STRIPED BASS SPAWNING IN THE ARKANSAS RIVER TRIBUTARY OF KEYSTONE RESERVOIR, OKLAHOMA

DAVID L. COMBS, Oklahoma Department of Wildlife Conservation, 4101 Boston, Muskogee, OK 74401

Abstract: Spawning locations of striped bass (*Morone saxatilis*) were identified over a 118 km reach of the Arkansas River from the collection of 8,828 striped bass eggs during 1976-78. Although certain spawning locations remain constant from year to year others vary significantly within the 118 km stretch of river. Spawning began between 7 and 14 April when water temperature reached 15.5 to 18.5C and had a duration of 27 to 51 days. Spawning peaks occurred annually, generally within a few days from one year to the next. Water temperature, discharge, velocity, total dissolved solids, specific conductance, salinity, pH, alkalinity and dissolved oxygen were monitored, however, no relationship to egg production was found. However, salinity affected egg chorion diameters during the study. Chorion diameters of striped bass eggs in the Arkansas River (1.7 to 2.0 mm) were much smaller than previously reported for striped bass, due to high salinities arresting chorion expansion.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 33: 371-383

Striped bass were introduced into Oklahoma waters in 1965 as an additional sportfish and biological management tool to control overabundant clupeid populations. From 1965 through 1969, 2.75 million striped bass were stocked into Keystone Reservoir resulting in a naturally reproducing population. Natural reproduction was first verified in 1970 (Mensinger 1970) and has occurred for 9 consecutive years in the Arkansas River tributary of Keystone Reservoir.

States containing anadromus and/or freshwater spawning populations of striped bass such as California (Farely 1966, Turner and Farely 1971, Turner 1976), Maryland (Hollis 1962, 1963, 1967; Mansueti and Hollis 1963; Dovel and Edmunds 1971; Johnson and Koo 1975), New York (Rathjen and Miller 1957), North Carolina (McCoy 1959, Fish 1960, Humphries 1965, Kornegay and Humphries 1975, Marshall 1976), South Carolina (Scruggs 1955, May and Fuller 1962), and Virginia (Neal 1967, 1971, 1976) have located spawning areas to insure the maintenance and viability of these areas. In these states, as in Oklahoma, management of the striped bass fishery is dependent upon protection of the spawning areas. The purpose of the study was to determine spawning locations and the range of values of physicochemical parameters required to initiate spawning and to make recommendations on proper water releases from an upstream impoundment to maintain spawning areas and provide suitable spawning conditions. The project was funded through the Federal Aid in Fish Restoration act, Dingell-Johnson Project F-29-R-10, Oklahoma.

MATERIALS AND METHODS

Egg netting techniques utilized were similar to those developed by Mensinger (1971). Collecting nets were conical shaped plankton nets with a mouth diameter of 50 cm, a mesh size of 64 microns, and a length of 160 cm. One quart canning jars were attached to the ends of the nets as collecting bottles.

Egg collections were made just below the water surface at midstream as described by Kornegay and Humphries (1975). Sets were made from bridges and anchored boats. During 1976 and 1977, the primary sampling stations were Blackburn and Ralston Bridges located approximatley 31 and 55 km upstream from Keystone Reservoir (Fig. 1). During 1978, Ralston Bridge constituted the primary sampling site.

Throughout the 3 study years, samples of 5 min duration were made. Sampling was initiated in April when water temperatures reached 15C and was terminated when

