Shrimp Monitoring and Assessment in Alabama[1]

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Abstract: Shrimp (*Penaeus* sp.) at 50 stations throughout Alabama's estuarine area are sampled utilizing 4.9-m otter trawls, a 15.2-m bag seine and 1.8-m beam plankton trawls to monitor abundance and growth. A monthly index is determined for postlarval and juvenile shrimp by species and used each year to estimate relative abundance. A model has been developed to predict the opening day of shrimping season as much as 6 weeks in advance using estimates of brown shrimp (*Penaeus aztecus*) growth. Daily mean numbers of shrimp per pound collected in samples are plotted against time for growth rate estimates.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 36:403–409

The shrimp fishery is the most valuable fishery in Alabama. Management of this resource receives high priority by the Marine Resources Division (MRD) of the Alabama Department of Conservation and Natural Resources. Shrimp are worth approximately $120 million annually to the state's economy. If the associated industries such as ship building, ice plants, transportation, processing, trawl construction and other services are considered, the industry's value probably exceeds $800 million.

Alabama's estuaries lie within the entire Gulf coastline of Mobile and Baldwin counties. The primary estuaries are Mobile Bay, Mississippi Sound and Perdido Bay. All of the estuaries are interconnected naturally or by the Gulf Intracoastal Waterway (GIWW) except Little Lagoon. Alabama's estuaries consist of 158,941 ha of open water area averaging a depth of approximately 3 meters and contains approximately 13,846 ha of marsh (Crance 1971).

Alabama's shrimp resource is composed almost entirely of brown shrimp and white shrimp (*Penaeus setiferus*). Management of Alabama's

[1] This study was made in cooperation with the U.S. Department of Commerce, NOAA, National Marine Fisheries Service under P.L. 88–309 (Project 2–330–R).

shrimp resources involves the assessment and monitoring of shrimp in Alabama's estuarine waters, the determination of shrimp harvest seasons, and establishing permanently closed nursery areas for young shrimp. Brown shrimp and white shrimp are managed in Alabama because of their value to commerce and recreation. Although a biological assessment and monitoring program for shrimp began in 1968, the sampling program was not expanded to its present design until 1977 (Heath 1978).

Shrimp at 50 stations throughout Alabama's estuarine waters are sampled monthly. Supplemental samples are taken during critical management periods. Sample frequency increases to weekly during periods when areas are closed to shrimping in order to closely monitor growth and distribution. Postlarval (<25 mm from tip of rostrum to tip of telson), juvenile and adult shrimp are sampled.

A 1.8-m beam plankton trawl constructed of 0.935-mm aperture mesh is manually towed approximately 130 m over grassbeds or along the edge of marsh to collect postlarval penaeids. Total number of postlarvae of each species per sample is recorded. The monthly total catch of each species is divided by the number of samples taken to obtain a monthly catch per unit effort (CPUE). These monthly CPUE's are compared to previous years' data to obtain a relative estimate of the potential success of the up-coming season.

Juvenile and adult shrimp are collected along shore using a 15.2-m bag seine with 5-mm bar mesh. The seine is pulled approximately 7 m from shore, pivoted 180 degrees and returned to shore. In addition, open water areas are sampled with a 4.9-m otter trawl equipped with a 6.35-mm mesh liner in the bag. The trawl is towed for 10 minutes at each station. Samples are preserved in formalin and returned to the laboratory for analysis.

Shrimp are sorted and up to 50 individuals of each species are measured. Total length, total number and weight are recorded by species. The mean number of shrimp per pound ("count") is determined from all samples collected in 1 day and the data used in growth rate estimates. This mean size is determined by counting all shrimp of a particular species collected on a single day. The total weight is then divided by the total number to obtain a mean number of shrimp per pound. Pounds are used as the unit of measurement because 68 shrimp per pound is the legal size in Alabama and this is the definition accepted and understood by shrimpers. The total number of juvenile and adult shrimp collected per month is divided by the number of seine and trawl samples taken to obtain a monthly index. Monthly indices are compared with previous years' data to predict the relative abundance of harvestable shrimp for the up-coming season.

Bottom water temperature, salinity and dissolved oxygen samples are measured at each station. Temperature is determined with a hand-held ther-

mometer and salinity is measured with a refractometer. Dissolved oxygen is determined using the sulfamic acid modification of the Winkler Method.

Results and Discussion

Assessment and monitoring of postlarval penaeid shrimp has proven very successful as an early indicator of brown shrimp abundance. This is particularly important with brown shrimp which comprise 70% of Alabama's shrimp harvest. The methods are not adaptable to white shrimp monitoring in Alabama because the white shrimp that are found in open areas at less than legal size (68 shrimp per pound heads-on in Alabama) tend to migrate rapidly between open and permanently closed areas subject to tidal and hydrographic conditions. In addition, it is impossible to adequately assess postlarval white shrimp due to the inaccessibility of white shrimp nurseries. The water or mud in these areas is too deep to wade and tow the beam plankton net.

