Gulf and Caribbean Research

Volume 7 | Issue 3

January 1983

Multilinear Models for the Prediction of Brown Shrimp Harvest in Mississippi Waters

Frederick C. Sutter III
Gulf Coast Research Laboratory

J.Y. Christmas
Gulf Coast Research Laboratory

Recommended Citation

Sutter, F. C. III and J. Christmas. 1983. Multilinear Models for the Prediction of Brown Shrimp Harvest in Mississippi Waters. Gulf Research Reports 7 (3): 205-210.
Retrieved from https://aquila.usm.edu/gcr/vol7/iss3/2
DOI: https://doi.org/10.18785/grr.0703.02

Gulf Research Reports, Vol. 7, No. 3, 205–210, 1983

MULTILINEAR MODELS FOR THE PREDICTION OF BROWN SHRIMP HARVEST IN MISSISSIPPI WATERS

FREDERICK C. SUTTER III AND J. Y. CHRISTMAS
Section of Fisheries Research, Gulf Coast Research Laboratory, Ocean Springs, Mississippi 39564

ABSTRACT A multilinear regression analysis of water temperature, salinity, and number of postlarval brown shrimp in nursery areas was used to predict the June and July commercial harvest of brown shrimp in Mississippi waters. A total of 80.2% of the variation in harvest was accounted for by this model. When an effort variable was added to the equation, the amount of variation explained by these parameters increased to 85.4%. The coefficients of the two multilinear equations were recalculated exclusive of the data set for the last year to test the predictive capabilities of the models. For that year, the first model showed a percent error of 38.2%, and the second model, 35.3%.

INTRODUCTION

Prediction of commercial brown shrimp harvest from a postlarval index has been used with various degrees of success in several areas of the Gulf of Mexico and Atlantic coasts (Christmas and VanDevender 1981). Williams (1969) tried unsuccessfully to correlate the number of brown shrimp postlarvae and the subsequent commercial harvest in North Carolina. Baxter (1962) and Berry and Baxter (1969) examined the number of postlarval shrimp relative to commercial and bait shrimp harvest in Galveston Bay, Texas; however, a juvenile index gave a better reflection of size of shrimp stocks. St. Amant et al. (1966), and Gaidry and White (1973) also examined postlarval/harvest relationships with mixed success for areas in Louisiana.

Postlarval brown shrimp data from Mississippi waters from the years 1963–1964 and 1971–1976 were examined by Christmas and VanDevender (1981) relative to predicting commercial harvest from Gulf Coast Shrimp Data (U.S. Department of Commerce 1963 et seq.) for areas 11.1, 12.1, and 11.0 (Figure 1). They found a positive correlation between the number of postlarvae and resultant commercial harvest. After 1975, Gulf Coast Shrimp Data statistical areas 11.1 and 12.1 were combined and designated as area 11.1. To avoid confusion, these areas will now be referred to only as Mississippi waters. The samples discussed by Christmas and VanDevender (1981) differed from other studies from the Gulf of Mexico in that their samples of postlarvae were obtained from protected nearshore estuarine areas (or 'nursery' areas) rather than from open passes into the estuary. The results from Mississippi waters may provide a better indication of the number of postlarvae that will survive to harvestable size.

Temperature and salinity have been noted to have an appreciable effect on growth and survival of brown shrimp (Gunter et al. 1964, Zein-Eldin and Aldrich 1965, Christmas and VanDevender 1981). Barrett and Gillespie (1973) also found water temperature had an effect on subsequent brown shrimp harvest in Barataria Bay, Louisiana. In this study, temperature and salinity were examined together with a postlarval index in developing predictive models of the commercial harvest of brown shrimp in Mississippi waters.

MATERIALS AND METHODS

Data Base

Data on number of postlarvae, temperature, and salinity were obtained for 1963–1964 from Christmas et al. (1966), 1966 and 1967 (unpublished data), 1971–1973 from Christmas et al. (1976), and 1973–1981 from an ongoing assessment and monitoring program in Mississippi waters (PL 88–309, Projects 2–215–R and 2–296–R). The beam plankton trawl (BPL) used to collect postlarvae in all of the

