SPP 22

Creel Survey and Biological Study of the Striped Bass Fishery of the Annapolis River, 1978

B. M. Jessop

Freshwater and Anadromous Division
Resource Branch
Department of Fisheries and Oceans
Halifax, Nova Scotia

April, 1980

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1566

Government of Canada Fisheries and Oceans
Gouvernement du Canada Pêches et Océans

Canadian Manuscript Report of Fisheries and Aquatic Sciences

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CREEL SURVEY AND BIOLOGICAL STUDY OF THE STRIPED BASS FISHERY OF THE ANNAPOLIS RIVER, 1978

B.M. Jessop

Freshwater and Anadromous Division
Resource Branch
Department of Fisheries and Oceans
Halifax, Nova Scotia
B3J 2S7

Cat. No. Fs 97-4/1566 ISSN 0706-6473

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The 1978 creel and biological survey of the striped bass angling fishery of the Annapolis River continued previous efforts to evaluate the status of the stock. A stratified, random-sampling design was employed in the creel survey to estimate total catch and effort at major fishing sites during the period May 15-September 8. Parameters such as angler origin, bait used, and shore vs. boat fishing were also examined.

At the upriver sites, total fishing catch and effort by shore-based anglers was estimated at 65±46 fish (±2 S.E.) and 653±322 hours, while at the causeway it was 116±29 fish and 5,618±311 hours. A statistical check for internal consistency of the data indicated good credibility of the estimates.

The age-structure, length and weight composition, and sex ratio were determined for the stock of angled fish. Comparison of these and other parameters with data from previous surveys indicated a progressive ageing and declining abundance of the stock. These factors, coupled with the evident failure of reproduction since about 1971, do not bode well for the future success of the sport fishery or the stock. Possible causes of the reproductive failure are discussed.

Key words: Creel survey, biological study, striped bass, Nova Scotia.

RÉSUMÉ

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L'étude biologique effectuée en 1978 sur les bars d'Amérique capturés à la ligne dans la rivière Annapolis est le prolongement d'essais antérieurs visant à évaluer la situation de la population. Pour cette étude, on a utilisé une méthode d'échantillonnage stratifié et au hasard afin d'évaluer la prise totale et l'effort fourni aux principaux endroits où cette pêche se pratique durant la période qui va du 15 mai au 8 septembre. On a aussi analysé des paramètres comme l'origine du pêcheur, l'appât utilisé, et la pêche de plage par rapport à la pêche de bateau.

Aux endroits situés en amont, la prise totale en poissons et le temps exigé du pêcheur étaient évalués à 65±46 poissons (±2 S.E.) et 653±322 heures, tandis qu'à la digue, les résultats étaient de 116±29 poissons et 5,618±311 heures. La vérification statistique relative à l'uniformité interne des données indiquait la vraisemblance de ces calculs.

On a déterminé la composition par âge, la longueur et le poids, de même que la proportion des sexes pour les poissons pêchés à la ligne. La comparaison de ces renseignements et ainsi que d'autres paramètres avec les données tirées d'études antérieures démontrent qu'il y a vieillissement progressif et réduction de la population. Tous ces éléments alliés à l'échec évident de la reproduction depuis 1971 environ, n'augurent rien de bon pour le succès de la pêche sportive ou pour la population de poissons. On discute des causes probables de l'échec de la reproduction.

Mots clès: enquête de pêche, étude biologique, bar d'Amérique, Nouvelle-Écosse.