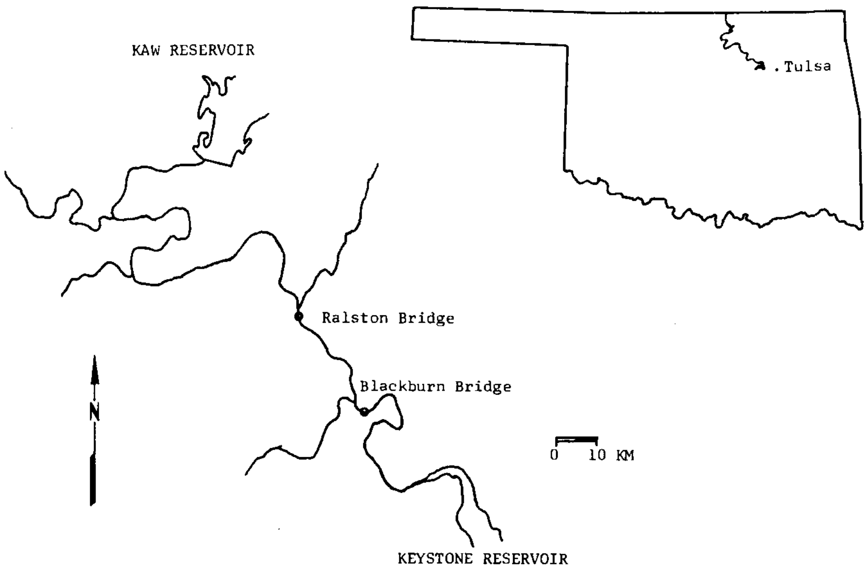

Fig. 1. Egg sampling sites on the Arkansas River tributary of Keystone Reservoir.

temperatures exceeded 24C. the periodicity of egg sampling varied: during 1976 and 1977 daylight samples were taken hourly on sampling days, while in 1978 a systematic 24-h sampling program was initiated. During 1978, egg samples were taken at 3-h intervals on alternate days. Systematic sampling began when striped bass eggs were found in random samples.

Samples taken were immediately strained through an identical mesh net, where eggs could be observed and removed. Eggs recovered were fixed in 10% formalin to halt further development.

Striped bass eggs were identified by the use of descriptions and drawings of Mansueti (1958) and Bayless (1972). Eggs recovered were compared with known striped bass eggs and identified (Jack Harper and Thomas Kingsley personal communication, Oklahoma Dept. Wildlife Conservation, Oklahoma City, Oklahoma). During 1978, eggs recovered and identified as striped bass eggs were hatched and reared to 4 day old fry resulting in positive identification.

Preserved eggs were examined individually under a dissecting scope to determine their developmental stages. Eggs were staged and their ages were estimated with drawings and a nomograph developed by Brown and Hassler (1973).

Spawning location estimates were made by back calculations based on the age of the eggs and their transport rates. Neal (1971) determined egg transport rates to be 80% of the current velocity.The spawning location was then estimated by multiplying the egg's age by the egg transport rate and recorded as that distance upstream from the sampling location.

Spawning intensities were analyzed utilizing egg catches weighted according to water volumes as described by Turner (1976). Statistical comparisons of spawning site distributions within and between spawning seasons were made utilizing chi-square analysis.

Chorion and oil globule diameters of striped bass eggs were measured by use of an ocular micrometer in a dissecting microscope.

During 1976 and 1977, physicochemical water parameters recorded were temperature, current velocity, specific conductance, total dissolved solids, flow, and salinity. Parameters recorded during the systematic survey in 1978 were temperature, dissolved oxygen, pH, specific conductance, total dissolved solids, salinity, flow, alkalinity, and current velocity. Water quality parameters were compared to egg catches in an attempt to determine if any correlation existed between these parameters and spawning intensity.

RESULTS

Striped bass spawning durations, intensities, and locations were made from the capture and identification of 8,828 striped bass eggs from 33.2 h of egg net sampling in the Arkansas River during the 1976, 1977, and 1978 spawning seasons.

During the 3 study seasons, spawning activity on the Arkansas River began within the 1 week period 7 to 14 April. Spawning activity was detected from 7 April to 27 May 1976, from 14 April to 10 May 1977, and from 10 April to 24 May in 1978. Spawning durations ranged from 27 days in 1977 to 51 days in 1976.

Spawning intensities of the weighted catch data showed similar peaks in spawning activity from season to season. During 1976, 2 peaks in spawning activity were noted, occurring on 20 April comprising over 35% of the total egg catches, and on 7 May (Table 1). Three peaks in spawning activity were observed in 1977, occurring on 18, 25, and 30 April. The peaks in 1977 accounted for over 51% of the total egg catches. The 3 spawning peaks observed in 1978 (18 and 24 April, and 10 May) were similar to previous years. Spawning activity occurred during 1976 with over 85% of the weighted catch sampled between 13 April and 7 May (Figure 2). Eighty-one percent of the weighted catch was sampled between 18 and 30 April in 1977 and between 16 April and 10 May in 1978.

