm that this protocol could get relatively accurate measurements of fish hanging on the leaderboard (see **Appendix 2** for examples).

- All length estimates for oil barrels and Mrs. Hudson were within 5 inches of the true length.
- Most lengths (>60%) were within 2 inches of true length for the oil barrel and Mrs. Hudson.

The length distribution presented represents a preliminary development of a length distribution. This represents 15 photographs of the potential 700 hundred photographs that will be analyzed. The number of photograph should enable annual or bi-annual length distributions to be developed for a historic period when little biological data are available. The maximum estimated fork length from the limited preliminary analysis (48 inches) was within the range annual maximum sizes in SEDAR 38 Update (few fish greater than 47 inches up to a maximum of 63 inches), and peak sizes ranged from 26 to 29 inches which was similar to SEDAR 38 Update (25 to 30 inches fork length).

- Lengths ranged from 18 to 48 inches fork length
- Peak lengths ranged between 26 to 29 inches fork length

SSC Discussion Questions

- Is this methodology appropriate to use for measuring fish in pictures?
- Can an informative size composition of catch be derived using this methodology?
- Does the methodology adequately address uncertainty for the size composition?

References

McClenachan, L. 2009. Documenting Loss of Large Trophy Fish from the Florida Keys with Historical Photographs. *Conservation Biology*. Volume 23. No. 3: 636-643.

SEDAR (Southeast Data, Assessment and Review). 2020. SEDAR 38 Update to South Atlantic King Mackerel Stock Assessment Report. Southeast Data, Assessment and Review, 4055 Faber Place, Ste 201, North Charleston, S.C. 29405. 66 pp. Available at: http://sedarweb.org/docs/suar/SEDAR38_Update_SATL_SAR.pdf

Appendix 1. Scalars used in the selection of a scalar for length analysis.

Appendix 1 Figure 1. Scalars used in the selecting scalar for length analysis

Appendix 1 Table 1. Label name and length of scalars

Label	**G**	**D**	**F**	**B**	**C**	**E**	**A**
Scalar	**Avg 2x3**	**Letter H**	**SAFMC Logo**	**FISHstory Logo**	**Wood Vertical**	**Wood Horizontal***	**White Board**
True Length (inches)	2 7/16	3	5 7/8	8 1/2	11	41	81

Appendix 2. Example photographs from FISHstory

Appendix 2 Figure 1. Example photograph measured in FISHstory. Oil barrel is present in photograph on the right and used to estimate accuracy.

Appendix 2 Figure 2. Example photograph measured in FISHstory. Phyllis Hudson is present in photograph on the right and used to estimate accuracy.

Appendix 2 Figure 3. Example photograph measured in FISHstory. Phyllis Hudson is present in photograph on the left and used to estimate accuracy.

Appendix 2 Figure 4. Example photograph measured in FISHstory. Oil barrel is present in photograph on the right and used to estimate accuracy.