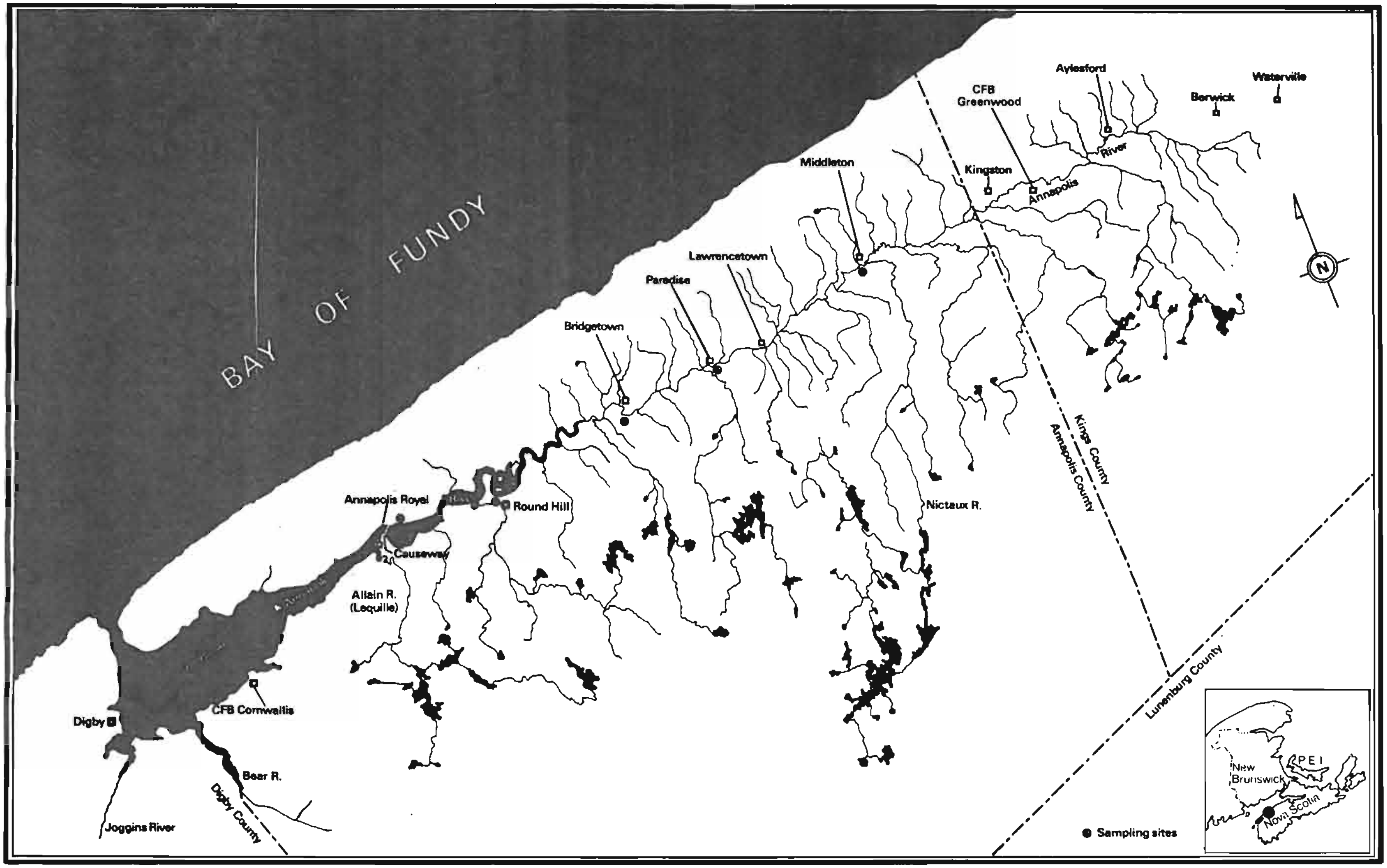

FIG. 1. Annapolis River system, Nova Scotia.

INTRODUCTION

Angling for striped bass *(Morone saxatilis)* continues as an important recreation in the lower Annapolis River valley (Fig. 1). Previous creel surveys (Jessop and Doubleday 1976; Jessop and Vithayasai 1979) have provided information on the angling catch and effort, fishing methods, location and season of capture, and biology of the stock. Detailed information on the timing, location and success of spawning is given by Williams (1978).

One consequence of these studies was the 1977 closure on angling for striped bass in that portion of the river between a point approximately 4 km upstream of the causeway and the Lawrencetown bridge during the period April 1-June 30. The closure first came into effect on June 5, 1977, and undoubtedly was instrumental in the greatly increased egg deposition observed that year (Williams 1978). However, local angler opposition to the closure resulted in a regulation revision, reducing the closed area as of May 5, 1978, to that stretch of river between Hebb's Landing (about 9 km downstream from Bridgetown) and the Lawrencetown bridge. The daily bag limit was also reduced from five to two fish.

The two principle objectives of this study were the conduct of a creel survey to estimate the total catch and effort of the striped bass angling fishery on the lower Annapolis River between May 15 and September 8, 1978, and to collect life-history data from the catch for comparison with the data of previous years, in evaluation of the status of the population.

DESCRIPTION OF STUDY AREA

The Annapolis River flows southwest and empties into the Annapolis Basin in southwestern Nova Scotia (Fig. 1). Digby Gut connects the Basin to the Bay of Fundy. The main stem of the river is approximately 142 km long and drains an area of 2,130 km^2.

A causeway at Annapolis Royal limits upstream tidal fluctuation but permits free passage of fish. The river above the causeway is an extensive, highly stratified estuary, with a wedge of saline water overlain by outflowing low-salinity water (Jessop 1976). Saline water extends to about 2 km above Bridgetown during the summer, while the head of tide is located near Paradise, about 39 river km above Annapolis Royal.

Much of the Annapolis Valley is cultivated – mainly mixed farming and fruit orchards. Soils in the valley and on the bordering mountains are mainly tills, containing high amounts of clay and silt derived from shale and sandstone (Smitheringale 1973). Additional descriptive details may be found in Jessop and Doubleday (1976).

METHODS

Statistical Methods

The creel survey involved sampling all major fishing areas for systematic variation in fishing catch and effort with time, utilizing a two-stage, random sampling design. The target populations consisted of the striped bass sport fishery at two upriver locations (Round Hill and Tupper Brook) during the period 0700-2100 hours, May 16-June 30, and at the causeway during the period 0500-2300 hours, May 15-September 15 (Fig. 2). From May 16 to May 18, the Hebb's Landing site was sampled instead of Round Hill; beginning May 23, Hebb's Landing was combined with Tupper Brook, since both could be observed together, and Round Hill was added. At the upriver sites, sampling was conducted on three randomly selected days per week (sampling rate 3/7), while at the causeway,

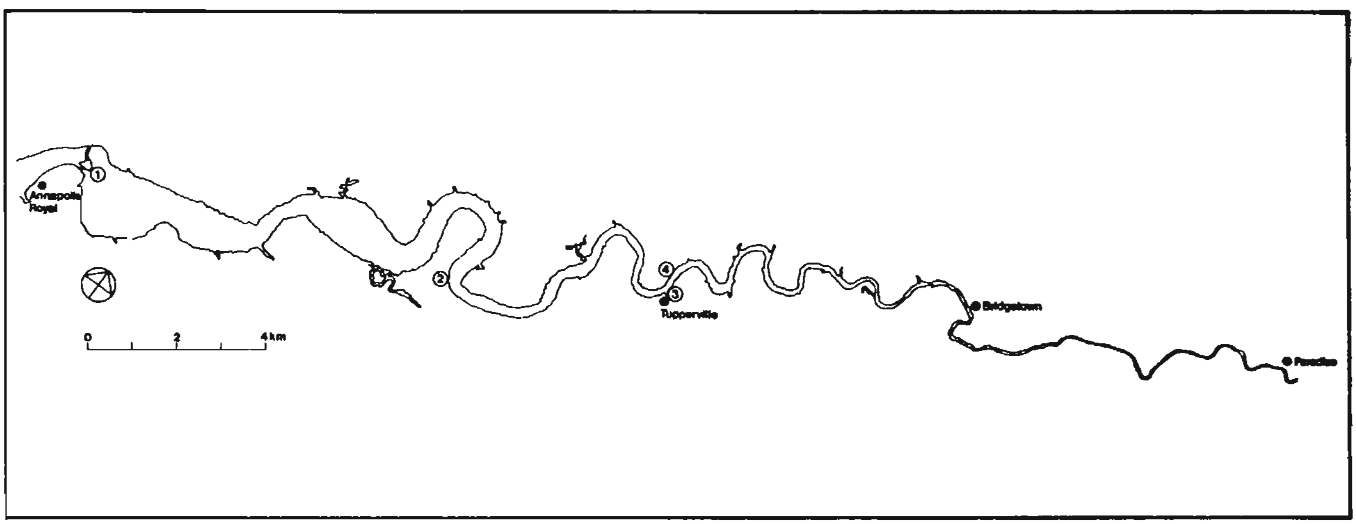

FIG. 2. Creel survey area and sampling sites, Annapolis River.

sampling was conducted every day. No distinction was made between weekdays and weekends or holidays at the upriver sites. Each day was divided into nine sampling units (seven at upriver sites) consisting of two-hour time periods, of which four were randomly selected for interviewing. The sampling schedules for upriver and causeway sites were independently derived.