Spawning locations were estimated based on the staging of 2,155 eggs in 1976, 2,661 in 1977, and 3,048 in 1978. Spawning locations in 1976 (Table 2) ranged within a 106 km stretch of river from 45 km above Keystone Reservoir to the stilling basin of Kaw Dam located 150 km above the reservoir. The greatest number of eggs recovered from any one location in 1976 (24%) originated in the stilling basin of Kaw Dam. Spawning locations in 1977 ranged from 32 to 150 km above Keystone along 118 river kilometers. The primary spawning area in 1977 was located 58 km above the reservoir and was the source of 23% of all egg catches. During 1978 the primary sampling station was 54 km above the reservoir eliminating any observation of spawning activity below this point. Spawning activity above the sampling site was distributed within an 86 km span of river from 58 to 144 km above Keystone Reservoir. the primary spawning location in 1978 was the same as in 1977 with 23% of the egg catches originating from that section of river.

Chi-square analysis to determine the uniformity of spawning activity within the span of river in which spawning occurred indicated that spawning activity was not uniformly distributed in the river during 1976 ($P < .001$, $X^2_{33} = 8{,}057$), 1977 ($P < .001$, $X^2_{37} = 6{,}714$) or 1978 ($P < .001$, $X^2_{30} = 7{,}140$). Certain spawning locations appeared to remain constant during the study, but analysis showed significant changes in spawning locations for all estimated spawning sites between 1976 and 1977 ($P < .001$, $X^2_{37} = 2{,}746$) and the sites above Ralston Bridge in 1976, 1977, and 1978 ($P < .001$, $X^2_{30} = 5{,}993$).

Physicochemical spawning conditions in the Arkansas River during the 1976-78 spawning seasons are reported in Tables 3 and 4 and Figs. 3 and 4. Coefficients of determination were determined for each physicochemical parameter and combinations of parameters with the number of eggs caught during each sampling period in 1978. the coefficients of determination for all parameters and combinations were extremely low, indicating that the factors measured had little relationship to spawning intensity of striped bass.

TABLE 1. Weighted egg catches from the Arkansas River during 1976, 1977, and 78 spawning seasons.

Date	Number/100m^2			Weighted Catch (%)			Cumulative Weighted Catch (%)		
	1976	1977	1978	1976	1977	1978	1976	1977	1978
April 7	0.24			0.8			0.8		
10			0.01			0.1			0.1
12			0.00			0.0			0.1
13	2.12			7.8			8.6		
14	2.47	0.06	0.14	9.4	0.2	5.5	18.0	0.2	5.6
15	1.92	0.21		7.9	0.8		25.9	1.0	
16	0.80	0.63	0.51	3.4	2.3	11.7	29.3	3.3	17.3
18		2.11	0.94		9.2	18.9		12.5	36.2
20	2.52	0.59	t	35.1	2.4	t	64.4	14.9	36.2
21		1.21			6.0			20.9	
22		0.37	0.02		2.5	0.5		23.4	36.7
23		0.85			7.0			30.4	
24			1.56			22.8			59.2
25		2.38			20.0			50.4	
26		0.26	0.07		2.6	1.0		53.0	60.5
28		1.44	0.33		9.5	3.9		62.5	64.4
29									
30	0.00	3.25	0.08	0.08	22.0	1.0	64.4	84.5	65.4
May 2			0.01			0.1			65.5
3	0.01	0.04		0.2	4.8		64.6	89.3	
4	0.01	0.06	0.00	0.3	0.9	0.0	64.9	90.2	65.5
5	0.00	0.24		0.0	2.8		64.9	93.0	
6	0.28	0.07	0.03	6.1	6.8	0.5	71.0	99.8	66.0
7	0.52			15.2			86.2		
8	0.02		0.12	0.6		5.1	86.8		71.1
10		0.03	0.53		0.2	16.2		100.0	87.3
11	0.16			4.6		91.4			
12						4.5			91.8
3	0.06			1.8			93.2		
14			0.01			0.2			92.0
16			0.20			5.2			97.2
17	0.14			4.3			97.5		
18	0.03		0.02	0.9		0.2	98.4		97.4
19	0.05			1.4			99.8		
20			0.05	t		2.1			99.5
22									
24			0.01			0.3			99.8
27	t			0.1			99.9		