The most useful index for yearly comparison is the peak index of postlarvae which normally occurs in March or April (Table 1). The peak was probably missed in 1977 because assessment began in April 1977. The peak abundance of postlarval brown shrimp in 1979 was delayed until June due to a strong spring flood. There was a strong relationship between postlarval brown shrimp abundance and commercial landings from inshore waters of Alabama during 1978-81 (Table 2). The above average harvest of brown

Table 1. Monthly Catch Per Unit Effort (CPUE) of Postlarval Brown Shrimp from Alabama Estuarine Waters during 1977–81

	Brown Shrimp CPUE				
Month	1977[a]	1978	1979	1980	1981
January		0.0	0.0	0.3	0.0
February		0.0	0.0	0.8	0.0
March		45.5	9.7	9.7	20.2
April	29.0	93.2	4.3	29.2	61.7
May	22.0	42.0	12.4	22.2	21.3
June	40.8	13.7	169.0		7.7
July	36.3	10.7	20.8	6.3	43.3
August	2.3	4.8	14.8	4.7	14.0
September	1.3	13.6		11.2	0.3
October	4.0	5.7	2.5	3.6	0.0
November	6.0	5.7	2.5	3.6	0.0
December	0.0	0.0	0.0	1.3	0.0

[a] Sampling program began in April 1977.

Table 2. Peak Monthly Catch Per Unit Effort (CPUE) of Postlarval Brown Shrimp and Reported Commercial Landings from Alabama Inshore Waters (Department of Commerce, NOAA, pers. commun.)

	Brown Shrimp	
Year	Peak CPUE	Pounds (heads-off)
1978	93.2	1,782,379
1979	169.0	1,897,031
1980	29.2	880,104
1981	61.7	1,131,343

shrimp during 1978 was preceded by a peak index of 93.2 postlarval shrimp per tow. The brown shrimp harvest in 1980 was one of the poorest in several years and was preceded by a peak index of 29.2 postlarval brown shrimp per tow.

When juvenile shrimp begin to appear in samples, the monthly indices are compared with previous years' data to refine the estimate of the upcoming season (Table 3). The reported brown shrimp catch in 1977 was the greatest in many years and the peak index of juvenile brown shrimp was 175.2 per tow in May. In comparison, the 1980 catch was very poor and was preceded by a peak index of 26.0 in July; this peak was much later than in other years due to the effect of severe flood conditions upon the environment of the estuaries (Table 4). The appearance of a peak in abundance of juvenile brown shrimp before the peak in postlarval brown shrimp in 1979 was probably due to spring flooding of that year. However, the flood of 1979 was not as severe as the flood of 1980 and mortality of postlarvae was less in 1979 than 1980. As the flood subsided, a movement of postlarvae toward

Table 3. Monthly Catch Per Unit Effort (CPUE) of Juvenile and Adult Brown Shrimp (*Penaeus aztecus*) from Alabama Estuarine Waters during 1977–81

Month	1977	1978	1979	1980	1981
January		0.0	0.1	0.0	0.1
February		0.0	0.0	0.0	0.2
March		0.0	0.0	0.2	0.1
April	133.6	9.3	7.3	2.2	17.4
May	175.2	55.2	45.0	5.2	52.2
June	72.5	34.8	38.2	19.2	65.1
July	8.4	20.3	17.6	26.0	18.2
August	1.1	2.1	8.0	2.2	2.6
September	3.7	4.3	0.4	0.5	2.2
October	8.1	3.1	3.2	0.1	0.8
November	8.8	1.7	2.5	8.5	0.4
December	10.1	2.5	0.3	3.0	0.3

more traditional nurseries caused an unnaturally high concentration of postlarvae in samples. The lack of a later juvenile brown shrimp peak was probably masked by commercial catch and extended season resulting in a lower catch per sample.

Alabama's estuarine waters are closed to shrimping when shrimp smaller than 68 shrimp per pound heads-on ("count") begin to appear in areas where shrimping normally occurs. This protects the shrimp until they grow to the legal size, at which time the waters are reopened to shrimping. Closure is generally imposed at the end of April or beginning of May based upon shrimp size from field data. The closure may be for all Alabama estuaries or portions as necessary. It is important to the shrimp fishery to receive an accurate estimate of when brown shrimp will reach legal size of 68 per pound.

In 1978, an attempt was made to develop a model using daily mean "count" to predict the opening date of the shrimp season in a given year. The daily mean "count" was determined from all seine and trawl samples on a given day and were compared by sampling day. Day 1 is designated as the first of 2 sample days which indicated shrimp growth. The data were fitted to several regression models. The best fit was found to follow an exponential curve, $y=ae^{bx}$ (y=count, x=sample day, a is intercept, and b=slope or growth rate). The correlation coefficient (R) was 0.99. When data from 1978 were applied to the model, the predicted opening date was June 1. Shrimp collected on May 31, 1978 had a mean "count" of 73 shrimp per pound. The equation predicted that shrimp would be 75 count on that day.