Randomization of area-time pairs was achieved by coding separately each time interval and location, then matching the codes with numbers drawn from tables of random premutations of nine numbers (Cochran and Cox 1957). The randomized lists of time and location were then paired by date and a sampling schedule was prepared. Neither the 2300-0500 hour time period at the causeway nor the 2100-0700 hour period upriver were sampled because of logistic difficulties and the generally much-reduced fishing activity during those times. Occasionally, scheduled periods were not sampled because of program conflicts.

For each sample period, records were kept of date, location, number of anglers, observed time fishing, catch, baits used, angler sex and residency, and shore or boat use. At the beginning of each sample period, all striped bass fishermen present at the site were interviewed to determine the baseline data, then observed throughout the sample period. The observed start of fishing was recorded for newly arrived fishermen, as was the time of cessation of angling for each fisherman. Break periods of more than about 10 minutes were not included in the observed fishing time.

Observed fishing time is the time that the angler was observed fishing during a sample period and cannot exceed two hours. All recorded catches were observed caught within the sampling period.

Conventional methods of two-stage mean and variance estimation were used to calculate for each location the estimated total catch and effort and associated confidence intervals. If $\bar{y}_i$ is the mean of four observations (i.e., average number of man-hours of fishing effort per 2-hour period) on the i^{th} day, then $\hat{T}_i=9\bar{y}_i$ is the estimated total effort for that day. The total weekly fishing effort becomes $\hat{T} = \sum_{i=1}^{7} T_i$.

The estimated variance of T_i is $V_i=\frac{K(K-k)}{k}S_i^2$ where k (k=4) is the number of periods sampled from the available K (K=9) total of daily sample periods.

For the upriver sites, where only 3 of 7 days/week were sampled, the total weekly angling effort becomes $\hat{T}=\frac{K}{k}\sum_{1}^{k}\hat{T}_i$, where K=7 and k=3.

The variance components are estimated as:

$$S^2_{\hat{T}} = \frac{1}{k-1}\left[\sum_{1}^{k}\hat{T}_i^2 - \frac{1}{k}\left(\sum_{1}^{k}\hat{T}_i\right)^2\right],\text{ from which}$$

$$S^2_B = S^2_{\hat{T}} - \bar{v},\ \bar{v} = \frac{1}{k}\sum_{1}^{k} v_i \text{ and } \hat{V}(\hat{T}) =$$

$$\frac{K^2}{k}\bar{v} + K\frac{(K-k)}{k}S^2_B = \frac{K(K-k)}{k}S^2_{\hat{T}} + K\bar{v}.$$

A validity check was made of the internal consistency of the data from each fishing location using the method described in Jessop and Vithayasai (1979).

Biological Sampling

Angled striped bass were measured for fork length (to nearest 0.5 cm) and weighed (to nearest 20 g). Sex, state of maturity, date and location of capture were recorded and a scale sample was collected for most fish observed. The collection of complete information from each fish was not always possible and the numbers of fish used in each data category may vary. Some fish caught outside of sampling periods were also sampled.

Scales were independently aged twice by using a Nikon profile projector at 20X magnification and, where differences occurred, a third time. Majority agreement was accepted as the correct age and all readable scales were assigned an age. A virtual annulus was counted at the scale edge unless recent growth was evident.

RESULTS

Sampling Statistics

A total of 523 two-hour periods was sampled between May 15 and September 8: 71 at upriver sites and 452 at the Annapolis Royal causeway. Interviews were conducted with 132 anglers encountered in 32 sample periods at the upriver sites, for an average of 4.13 anglers per sample (range 1-16). The remaining 39 periods contained no anglers. Data from the upriver sites (Tupper Brook, Hebb's Landing and Round Hill) have been pooled for analysis because of the low sampling and angling effort at individual sites. At the causeway, 446 sample periods contained a total of 2,455 anglers, for an average of 5.50 interviews per sample period (range 1-26). The number of interviewees exceeds the actual number of individual anglers, since an individual may be interviewed in more than one sample period per day. Most anglers were male – 96.5% of anglers at the causeway and 92.4% of anglers at upriver sites. Total observed fishing effort at the causeway was 2,445.7 hours, during which 49 striped bass were caught by 44 anglers, or 1.8% of those interviewed. The 41 fish sampled averaged over 6 kg in weight. The catch rate was 0.02 fish per hour or, conversely, 49.9 hours were expended, on average, for each fish caught. At the upriver sites, the total observed fishing effort was 152.8 hours, during which 15 striped bass were caught by 11 anglers, or 8.3% of those interviewed. The 13 fish sampled averaged 5.3 kg in weight.

About 10.2 hours of angling effort were required for each bass caught (catch rate 0.10 fish/hour). On a per sample basis, the observed catch rate ranged from 0 to 3 fish/hour upriver and from 0 to 4 fish/hour at the causeway. Data on anglers fishing from boats are located in Appendix A.

Almost 80% of the total number of shore-based striped bass anglers interviewed were from Nova Scotia, of which about 56% were from Annapolis and Kings counties (Table 1). The United States and other countries accounted for about 12% of anglers interviewed, while slightly more than 8% came from other provinces. Anglers fishing upriver were almost entirely (98%) Nova Scotia residents, of which 84% were from Annapolis and Kings counties. About 79% of the fishermen at the causeway were Nova Scotians, of which 54% were from Annapolis and Kings counties; the remainder were tourists from other provinces (9%) or other countries (12%).

TABLE 1. Residence of striped bass anglers, by fishing location, as a percentage of total anglers interviewed (n=2,587), Annapolis River creel survey, 1978.