denotes values <0.01

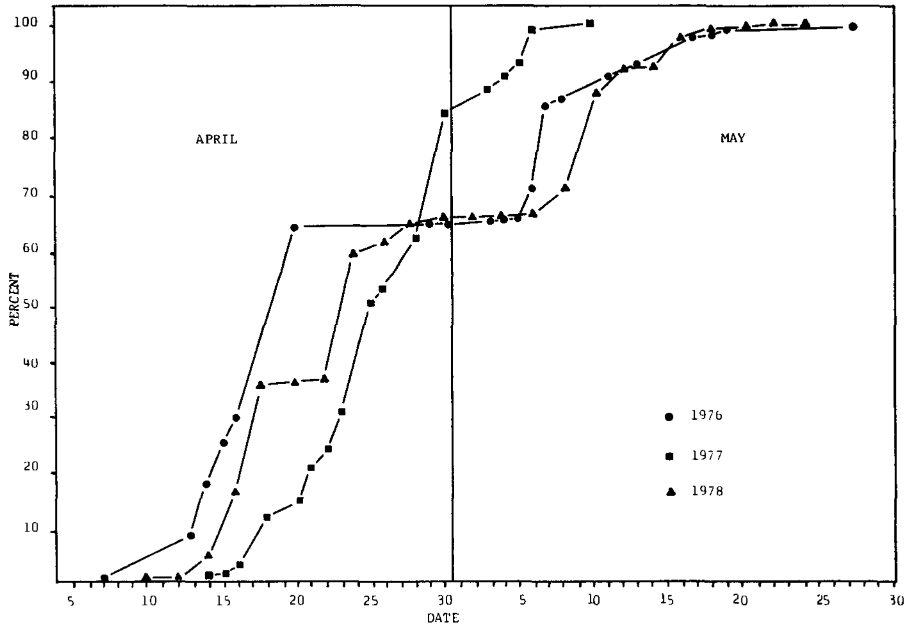

Fig. 2. Cumulative percentage of striped bass spawning by date for 1976, 1977 and 1978 spawning periods on the Arkansas River tributary of Keystone Reservoir.

DISCUSSION

The initiation of spawning activity on the Arkansas River coincides with spawning activity reported in California (Turner 1976), Maryland (Rathjen and Miller 1957), North Carolina (Kornegay and Humphries 1975; Marshall 1976), South Carolina (Scruggs 1955; May and Fuller 1963), and Virginia (Neal 1971, 1976) where spawning activity began in April and terminated in late May to early June.

The initiation of spawning activity and its duration is temperature dependent (Calhoun et. al. 1950, Rathjen and Miller 1957). Spawning activity was first detected when water temperature reached 15.5 to 18.5C from 1976-78. these values are slightly higher than those reported in previous studies. Rathjen and Miller (1957), McCoy (1959), Hollis (1963, 1967), Kornegay and Humphries (1975), Marshall (1976), and Neal (1976) reported that spawning does not begin until temperature reaches approximately 14.4 to 15.6C.

Duration of spawning activity in the present study ranged from 27 to 51 days. Water temperature is influenced by discharges from Kaw Dam. Increased discharges depress river water temperature and allow temperature to rise at a slower rate than during periods of low flow (Figs. 3 and 4). As the temperature rises at a slower rate the critical spawning termination temperature is delayed resulting in a longer spawning season. During the study spawning activity was terminated at 17.0 to 26.5C, which is in general agreement with values reported in previous studies.

Kornegay and Humphries (1975) reported that peaks in the spawning activity on the Tar River coincided with sharp rises in water temperature in 1965. However, in 1975

TABLE 2. Percentage of egg catches back calculated to spawning sites (river kilometers) above Keystone Reservoir during 1976-78.

Spawning Site	1976	1977	1978
32	0.0	0.2	---
35	0.0	0.2	---
38	0.0	3.8	---
42	0.0	2.5	---
45	0.3	2.2	---
48	0.9	0.9	---
51	0.0	2.2	---
54	6.9	2.0	---
58	16.7	23.4	23.3
61	6.4	2.0	0.0
64	0.0	6.3	13.8
67	0.0	1.2	3.9
70	0.0	3.6	1.4
74	0.0	2.1	4.9
77	0.0	3.2	11.8
80	t	4.4	3.6
83	11.2	1.8	2.1
86	0.0	1.4	5.8
90	3.6	10.5	2.6
93	0.5	1.1	7.7
96	0.7	1.3	4.1
99	0.4	8.8	2.5
102	t	0.4	2.2
106	6.6	0.9	1.4
109	0.0	0.3	2.8
112	0.0	0.6	2.5
115	0.2	6.1	1.5
118	0.0	3.5	0.8
122	0.7	0.7	0.1
125	0.0	0.2	0.9
128	0.0	0.2	0.2
131	16.0	0.5	t
134	4.7	0.2	0.0
138	0.2	0.8	0.0
141	0.2	0.1	0.1
144	0.0	0.0	t
147	0.0	0.2	0.0
150	23.8	0.2	0.0