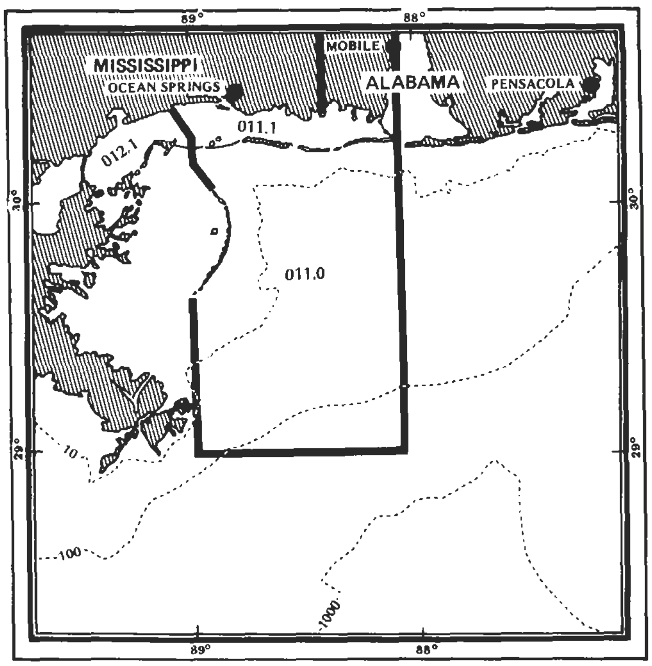

Figure 1. Location of statistical areas used for Gulf Coast Shrimp Data.

Manuscript received April 13, 1983; accepted July 25, 1983.

studies was described by Christmas et al. (1966). Beam plankton trawl samples were taken twice a month at four stations (1, 4, 11, and 13, detailed station description and location in Christmas et al. 1966).

Commercial harvest data of brown shrimp for 1963–1964, 1966–1967, and 1971–1981 were obtained from the Gulf Coast Shrimp Data for June and July in Mississippi waters and summarized in Table 1.

Model Development

Christmas and VanDevender (1981) discussed several relationships between number of postlarvae and commercial harvest in Mississippi waters; however, they did not combine all of these relationships in a single equation. The first step of the present investigation was to define the relationship between these two parameters. Identification of which values were to be used in the calculation of a postlarval index had to be determined. These results were then put in the form of variable definitions. Monthly catch-per-unit-effort values of brown shrimp postlarvae from stations 1, 4, 11, and 13 are shown in Table 2 (for 1963–1964, 1966–1967, and 1971–1981). From these data the following guidelines were established for the calculation of the postlarval index:

1) The average catch-per-unit-effort values for March, April, and May are always included in the calculations;

2) the February CPUE value is included in the index if the mean catch is greater than 5;

3) the June CPUE value is included in the index if the mean catch is greater than 10.

The months of March, April, and May were always used in the calculation of the postlarval index because these were the months of peak abundance of postlarvae in the nursery area. Because postlarvae arrive in some years as early as February and/or continue to be recruited into June, guidelines (2) and (3) were established. For example, using the information from Table 2, the 1981 postlarval index =

$$\frac{(10.8 + 358.0 + 13.0)}{3} = 127.3.$$

The relationship between the postlarval index (X) and commercial harvest in Mississippi waters (Y) was described by a least squares regression analysis. Harvest data were defined as the catch in June and July from Mississippi waters for 1963–1964, 1966–1967, and 1971–1981. For ease in data manipulation, these values were scaled by a divisor of 100,000. The resulting equation was $Y = 0.331 + 0.01X$; $r = 0.81$; $N = 10$. Data from 1967, 1975, 1977, 1979, and 1980 were not included in the regression analysis because of the extremely low catch of brown shrimp postlarvae in these years (less than 60, Table 2) suggesting that for those years, the BPL samples were not representative of the number of postlarvae in the nursery area.

With the relationship between postlarvae and commercial harvest established for all available data, several other predictor variables were examined in an attempt to enhance the predictive capabilities of a brown shrimp commercial harvest model for Mississippi waters. Variables used included:

1) Salinity (X_1). The salinity data used for this variable were obtained at BPL stations 1 and 11 for March, April, and May. These two stations were used because they gave the best indications of inshore nursery conditions in Mississippi waters. This variable was calculated as the average salinity of stations 1 and 11 for March through May (peak months of postlarvae abundance in the nursery area).

2) Interaction index (X_2). Both temperature and salinity are critical to the survival and growth of postlarvae in nursery

TABLE 1.

Number of pounds of brown shrimp caught and number of trips from Mississippi waters during June and July (Gulf Coast Shrimp Data).