Residence	Location		
	Causeway	Upriver	Totals
Total Nova Scotia	74.8	5.0	79.8
Annapolis County	22.9	2.9	25.8
Kings County	17.2	1.3	18.5
Halifax County	10.6	0.2	10.8
Other counties	24.2	0.6	24.8
Other provinces	8.2	0.1	8.3
United States and other countries	11.8	0.0	11.8
Totals	94.9	5.1	100.0

Although some angling occurred upriver during the period between ice-out and April 1, when the upriver closure began, the most active upriver fishing occurred between May 5 and late June, following the opening to angling of the river as far upstream as Hebb's Landing. From mid-June onward, angling activity was concentrated at the causeway. Direct comparison between upriver sites and the causeway of the total observed fishing effort and catch (Table 2) is not possible because of the sampling scheme employed upriver, in which only 3 of 7 days per week were surveyed. Simple expansion of the upriver data by the factor 7/3 indicates that approximately 15% of the observed total angler effort and 42% of the catch occurred upriver. Virtually all fish caught upriver were taken by anglers from Annapolis and Kings counties (Table 2). Kings County residents fished about half as much as did Annapolis County residents and experienced proportionate catch rates (catch per angler and catch per hour). At the causeway, fishermen from Annapolis and Kings counties had similar

TABLE 2. Observed striped bass catch, effort and catch/effort statistics, according to angler residency and fishing location, Annapolis River creel survey, 1978.

Residence	No. of anglers	Angler effort (hr)	Angler catch	Av. fish per angler	Av. hours per angler	Av. fish per hour
Causeway						
Annapolis County	592	559.5	17	0.03	0.95	0.03
Kings County	445	483.2	14	0.03	1.09	0.03
Halifax County	273	272.2	3	0.01	1.00	0.01
Other Nova Scotia counties	626	629.5	10	0.02	1.01	0.02
Other provinces	213	212.1	3	0.01	1.00	0.01
United States & other countries	304	285.3	2	0.01	0.94	0.01
Totals	2,453[1]	2,441.7	49	0.02	1.00	0.02
Upriver						
Annapolis County	75	79.7	11	0.15	1.06	0.14
Kings County	34	43.3	3	0.09	1.27	0.07
Halifax County	4	3.8	0	0.00	0.96	0.00
Other Nova Scotia counties	16	19.9	1	0.06	1.25	0.05
Other provinces	3	6.0	0	0.00	2.00	0.00
United States & other countries	0	0.0	0	0.00	0.00	0.00
Totals	132	152.8	15	0.11	1.16	0.10
Totals	2,585	2,594.5	64	0.02	1.00	0.02

[1]Two additional anglers were of unknown origin, for a total of 2,455 anglers and angler effort of 2,445.7 hours.

catch rates, rates which were higher than for anglers from other locations. Local fishermen caught 70% of the total fish observed angled at the causeway by provincial residents and 63% of the fish caught by all anglers.

Anglers employed a variety of baits to catch striped bass. Most anglers, particularly those using alewives or bucktails, continued with a particular bait during a given sample period; but some anglers used several baits, in which case the bait most often used was recorded. The popularity of baits varied with fishing location, such that 92% of anglers interviewed at upriver sites were using whole alewives and 59% of anglers at the causeway used bucktails (Table 3). At each location, the most successful baits were also the most popular. Catch per angler was six times greater for those using whole alewives at upriver sites than for those using bucktails at the causeway, while mean fishing effort per fish caught was about five times less.

Temporal Variation in Fishing Effort and Catch

Some angling activity, primarily by boat, occurred in the upriver area in late March and between May 5 and the start of the creel survey on May 16, the details of which are unavailable. Very little fishing took place at the causeway prior to the start of the creel survey on May 15. Conversations with anglers suggested that relatively few fish were caught in these periods at either location.

At the upriver sites, fishing pressure increased until the end of May, then began a sharp decline towards cessation in late June (Fig. 3 and Appendix B). Catch per hour (sum of all fish observed caught divided by observed fishing effort) peaked during late May. Fishing effort was closely correlated with catch, but with a slight lag, indicating that as angling success declined, angler effort declined in response. Fishing activity at the causeway increased during May, reached a peak in early July, then declined irregularly through July and August, and increased again in late August and early September (Labour Day holiday). Catch per hour was highest in June, declined to a low level in mid-July, then fluctuated at a low level before increasing in early September.

Comparison of the mean number of anglers per sample fishing at the upriver sites on weekends and holidays combined, versus weekdays, indicates that slightly, but not significantly ($P>0.05$), more anglers fished on weekends than on weekdays (Tables 4 and 5). Annapolis County residents were the most active fishermen upriver during both weekends and weekdays, while Kings County residents were only slightly more active than non-local anglers. At the causeway, non-local anglers outnumbered local anglers on both weekends and holidays, and on weekdays (Table 6).

TABLE 3. Observed striped bass catch, effort and catch/effort statistics, according to bait type and fishing location, Annapolis River creel survey, 1978.

Bait type	Upriver: Angler[1] No.	%	Total effort (hr)	Total catch	Av. hr per angler	Av. fish per angler	Av. hr per fish	Causeway: Angler No.	%	Total effort (hr)	Total catch	Av. hr per angler	Av. fish per angler	Av. hr per fish
Alewife[2]	119	91.5	144.3	15	1.21	0.13	9.6	11	0.4	9.2	0	0.83	0.00	-
Alewife or herring pieces	0	0.0	0.0	0	0.00	0.00	-	22	0.9	20.8	0	0.95	0.00	-
Plugs	8	6.2	5.2	0	0.65	0.00	-	635	25.9	633.0	12	1.00	0.02	52.8
Bucktail	1	0.8	0.7	0	0.70	0.00	-	1,443	58.8	1,460.4	31	1.01	0.02	47.1
Other lures and bait	2	1.5	1.2	0	0.60	0.00	-	342	13.9	313.5	3	0.92	0.01	104.5

[1]Only anglers whose bait was recorded are included.
[2]Whole fish, live or dead.

TABLE 4. Number of anglers/sample by origin and time of week at the upriver sites, Annapolis River creel survey, 1978.