denotes values <0.1%

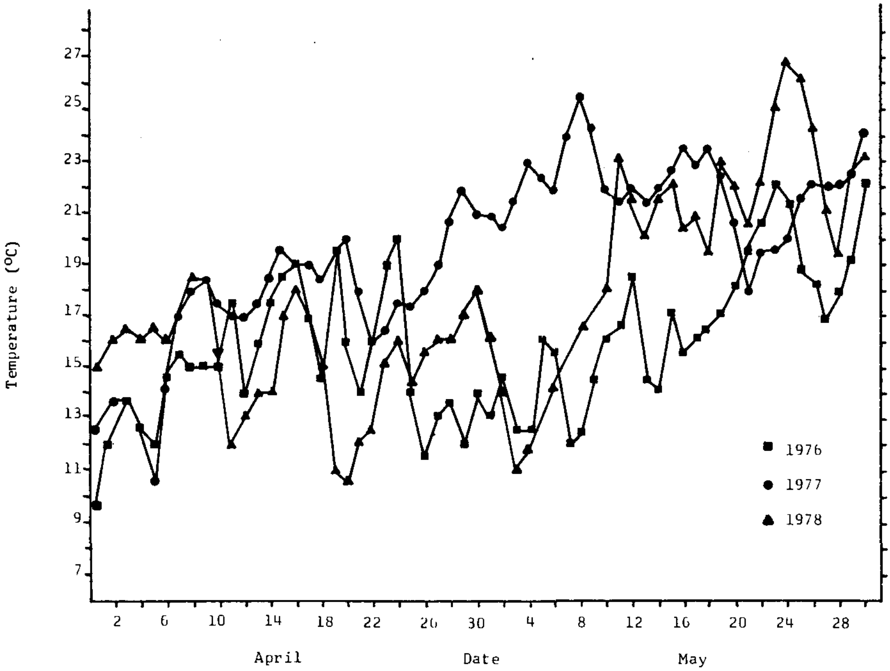

Fig. 3. Mean daily water temperatures (°C) on the Arkansas River during spawning periods from 1976-78.

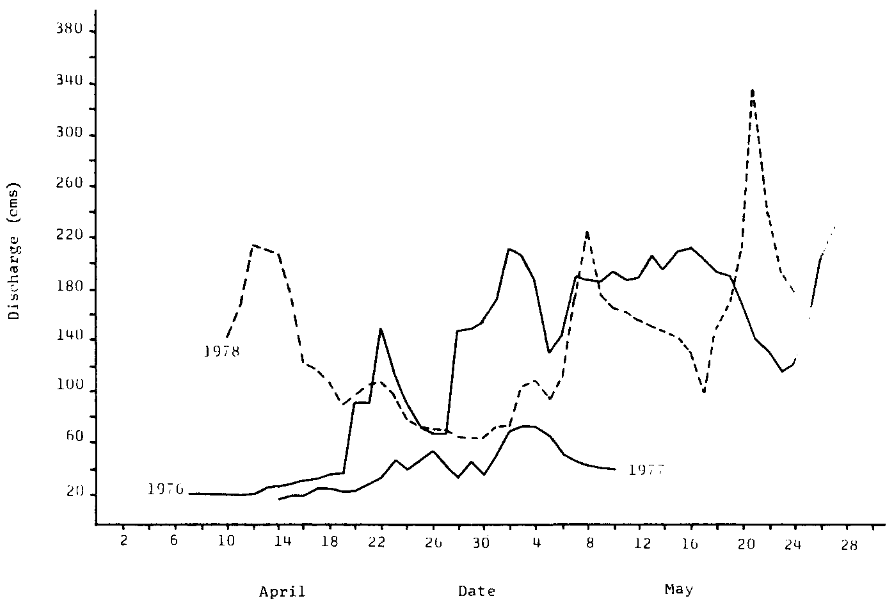

Fig. 4. Mean daily discharge (cms) on the Arkansas River during spawning periods 1976-78.

TABLE 3. Mean daily total dissolved solids (mg/l) on the Arkansas River during 1976, 77 and 78 spawning periods.