	June		July		June & July	
Year	lbs	No. of Trips	lbs	No. of Trips	lbs	No. of Trips
1963	475,286	711.3	330,459	640.0	805,745	1351.3
1964	617,902	972.0	384,799	990.0	1,002,701	1962.0
1966	494,550	--	703,355	2011.0	1,197,905	--
1967	2,085,374	2376.0	806,947	2008.0	2,892,321	4384.0
1971	119,403	324.0	1,667,752	2604.0	1,787,155	2928.0
1972	501,845	851.2	704,832	1366.0	1,206,677	2217.2
1973	199,981	598.0	310,121	1206.0	510,102	1804.0
1974	618,837	971.3	431,925	1351.3	1,050,762	2322.6
1975	366,808	655.0	584,207	1311.0	951,015	1966.0
1976	1,224,605	1665.6	858,623	2329.5	2,088,228	3935.1
1977	2,755,454	2310.8	675,028	1383.1	3,450,482	3693.9
1978	668,982	556.1	261,824	562.3	930,806	1118.1
1979	1,395,295	1751.4	850,213	2343.7	2,245,509	4095.1
1980	696,083	624.1	942,344	1233.5	1,638,427	1857.6
1981	1,201,705	1332.0	393,524	1074.0	1,595,029	2406.0

TABLE 2.

Monthly catch-per-unit-effort values of brown shrimp postlarvae from stations 1, 4, 11, and 13, and respective postlarval index values.

Year	Month					Postlarval index
	February	March	April	May	June	
1963	0.0	64.5	101.5	126.5	163.9	112.8
1964	12.8	157.5	167.8	57.5	121.0	103.8
1966	--	156.2	291.0	68.6	58.8	143.6
1967	13.8	82.5	164.6	4.6	10.9	55.3
1971	2.2	334.2	90.6	2.6	0.2	142.4
1972	4.1	236.2	153.3	33.8	13.4	109.2
1973	3.6	76.9	107.0	51.7	36.0	67.9
1974	7.8	174.9	227.2	40.4	65.8	103.2
1975	24.9	65.4	46.6	10.5	30.4	35.6
1976	5.0	269.5	150.1	50.1	84.6	138.6
1977	7.0	28.1	94.5	47.9	45.0	44.5
1978	0.0	36.9	353.4	105.2	33.3	132.2
1979	1.5	13.2	29.9	37.6	4.4	26.9
1980	1.9	4.5	18.4	27.1	5.2	16.7
1981	0.8	10.8	358.0	13.0	1.8	127.3

areas. The interaction variable was based on temperature and salinity values from stations 1, 4, 11, and 13 in March, April, and May (as a measure of the environmental conditions for postlarvae in Mississippi Sound). In the calculation of this index, the average salinity values from stations 1, 4, 11, and 13 were combined and an overall monthly mean was determined. The resulting value was then multiplied by the average monthly temperature from the same four stations. The products of the monthly mean temperature times mean salinity for March, April, and May were summed.

Example: Interaction Index for 1981

	Months		
	March	April	May
Salinity	21.9	15.0	21.2
Temperature	16.4	24.7	25.0
Salinity x Temperature	359.16	370.50	530.00
			$\Sigma = 1259.76$

3) Postlarval index (X_3). The postlarval index was explained earlier in the text. Values of this parameter were given in Table 2 for 1963, 1964, 1966, 1967, and 1971–1981.

An assigned range of numbers for each index, a value of −1, 0, or 1 depending on how the respective parameter was to be weighted, dampened the variability of the salinity, interaction, and postlarval indices. The following criteria were used:

Salinity index:

a) if the salinity index is greater than 14, then $X_1 = 0$
b) if the salinity index is less than 14, but greater than 9, then $X_1 = 1$
c) if the salinity is less than 9, then $X_1 = -1$

Interaction index:

a) if the interaction index is greater than 900, then $X_2 = 0$
b) if the interaction index is less than 900, but greater than 650, then $X_2 = 1$
c) if the interaction index is less than 650, then $X_2 = -1$

Postlarval index:

a) if the postlarval index is greater than 135, then $X_3 = 1$
b) if the postlarval index is less than 135, but greater than 100, then $X_3 = 0$
c) if the postlarval index is less than 100, but greater than 60, then $X_3 = -1$
d) if the postlarval index is less than 60, then that year was not included in model construction.