Time of week	Origin: Annapolis County No./sample	Origin: Kings County No./sample	Origin: Non-local No./sample	Total No./sample	No. of samples	Anglers No.	Anglers %
Weekend + holiday	1.50	0.36	0.29	2.14	14	30	22.7
Weekday	0.98	0.47	0.33	1.79	57	102	77.3
Total	1.08	0.45	0.32	1.86	71	132	100.0

TABLE 5. Fishing pressure by day of the week and location, Annapolis River creel survey, 1978[1].

Day	Upriver: No. of samples	Upriver: No. anglers per sample	Upriver: Standard deviation	Causeway: No. of samples	Causeway: No. anglers per sample	Causeway: Standard deviation
Monday	6	3.00	2.37	63	4.57	3.86
Tuesday	8	0.88	1.64	68	4.18	3.60
Wednesday	18	3.50	4.76	68	4.49	3.64
Thursday	15	0.33	0.62	63	5.60	4.17
Friday	10	0.90	2.18	66	4.97	3.68
Saturday	3	0.00	-	64	7.77	5.06
Sunday	11	2.73	3.00	60	6.75	4.33

[1]Holidays are not segregated.

TABLE 6. Number of anglers/sample by origin and time of week at causeway, Annapolis River creel survey, 1978.

Time of week	Origin: Annapolis County No./sample	Origin: Kings County No./sample	Origin: Non-local No./sample	Total No./sample	No. of samples	Anglers No.	Anglers %
Weekend + holiday	1.41	1.65	4.21	7.26	136	998	40.4
Weekday	1.27	0.70	2.66	4.62	316	1,460	59.6
Total	1.31	0.98	3.12	5.42	452	2,488	100.0

Of the local anglers, Annapolis County residents were more active during the weekdays than Kings County residents, perhaps because of the travel distance involved for the latter. On weekends and holidays, Kings County anglers outnumbered those from Annapolis County. Significantly more ($P<0.001$) anglers fished on the weekends and holidays than during weekdays.

Within a week, daily fishing activity (Table 5) at the upriver sites was quite variable, a result partly due to sampling variability; but at the causeway, weekday fishing was relatively constant, with no significant differences between weekdays ($P>0.05$).

Fishing activity by shore-based anglers was greatest during daylight hours, both at upriver sites and at the causeway (Table 7). At both sites, three activity periods are evident: an early morning period of light fishing activity, an extended mid-day period of moderate fishing activity and an evening period containing the peak of daylight fishing activity. Virtually no overnight fishing activity occurred at the upriver sites, although it was fairly popular at the causeway.

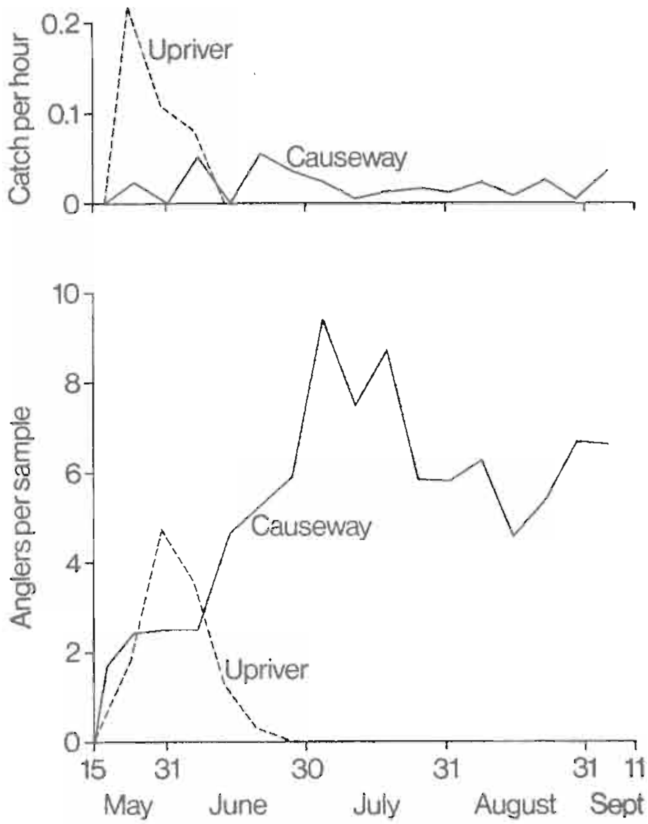

FIG. 3. Mean number of anglers per sample and catch per hour, by week, in the striped bass sport fishery at the upriver and causeway sites, Annapolis River creel survey, 1978.

TABLE 7. Fishing pressure and catch per unit of effort, by location and time period, Annapolis River creel survey, 1978.

Time period	No. of samples	Anglers per sample	Standard deviation	Catch per hour
Upriver[1]				
0700-0900	9	0.56	0.726	1.304
0900-1100	8	0.63	1.458	0.199
1100-1300	13	2.54	3.477	0.147
1300-1500	12	2.50	3.848	0.057
1500-1700	11	1.18	2.412	0.000
1700-1900	7	2.14	2.268	0.065
1900-2100	8	3.88	5.489	0.082
Causeway[2]				
0500-0700	55	3.18	3.405	0.074
0700-0900	50	3.82	3.687	0.024
0900-1100	50	5.50	4.279	0.004
1100-1300	51	5.57	4.095	0.000
1300-1500	54	5.66	4.321	0.011
1500-1700	49	5.44	3.511	0.008
1700-1900	51	5.66	4.134	0.004
1900-2100	41	8.73	5.601	0.020
2100-2300	51	6.93	4.487	0.038

[1]May 16-June 30.
[2]May 15-September 8.

Anglers were most likely to be successful when fishing in the early morning and evening at both the upriver and causeway sites. Large numbers of anglers fished the causeway during midday, when fishing success was usually low. Incidental observations of the fishing effort and success of anglers during the 2300-0500 hour period that was not sampled indicated that a rather small number of anglers enjoyed good fishing success.

Analysis of Catch and Effort Data

The estimated total catch and effort values for the upriver sites during the period May 16-June 30, 1978, were 65±46 fish (±2SE; 95% confidence interval) and 653±322 hours (Table 8). During the period

TABLE 8. Weekly estimates of total catch and effort in the striped bass sport fishery, by location, Annapolis River creel survey, 1978.