Date	1976	1977	1978
April 7	1403	---	---
10	---	---	555
12	---	---	511
13	1300	---	---
14	1282	1219	536
15	1294	1156	---
16	1323	1138	648
18	---	1170	617
20	851	1184	633
21	---	1035	---
22	---	1029	694
23	---	1058	---
24	---	---	733
25	---	966	---
26	---	914	656
28	---	1920	697
30	---	1414	724
May 2	---	---	528
3	673	724	---
4	845	874	303
5	1392	805	---
6	1127	920	424
7	759	---	---
8	834	---	318
10	---	1771	558
11	569	---	---
12	---	---	690
13	644	---	---
14	---	---	691
16	---	---	698
17	684	---	---
18	776	---	635
19	770	---	---
20	---	---	526
22	---	---	---
24	---	---	560
27	440	---	---

TABLE 4. Mean daily Dissolved Oxygen, pH, and alkalinity values recorded during the systematic survey of 1978 on the Arkansas River.

Date	Dissolved Oxygen (mg/l)	pH	Alkalinity (mg/l)
April 10	8.8	7.5	188
12	9.5	7.7	153
14	9.6	8.2	169
16	9.6	8.4	170
18	9.9	8.3	171
20	10.4	8.1	154
22	10.7	8.5	176
24	10.3	8.4	178
26	10.9	8.5	181
28	10.0	8.4	174
30	9.5	8.3	170
May 2	10.2	8.1	190
4	10.9	8.1	158
6	9.9	7.3	175
8	8.6	7.4	159
10	8.8	8.0	171
12	8.4	8.4	181
14	9.6	8.4	176
16	9.0	8.4	182
18	7.8	8.2	188
20	8.1	7.7	156
22	---	---	---
24	10.1	7.7	185

peaks were correlated with rises in water. Neal (1976) suggested that gradually rising or falling discharges accompanied by stable water temperature created peak spawning activities. Although the present study showed peaks in spawning activity during each year, these peaks could not be correlated with either water temperature or discharge. Decreases of spawning intensity were observed during 1976 and 1978 with decreases in water temperature. In 1976 spawning activity was extremely low or halted from 29 April to 6 May (0.5% of catch), a period when temperature ranged from 12 to 16C (Table 1 and Fig. 3). In 1978 spawning was interrupted from 20 to 22 April and again from 2 to 6 May. During these periods temperature ranged from 10.5 to 12.5C and 11.0 to 14.2C respectively (Table 1 and Fig. 3). Spawning activity during both seasons began again when mean daily water temperature reached 15 to 16C. Hollis (1967) and Marshall (1976) also observed that drops in water temperature interrupted spawning activity. Marshall (1976) stated that temperature decreasing to 12C coincided with termination of egg catches until temperatures rewarmed to 16C.

Striped bass showed a preference for certain spawning locations on the Arkansas River. Studies by Chadwick (1967) and Kornegay and Humphries (1975) indicate that striped bass spawning areas tend to remain constant. Other studies have stated that spawning locations may vary depending upon the physical conditions of the river; Calhoun et. al. (1950) and Farely (1966) stated that spawning locations were dependent upon temperature and discharge, while Radtke and Turner (1976) and Farely (1966) found that spawning locations were related to concentrations of dissolved solids. The variation in spawning locations during the present study suggests a dependency upon discharge. The Arkansas River is characterized by shallow sand and gravel flats which can effectively impede spawning migration during low flow periods as in 1977 (Fig. 4). The mean spawning location in 1977 was 70 km above Keystone Reservoir. During seasons of high flow spawning locations are determined by the pattern of discharge. The discharge pattern in 1976 was one of continual increase allowing major spawning concentrations to migrate 150 km to Kaw Dam. The mean spawning location in 1976 was 103 km above Keystone Reservoir. In 1978 the discharge pattern showed a continual decrease through a major portion of the season to a point simulating the low flow periods of 1977 prior to increased flows. The mean spawning location in 1978 was 77 km above Keystone Reservoir. Concentrations of total dissolved solids apparently affect the spawning locations of striped bass in the Arkansas River to a lesser extent than in California waters. Total dissolved solids of the Arkansas River (Table 3) ranged from 303 to 1920 mg/l, which were above the reported dissolved solid block of 300 mg/l by Radtke and Turner (1967) in California. Striped bass in the Arkansas River apparently penetrate high concentrations of dissolved solids to reach spawning locations and achieve successful spawns.