RESULTS AND DISCUSSION

A summary of the calculations for the predictor variables is given in Table 3. All values were then transformed according to the outline above. We placed the predictor variables; salinity index (X_1), interaction index (X_2) and postlarval index (X_3) in the form of a multilinear regression equation using the $\log_{10}$ of the June and July commercial harvest of brown shrimp $\times 10^{-5}$ from Mississippi waters as the dependent variable (Tables 2 and 3), giving:

Model 1

$$\log Y = 1.0189 - 0.2336(X_1) + 0.2226(X_2) + 0.2927(X_3)$$

where

$$F_{3,6} = 8.116 \ (p < .05)$$
$$R^2 = 0.802$$
Confidence Interval (95%) = 0.073

This model accounted for 80.2% of the variability of the June and July brown shrimp commercial harvest from Mississippi waters.

Christmas et al. (1966) found a significant correlation ($r = -.8018$, $p < .01$) between fishing effort and catch per 24 hour day of brown shrimp in Mississippi waters. To account for this relationship, we added an effort variable to the multilinear model. The only data available through 1981

TABLE 3.

Summary of the calculations used in the brown shrimp predictive harvest models.

Year	$\log_{10}$ Y Harvest of Mississippi Sound for June + July / 100,000	X_1 Salinity Index	X_2 Interaction Index	X_3 Postlarval Index	X_4 Number of Trips / 1000
1963	0.906	17.1	1451.6	112.8	1.35
1964	1.001	6.4	591.8	103.8	1.96
1966	1.078	10.5	940.4	143.6	2.40
1967	1.461	18.5	910.4	55.3	4.38
1971	1.252	9.0	732.0	142.4	2.93
1972	1.082	14.7	1282.0	109.2	2.21
1973	0.708	6.6	624.7	67.9	1.80
1974	1.021	5.1	624.5	103.2	2.32
1975	0.978	5.4	508.4	35.6	1.97
1976	1.320	11.2	770.7	138.6	3.94
1977	1.535	5.2	552.1	44.5	3.69
1978	0.970	10.0	866.3	132.2	1.12
1979	1.350	2.4	290.3	26.9	4.10
1980	1.214	6.5	692.0	16.7	1.86
1981	1.203	16.8	1259.7	127.3	2.42

that provided some indication of effort were the number of fishing trips as reported in the Gulf Coast Shrimp Data. The number of trips made in Mississippi waters during June and July (X, values divided by 1000 in Table 3) was found to correlate with the commercial yield ($\ln Y \times 10^{-5}$) for the same time frame and area, for 1963–1964, 1967–1968, and 1971–1981. This relationship was described by $\ln Y = 0.663 + 0.185\ X$; $r = 0.84$; $N = 15$.

The number of trips ($x\ 10^{-3}$) was included as another predictor variable (X_4) in the following multilinear regression equation:

Model 2

$$\log Y = 0.8611 - 0.1489\ (X_1) + 0.1653\ (X_2) + 0.1895\ (X_3) + 0.0760\ (X_4)$$

where

$$F_{4,5} = 7.300\ (p < 0.05)$$
$$R^2 = 0.854$$
$$CI_{95} = 0.073$$

The amount of variability explained by the predictor variables increased to 85.4% when the number of trips was included in the model. However, information on the number of trips is not available until after the commercial harvest has already taken place. If a series of effort values were used beforehand to estimate the potential harvest, then the effort variable might increase the value of the model as a resource management tool.

These two multilinear models were then applied to the data used to construct the models, and the results were plotted against actual harvest (Figure 2). Brown shrimp harvest estimates for 1967, 1975, 1977, 1979, and 1980, because they were not included in model construction, were determined by the use of an assigned postlarval index value of 0.

Test of the Multilinear Models

To properly verify the predictive capabilities of the two multilinear regression models, it is necessary to have data that were not used in model construction. Since these additional data were not available, the equations were recalculated after excluding the 1981 data set. The 1981 data (Table 3) employed in these new equations provided an estimate of the June and July harvest of brown shrimp in Mississippi waters for 1981.