Date	Total effort (hr)	Standard error	Total catch	Standard error
Upriver sites				
May 16-21	12.55	7.25	0.00	0.00
May 22-28	199.70	88.62	32.67	15.30
May 29-Jun 4	253.65	108.73	24.50	15.19
Jun 5-11	126.12	74.07	8.17	6.50
Jun 12-18	55.80	27.92	0.00	-
Jun 19-25	5.58	4.85	0.00	-
Jun 26-30	0.00	-	0.00	-
Total	653.40	161.30	65.34	22.52
Causeway				
May 15-20	38.13	13.57	0.00	-
May 21-27	112.97	25.93	2.25	1.68
May 28-Jun 3	120.85	16.20	0.00	-
Jun 4-10	129.60	17.85	6.75	2.90
Jun 11-17	299.28	21.18	0.00	-
Jun 18-24	330.75	26.70	18.75	4.26
Jun 25-Jul 1	414.73	53.57	18.00	8.49
Jul 2-8	581.30	73.13	13.50	4.54
Jul 9-15	452.97	44.80	2.25	1.68
Jul 16-22	543.30	46.97	6.75	2.90
Jul 23-29	384.93	29.52	6.75	3.75
Jul 30-Aug 5	341.63	38.27	4.50	1.94
Aug 6-12	405.45	41.82	9.00	4.74
Aug 13-19	271.15	27.58	2.25	1.68
Aug 20-26	347.48	29.35	9.00	3.06
Aug 27-Sep 2	454.95	36.77	2.25	1.68
Sep 3-8	388.08	46.02	13.50	5.30
Total	5,717.57	155.58	115.50	14.72

May 15-September 8, the catch and effort values for the Annapolis River causeway were 116±29 fish and 5,618±311 hours. Weekly estimates of catch and fishing effort varied systematically at each fishing location and differed between locations (Table 8; Fig. 2). At the upriver sites, both catch and effort peaked in late May. At the causeway, catch peaked in mid- to late June, then fluctuated at a low level until rising again in early September;

while effort reached a maximum in early July, then declined in an irregular manner before rising again at the end of August and beginning of September. Validity checks for internal consistency of the data suggest good credibility for the estimates of total catch and fishing effort (Appendix B).

Age and Growth

A total of 131 striped bass was sampled from the angling fishery, 29 of which were caught upriver and 102 at the causeway. The mean fork length (n=131) was 80.20 cm (range 42.0-106.7 cm) and the mean weight (n=126) was 6.38 kg (range 0.92-9.18 kg) (Table 9). No significant differences (P<0.05) in mean length or weight were found between fish angled at the causeway and upriver. Mean lengths and weights of striped bass did not differ significantly (P<0.05) between months, although there was a slight declining trend between May and August (Table 10). Length-frequency and length-weight distributions for the combined sexes are presented in Table 11. Males were not presented separately because of their small numbers (9) and similarity in weight to females at a given length.

TABLE 9. Mean lengths and weights of angled striped bass with sexes combined, by location, Annapolis River creel survey, 1978.

	Length (cm)			Weight (kg)		
Location	n	Mean	SD	n	Mean	SD
Upriver	29	81.90	11.712	26	6.44	3.328
Causeway	102	79.72	11.447	100	6.36	3.230
Combined	131	80.20	11.497	126	6.38	3.237

TABLE 10. Mean lengths and weights of 126 striped bass by month, sexes and locations combined, Annapolis River creel survey, 1978.

Month	No. of fish	Mean length (cm)	SD	Mean weight (kg)	SD
May 15-31	23	81.64	11.321	6.665	3.399
Jun 1-30	27	80.47	12.233	6.749	3.718
Jul 1-31	21	79.19	14.990	6.694	4.148
Aug 1-31	28	77.78	10.631	5.805	2.627
Sep 1-8	27	80.52	9.018	6.103	2.378
Total	126	79.88	11.444	6.377	3.237

The sex ratio of 93 striped bass was 1:9 (male:female), and was similar to fish caught both at the causeway and upriver sites. None of the fish angled during the spawning season appeared upon examination to have gonads sufficiently mature to indicate a potential for spawning, but all were mature fish (maturation stages 2 and 3; Nikolsky 1963), as were those angled after the spawning season. None appeared spawned out, although spawning occured on a number of occasions in June.

TABLE 11. Length-frequency and length-weight distribution of 126 striped bass, sexes and locations combined, Annapolis River creel survey, 1978.

Fork length (cm)	No. of fish	Mean weight (kg)	SD
41.0-42.9	1	0.92	-
49.0-51.9	1	1.41	-
61.0-63.9	1	3.50	-
64.0-66.9	6	3.467	0.231
67.0-69.9	8	3.899	0.366
70.0-72.9	17	4.159	0.298
73.0-75.9	22	4.622	0.409
76.0-78.9	12	5.132	0.557
79.0-81.9	9	5.910	0.896
82.0-84.9	14	6.583	0.704
85.0-87.9	8	7.620	0.695
88.0-90.9	6	8.008	0.465
91.0-93.9	3	0.257	1.006
94.0-96.9	5	9.310	1.004
97.0-99.9	3	11.800	0.964
100.0-102.9	3	12.490	1.091
103.0-105.9	6	15.853	2.379
106.0-108.9	1	14.98	-

Ages ranged from 4 to 20 years, with 71% of the fish occurring in age group 8-12 and a further 23% in age group 13-20 (Table 12). The mean age was 10.9 years.

TABLE 12. Mean length (n=130) and weight (n=124) by age for combined sexes of striped bass, Annapolis River creel survey, 1978.