The spawning success at certain spawning locations was affected by the velocity of the river. Albrecht (1964) reported that a current velocity of 0.305 m/sec was required to keep eggs in suspension. River velocities during the 1976-78 spawning seasons ranged from 0.503 to 0.725 m/sec in 1976, 0.500 to 0.573 m/sec in 1977, and 0.558 to 0.835 m/sec in 1978. The spawning velocities during the present study were well above the required minimum as reported by Albrecht. The minimum distance above Keystone needed to allow for hatching was computed at 72 km in 1976, 60 km in 1977, and 74 km in 1978. The percentage of eggs recovered that had a suitable length of flowing water to hatch during 1976, 1977, and 1978 spawning seasons were 69%, 63%, and 58% respectively. Flow rates or discharge must be suitable to allow for striped bass migration into the upper areas of the river and allow for suspension of the eggs, but at higher velocities the flow may be detrimental by carrying eggs out of the river into slack water prior to hatching. The portion of the Arkansas River providing successful reproduction is dependent upon river velocity from year to year.

Spawning habitat of striped bass has been characterized by Fish (1960), Mansueti and Hollis (1963), and Kornegay and Humphries (1975) as swift turbulent waters flowing over a rocky substrate. The Arkansas River normally has a swift flow during the spawning season over a substrate of fine gravel with rock riffles through much of the river. The river flow over these rock ledges and riffles as well as artifically created habitat such as abandoned bridge pilings and car body revetments create suitable turbulence to allow spawning.

Of the physicochemical parameters monitored during the study only salinity showed any effect on striped bass eggs. Albrecht (1964) reported that the survival of eggs is best in slightly saline waters (0.95 g/l). The mean salinities reported during the study approached Albrecht's values for optimum hatching success (Table 5). Salinity affected the size of striped bass eggs found in the study. Striped bass eggs in freshwater range in size from 2.4 to 3.9 mm (Mansueti 1958), 3.2 to 3.8 mm (Pearson 1939) and 3.2 to 4.0 mm (Merriman 1941) in diameter. Striped bass eggs from the Arkansas River ranged from 1.7 to 2.0 mm in diameter. Mansueti (1958) stated that abnormal egg sizes may be due to high salinities which arrest chorion expansion of the egg. Abnormal egg sizes in the Arkansas River are probably due to this phenomenon.

TABLE 5. Mean daily salinities (g/l) during sampling period from 1976-78 on the Arkansas River.

Date	Salinity	Date	Salinity	Date	Salinity
April 7	---	April 14	1.0	April 10	0.5
13	---	15	1.0	12	0.3
14	---	16	1.0	14	0.5
15	---	18	0.9	16	0.5
16	---	20	1.0	18	0.6
20	---	21	0.9	20	0.6
29	0.9	22	---	22	0.6
30	1.2	23	---	24	0.7
May 3	0.9	25	---	26	0.6
4	0.9	26	0.8	28	0.6
5	1.2	38	1.5	30	0.7
6	1.5	30	---	2	0.4
7	0.9	May 3	---	4	0.1
8	0.9	4	0.5	6	0.2
11	0.7	5	0.5	8	0.1
13	0.8	6	0.6	10	0.4
17	0.8	10	1.9	12	0.6
18	0.9			14	1.6
19	0.8			16	0.6
27	---			18	0.5
				20	0.2
				22	---
				24	0.3

LITERATURE CITED

Albrecht, A.B. 1964. Some observations on factors associated with survival of striped bass eggs and larvae. Calif. Fish and Game. 50:100-113.

Bayless, J.D. 1972. Artificial propagation and hybridization of striped bass *Morone saxatilis* (Walbaum). S.C. Wildl. and Mar. Res. Dept 135 p.

Brown J.T., and W.W. Hassler. 1973. A nomograph for age determination of striped bass (*Morone saxatilis*). Tech. Publ. No. 1, Nat. Mar. Fish. Service, Mid-Atlantic Coast Fish. p. 66.

Calhoun, A.J., C.A. Woodhull, and W.C. Johnson. 1950. Striped bass reproduction in the Sacramento River system in 1948. Calif. Fish and Game. 36:135-145.

Chadwick, H.K. 1967. Recent migrations of the Sacramento-San Joaquin River striped bass population. Trans. Am. Fish. Soc. 96:327-342.

Dovel, W.L., and J.R. Edmund, IV. 1971. Recent changes in striped bass (*Morone saxatilis*) spawning sites and commercial fishing areas in upper Chesapeake Bay; possible influencing factors. Ches. Sci. 12:33-39.

Farely, T.C. 1966. Striped bass spawning in the Sacramento-San Joaquin River system during 1963 and 1964. Calif. Dept. Fish and Game, Fish. Bull. 136:28-43.

Fish, F.F. 1960. the minimum river discharges recommended for the protection of the Roanoke River anadromus fishes. N.C. Wildl. Res. Comm., Raleigh, N.C. 51 p.