Comparison of related equations based upon different numbers of samples indicated that a prediction could be made based upon 3 mean daily "counts" that was within 1 week of the day predicted by all of that year's spring data (Table 5). This prediction resulted in selecting a premature opening date because the shrimp growth rate declined as legal size was approached. However, as more data were collected, the predicted opening

Table 4. Peak Monthly Catch Per Unit Effort (CPUE) of Juvenile and Adult Brown Shrimp and Commercial Brown Shrimp Landings from Alabama's Inshore Waters (Department of Commerce, NOAA, pers. commun.)

	Brown Shrimp	
Year	Peak CPUE	Pounds (heads-off)
1977	175.2	4,434,507
1978	55.2	1,782,379
1979	45.0	1,897,031
1980	26.0	880,104
1981	65.1	1,131,343

Table 5. Comparison of Prediction of the 1978 Opening Date Based Upon Various Numbers of Daily Average "Counts"

Number of Daily Average "counts"	Sample Dates	Predicted Opening Day	"r" Value
3	4/19, 4/21, 4/25	May 27, 1978	0.98
4	4/19, 4/21, 4/25, 4/26	May 31, 1978	0.99
5	4/19, 4/21, 4/25, 4/26, 4/28	June 2, 1978	1.00
6	4/19, 4/21, 4/25, 4/26, 4/28, 5/2	May 28, 1978	0.99
7	4/19, 4/21, 4/25, 4/26, 4/28, 5/2, 5/9	May 28, 1978	0.99
8	4/19, 4/21, 4/25, 4/26, 4/28, 5/2, 5/9, 5/11	May 26, 1978	0.99
12	4/19, 4/21, 4/25, 4/26, 4/28, 5/2, 5/9, 5/11, 5/17, 5/25, 5/26, 5/31	June 1, 1978	0.99

date was refined. The ability to predict within 1 week the opening day of shrimp season as much as 6 weeks in advance proved extremely valuable because of the increased ability to cooperate with other Gulf States in management procedures and provide timely information to shrimpers to enable them to plan their schedule.

Similar equations were generated for 1979, 1980 and 1981 ($R^2 = 0.97$, 0.93, and 0.97 respectively). These equations were used by administrators to set opening dates for the shrimp seasons in those years. Each year the average size of shrimp was legal or larger on the date predicted by the equation. Based upon these 4 years of data, it appears that barring unforeseen anomalies in shrimp growth or movement, this method of predicting growth rate for brown shrimp and the opening date for the brown shrimp season in Alabama is extremely accurate.

In 1982 the equation predicted an opening date of May 30 and field samples indicated an average size of 77 "count" on May 28, 1982. The equation had earlier predicted 82 "count" on May 28. Immediately prior to opening day of the 1982 season the shrimp "count" increased in the upper reaches of Mobile Bay due to a sudden emigration of large shrimp toward the Gulf of Mexico and small shrimp from the nursery areas. This is a problem that can arise with little or no warning, therefore, samples must be taken immediately before the predicted or proposed opening day to insure continued reliability of the equation. This situation is possible because brown shrimp can spawn over an extended period resulting in an immigration of several waves of postlarval shrimp into nursery areas. These shrimp can begin to emigrate in distinct size groups or a mixture of sizes depending upon environmental conditions in a given year.

The shrimp season in Alabama is set by regulation by the Commissioner of the Alabama Department of Conservation and Natural Resources upon recommendations from the Director of the Marine Resources Division. Equations generated by the method presented here have been used along with other considerations to make recommendations to the Commissioner since 1979. The ability to open the season by regulation provides considerable flexibility in the management of the shrimp resources. Openings and closures can be accomplished quickly which allows management based upon biological data. This allows for accomodation of plan changes when necessary due to anomalies in the environment from year to year such as flooding or unseasonably cool water temperatures. The equation is not used as the end all in management, but simply as a tool to extend the prediction. Adverse conditions in past years have tended to reduce the number of available shrimp rather than reduce the growth rate.

The delays evident in Table 5 between predicted opening dates and actual opening dates were due to cooperative efforts with Mississippi. In recent years, the waters of Alabama and Mississippi have been opened simultaneously to simplify enforcement and provide more area for shrimping. The latter is important because 2000 to 3000 boats work in the Alabama-Mississippi coastal area when the waters open. Though the biological data collected by both states have indicated similar opening dates, Mississippi administrators have chosen a later date for socio-economic reasons. Alabama administrators, after considering all aspects of the situation, felt it was in the best interest of Alabama's fishery to delay the opening to coordinate with Mississippi.

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