Age	No. of fish	Length (cm) Mean	Range	SD
4	1	42.0	-	-
5	1	49.0	-	-
6	2	63.70	62.9- 64.5	-
7	4	67.75	66.5- 69.5	1.258
8	19	71.19	66.0- 79.5	3.410
9	22	74.99	68.0- 82.5	4.132
10	18	78.28	71.5- 87.0	5.113
11	14	78.36	70.5- 86.5	4.381
12	19	82.55	71.2- 94.3	6.259
13	7	90.07	84.0-100.0	5.365
14	5	93.82	86.0-106.7	8.438
15	4	95.50	87.0- 99.5	5.817
16	7	97.50	91.0-104.5	4.831
17	3	101.30	93.5-105.4	6.758
18	0	-	-	-
19	3	103.50	102.0-104.5	1.323
20	1	105.0	-	-

TABLE 12. Continued

Age	No. of fish	Weight (kg) Mean	Range	SD
4	1	0.92	-	-
5	1	1.41	-	-
6	2	3.350	3.20- 3.50	-
7	4	3.618	3.26- 4.00	0.3027
8	18	4.081	3.54- 4.90	0.3787
9	21	4.791	3.84- 6.92	0.8186
10	18	5.454	4.22- 7.66	1.1597
11	14	5.882	4.20- 8.40	1.3757
12	17	6.315	3.94- 8.51	1.3451
13	6	7.978	6.00- 8.80	1.0223
14	5	10.106	6.40-14.98	3.2496
15	4	10.490	7.72-12.90	2.2069
16	6	12.145	8.80-19.18	3.7296
17	3	13.837	8.12-18.14	5.1573
18	0	-	-	-
19	3	13.483	12.92-14.23	0.6740
20	1	15.65	-	-

Mean lengths and weights increased regularly with age up to age 17 for females and for sexes combined.

Comparison of Life History and Creel Survey Data, 1972-78

Comparison of the striped bass life history data collected in the creel surveys of 1972 (Penney 1973), 1975 (Jessop and Doubleday 1976), 1976 (Jessop and Vithayasai 1979) and 1978 indicates a lack of recruitment and progressive decline in abundance of this stock which, if unchecked, could result in virtual extinction within 5-10 years. Surveys of spawning success (Jessop 1976; Williams 1978; Daborn 1978) and the creel-survey catch statistics support this conclusion.

Since 1972, there has been a progressive increase in the mean length, weight and age of the angled catch (Table 13). In 1972, 62% of the striped bass were less than 58 cm long compared with 36% in 1975, 5% in 1976 and 2% in 1978 (Fig. 4). Two length-frequency modes can also be followed over time. Similar changes occurred in the age composition of the catch, with fish of

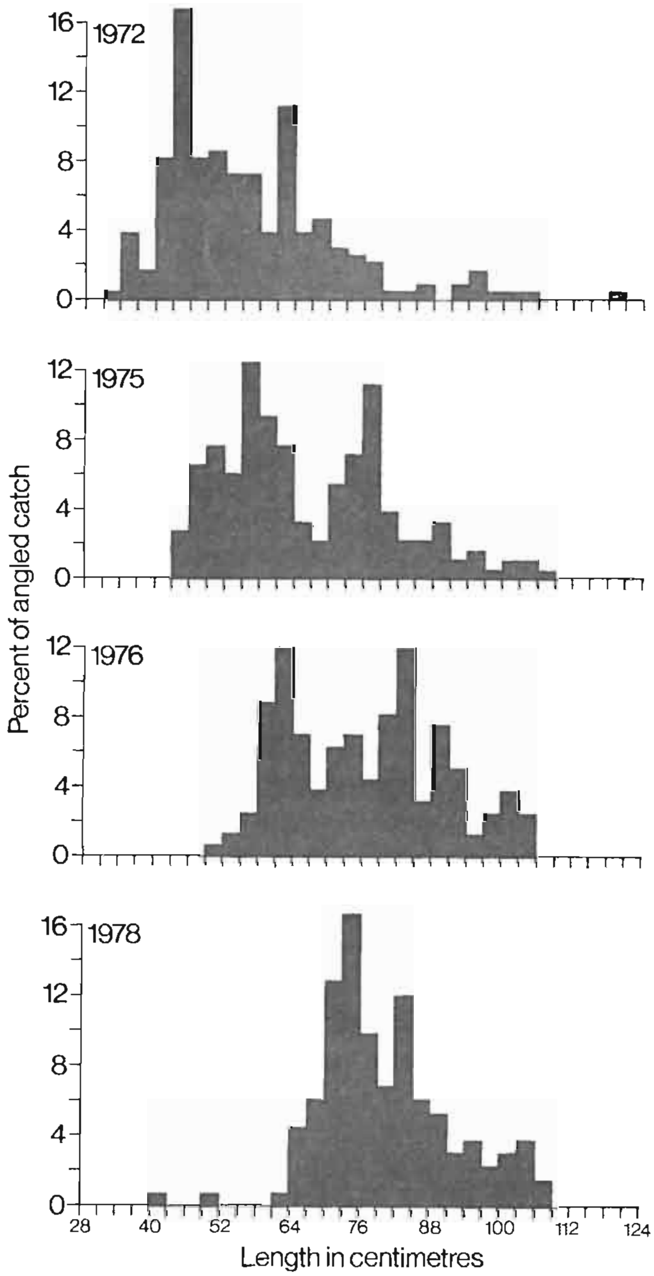

FIG. 4. Comparison of the length-frequencies of striped bass angled from the Annapolis River, 1972-78.

TABLE 13. Mean length, weight and age composition of striped bass, Annapolis River creel surveys, 1972-78.

Year	No. of fish	Mean length (cm)	No. of fish	Mean weight (kg)	No. of fish	Mean age (yr)	% Age 3-9	10+
1972[1]	232	55.88	232	2.70	182	6.0	90.7	9.3
1975	215	65.98	191	3.95	204	7.8	68.6	31.4
1976	160	76.30	155	5.89	159	9.4	54.1	45.9
1978	131	80.20	126	6.38	130	10.9	37.7	62.3

[1]Data from G.H. Penney, 1973.

age-group 3-9 years forming 90.7% of the catch in 1972 and 37.7% in 1978 (Table 13). From 1963 through 1971, the year classes were evidently quite successful. The proportion of females has also increased, from a male:female ratio of 1:1.1 in 1972, to 1:4.2 in 1975, 1:16.0 in 1976 and 1:9.0 in 1978. The latter figure is undoubtedly low, since 37 of the sample of 131 fish were unidentified as to sex, but most were large and probably female.