Model I: $\log Y = 0.9938 - 0.2253\ (X_1) + 0.2059\ (X_2) + 0.3095\ (X_3)$

where

$$F_{3,5} = 22.469\ (P < 0.005)$$
$$R^2 = 0.931$$
$$CI_{95} = 0.054$$

Model II: $\log Y = 0.8913 - 0.1697\ (X_1) + 0.1693\ (X_2) + 0.2393\ (X_3) + 0.0505\ (X_4)$

where

$$F_{4,4} = 20.99\ (p < 0.01)$$
$$R^2 = 0.954$$
$$CI_{95} = 0.051$$

With these equations, Model I gave an estimate of 0.994 which converts to 986,279 pounds of brown shrimp harvested from Mississippi Sound in June and July 1981. Model II yielded an estimate of $\log Y = 1.014$ (1,032,761 lbs). The actual yield for June and July 1981 was 1,595,879 lbs ($\log Y = 1.203$), which showed the percent error of Model I (after conversion to pounds of harvest) to be 38.2% and Model II, 35.3%.

CONCLUSION

Commercial harvest of brown shrimp can be predicted with some confidence (accounting for 80.2% of the variability)

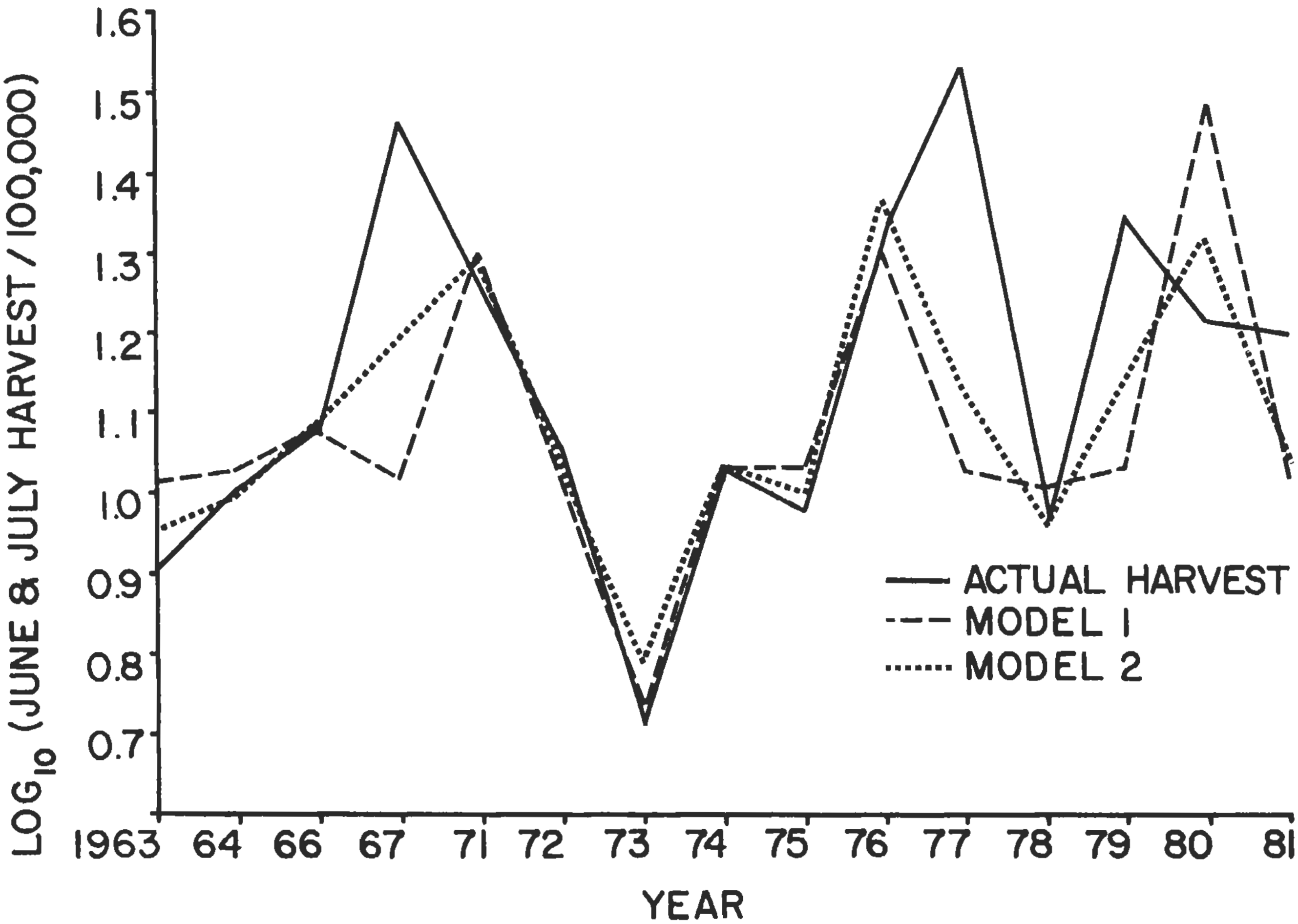

Figure 2. Predicted (Model 1 and 2) and actual June and July harvests of brown shrimp from Mississippi waters.