Hollis, E.H. 1962. A study of the spawning of striped bass. Maryland Dept. Game inland Fish. D.J. Project F-3-R-8, Performance Report, Job 3. 13 p.

______________. 1963. A study of the spawning of striped bass. Maryland Dept. Gáme Inland Fish. D.J. Project F-3-R-9, Job Completion Report, Job 3. 12 p.

______________.1967. An investigation of striped bass in Maryland. Maryland Dept. Game Inland Fish. D.J. Project F-3-R Job Completion Report. 56 p.

Humphries, E.T. 1966. Spawning grounds of the striped bass in the Tar River, North Carolina. Unpublished M.S. Thesis, East Carolina University, Greenville, N.C. 50 p.

Johnson, R.K., and T.S. Koo. 1975. Production and distribution of striped bass (*Morone saxatilis*) eggs in the Chesapeake and Delaware Canal. Ches. Sci. 6:39-55.

Kornegay, J.W., and E.T. Humphries. 1975. Spawning of the striped bass in the Tar River North Carolina. Proc. Annu. Conf. Southeast Assoc. Game Fish Comm. 29:317-325.

Mansueti, R.J. 1958. Eggs, larvae and young of the year striped bass, *Roccus saxatilis*. Md. Res. and Educ. Contrib. 112:1-35.

______________ and E.H. Hollis. 1963. Striped bass in Maryland tidewater. Nat. Res. Inst., Solomons, Md. Educ. Ser. No. 41:28 p.

Marshall, M.D. 1976. Anadromus fisheries research program Tar River, Pamlico River and Northern Pamlico Sound. N.C. LDiv. of Mar. Fish., Job Completion Report, AFCS-10. 90 p.

May, O.D., Jr., and J.C. Fuller, Jr. 1962. A study on striped bass egg production in the Congaree and Wateree Rivers. Proc. Annu. Conf. Southeast Assoc. Game Fish Comm. 16:285-301.

McCoy, E.G. 1959. Quantitative sampling of striped bass, *Roccus saxatilis* (Walbaum), eggs in the Roanoke River, North Carolina. Unpublished M.S. Thesis North Carolina State University, Raleigh, N.D. 136 p.

Mensinger, G.C. 1970. Observations on the striped bass, *Morone saxatilis*, in Keystone Reservoir, Oklahoma. Proc. Annu. Conf. Southeast Assoc. Game Fish Comm. 11:253-264.

Mensinger, G.C. 1971. Striped bass research study status of introduction. Oklahoma Det. Wildl. Cons. D.J. Project F-29-R, Job Progress Report, Job 1. 13 p.

Merriman, D. 1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic Coast. Fish. Bull. No. 35, U.S. Fish and Wildlife Service, 50:1-77.

Neal, W.E. 1967. Striped bass study. Virginia Comm. Game Inland Fish. D.J. Project F-5-R-12, Job Completion Report, Job 5. 68. p.

______________. 1971. Striped bass survey, Virginia Comm. Game Inland Fish. D.J. Project F-19-R-1, Progress Report, Job 8. 23 p.

______________. 1976. Landlocked striped bass survey. Virginia Comm. LGame Inland Fish. D.J. Project F-19-R, Project Completion Report. 35 p.

Pearson, J.C. 1938. The life history of the striped bass or rockfish, *Roccus saxatilis* (Walbaum). Bull. U.S. Bur. Fish. 49(20):825-851.

Radtke, L.D., and J.L.Turner. 1967. High concentrations of total dissolved solids block spawning migration of striped bass, Roccus saxatilis, in the San Joaquin River, California. Trans. Am. Fish. Soc. 96:405-407.

Rathjen, W.F., and L.C. Miller. 1957. Aspects of the early life history of the striped bass (*Roccus saxatilis*) in the Hudson River. N.Y. Fish and Game 4:43-60.

Scruggs, G.D., Jr. 1955. Reproduction of resident striped bass in Santee-Cooper Reservoir, South Carolina. Trans. Am. Fish. Soc. 85:144-159.

Turner, J.L., and T.C.Farely. 1971. Effects of temperature, salinity, and dissolved oxygen on the survival of striped bass eggs and larvae. Calif. Fish. and Game. 57:268-273.

Turner, J.L. 1976. Striped bass spawning in the Sacramento and San Joaquin Rivers in central California from 1963 to 1972. Calif. Fish and Game. 62:106-118.