from indices of temperature, salinity, and number of postlarvae in the nursery ground areas of Mississippi Sound. When the number of trips were added to the first multilinear model as a measure of commercial effort, the amount of variability explained by the predictor variables increased to 85.4%. Although these models are the result of a preliminary study, they do indicate several areas where further work may improve their predictive capabilities. The examination of factors that influence the number of postlarvae, postlarval growth and survival, and evaluation of parameters that affect the nursery ground areas should help to refine the predictive capabilities of the models. Studies of currents, movement patterns of juveniles and adults, and influence of fishing effort should also be addressed. The results of the present investigation indicate that predictive models of brown shrimp harvest in Mississippi Sound may be a practical management tool.

ACKNOWLEDGMENTS

We would like to thank the numerous fisheries personnel who were involved in the collection of samples used in this project. Dr. Thomas McIlwain, Richard Waller, James Warren, and John Supan reviewed and discussed many aspects of this paper. Thanks are accorded to Lucia O'Toole for typing the manuscript.

REFERENCES CITED

Barrett, B. B. & M. C. Gillespie. 1973. Primary factors which influence commercial shrimp production in coastal Louisiana. *La. Wildl. Fish. Comm. Tech. Bull.* 9:1–28.

Baxter, K. N. 1962. Abundance of postlarval shrimp—One index of future shrimping success. *Proc. Gulf Caribb. Fish. Inst.*, Fifteenth Annual Session, November, 1962, pp. 79–87.

Berry, R. J. & K. N. Baxter. 1969. Predicting brown shrimp abundance in the northwestern Gulf of Mexico. *In:* Proceedings of the World Scientific Conference on the Biology and Culture of Shrimps and Prawns, Mexico City, Mexico, 12–21 June 1967. *FAO Fish. Rep.* (57)3:775–798.

Christmas, J. Y., G. Gunter & P. Musgrove. 1966. Studies of annual abundance of postlarval penaeid shrimp in the estuarine waters of Mississippi, as related to subsequent commercial catches.

Gulf Res. Rept. 2(2):177–212.

Christmas, J. Y., W. Langley & T. VanDevender. 1976. Investigations of commercially important penaeid shrimp in Mississippi. Final Report, PL 88–309 Project No. 2–124–R. Gulf Coast Research Laboratory, Ocean Springs, Miss. 66 pp.

Christmas, J. Y. & T. N. VanDevender. 1981. Prediction of shrimp landings from investigations on the abundance of postlarval shrimp. *Kuwait Bull. Mar. Sci.* (2):301–310.

Gaidry, W. J. & C. J. White. 1973. Investigations of commercially important penaeid shrimp in Louisiana estuaries. *La. Wildl. Fish. Comm. Tech. Bull.* 8, 154 pp.

Gunter, G., J. Y. Christmas & R. Killebrew. 1964. Some relations of salinity to population distributions of motile estuarine organisms, with special reference to penaeid shrimp. *Ecology* 45:181–185.

St. Amant, L. S., J. G. Broom & T. B. Ford. 1966. Studies of the brown shrimp, *Penaeus aztecus*, in Barataria Bay, Louisiana, 1962–1965. *Proc. Gulf Caribb. Fish. Inst.*, 18th Ann. Ses. Pp. 1–17.

U. S. Department of Commerce. Gulf Coast Shrimp Data. 1963, 1964, 1966, 1967, 1971–1981. *Nat. Mar. Fish. Serv. Curr. Fish. Stat.* U. S. Dept. Comm., NOAA.

Williams, A. B. 1969. A ten-year study of meroplankton in North Carolina estuaries; Cycles of occurrence among Penaeidean shrimps. *Chesapeake Sci.* 10:36–47.

Zein-Eldin, Z. P. & D. V. Aldrich. 1965. Growth and survival of postlarvae *Penaeus aztecus* under controlled conditions of temperature and salinity. *U.S. Bur. Comm. Fish. Bull.* 205:199–216.