No significant difference (P>0.05) was found in the length-weight relationships of male (n=54) and female (n=190) striped bass obtained during three collection years (1975, 1976, 1978) from the Annapolis River. Thus, both sexes had similar weights for a given length over the range of lengths examined. Since male fish rarely exceeded 88 cm, the larger fish were usually female. The G.M. length-weight regression (Ricker 1973) for both sexes combined (n=239; 49 male, 190 female; r^2= 0.984) was logW=2.9973 logL-4.9156, where W is the weight in kilograms and L is the fork length in centimetres (Fig. 5).

Comparison of the length-weight relationships of each sex employed subsamples randomly drawn from the total numbers of each sex available, to a maximum of five males and ten females per 3-cm length interval. Virtually all available males were utilized.

Growth in length followed a slightly convex trend between the ages of 3 and 20 years, while growth in weight was essentially linear until age-14, following which a sharp increase in growth rate occurred to age-15 before a shallow convex trend was established (Fig. 6). Weight gain averaged 0.7 kg/year between ages-4 and 14.

Egg and larval surveys in 1975 (Jessop 1976), 1976 (Williams 1978) and 1977 (Daborn 1978) and 1978 (Jessop, unpublished) have established that annual spawning of striped bass occurs in the Annapolis River and that the resultant larval abundance is very low or nil. Evidently, there has not been a successful year-class of striped bass in the Annapolis River since 1971 or 1972.

The patterns of catch and fishing activity were similar in each creel survey. Fishing activity upriver peaked in late May and early June, while the period of maximum catch rate varied from late May to mid-June. At the causeway, fishing activity in 1975 and 1978 increased through May and June to peak in early July, fluctuated markedly and concurrently declined through to late August, then increased in September. In 1976, the pattern was more irregular and displayed a decline in late July. Catch rates were best in June and September in all surveys. Within a day, anglers were most active during the early evening in all surveys, but the catch rates were highest in the early morning. A secondary peak was observed in the early evening in two surveys and in early afternoon in the

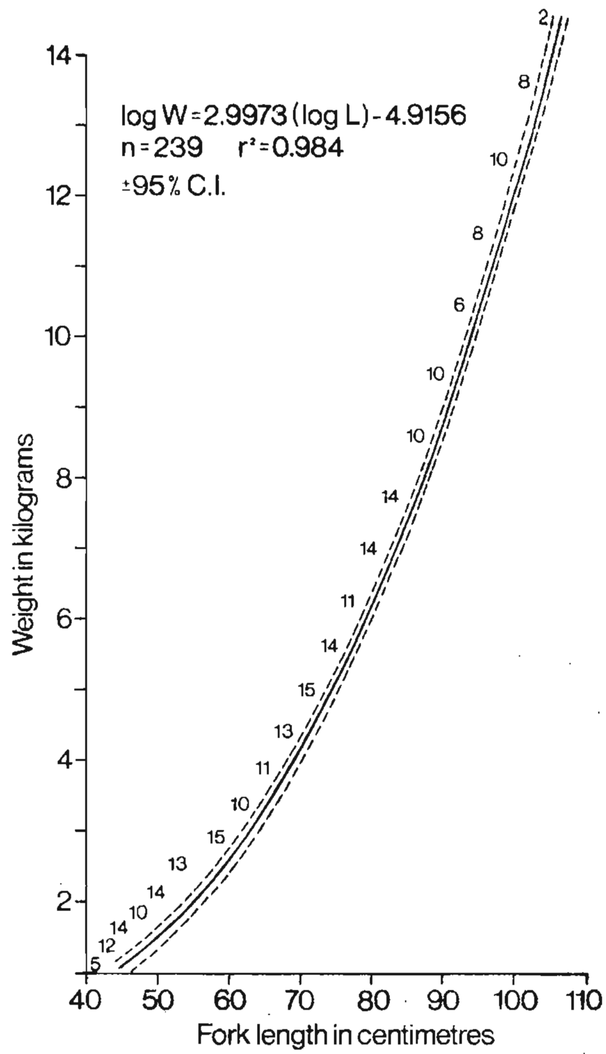

FIG. 5. Length-weight relationship for striped bass (sexes combined) from the Annapolis River. (Numbers adjacent to midpoint of each 3-cm length interval represent sample size for that interval, eg., n=2 for interval 106.0-108.9 cm.)

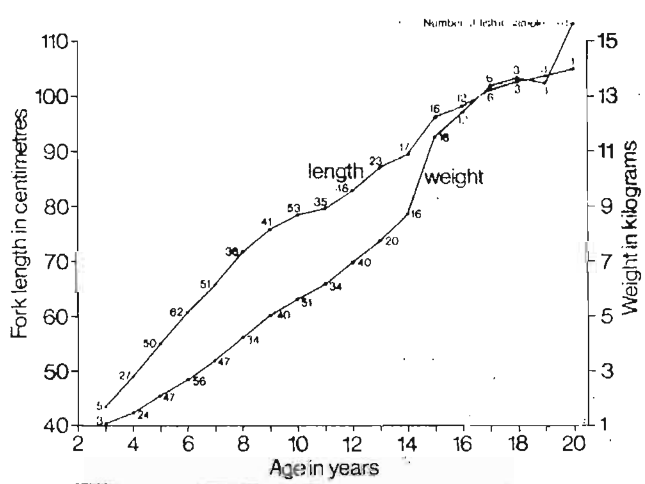

FIG. 6. Length (N=487) and weight (n=453) relationships with age of striped bass from the Annapolis River (sexes combined), from the years 1975, 1976 and 1978 combined.

third survey. In all years, the most frequently used bait types were alewives (usually live) and bucktails at the upriver and causeway sites, respectively.

Little change has occurred between surveys in the distributions, by origin, of anglers fishing at the causeway (Table 14), although the number of anglers interviewed in 1978 was more than double that of 1975. The fishing activity (anglers/sample) at the causeway in 1975 was greatest on weekdays, rather than on weekends and holidays; while in 1976 and 1978 the reverse was true, with the largest change amongst non-local anglers.

TABLE 14. Residence of striped bass anglers fishing at Annapolis Royal causeway, as a percentage of total anglers interviewed, by survey year.

Residence	Survey year 1972	1975	1976	1978
Total Nova Scotia	84	73	82	79
Annapolis County	38	22	28	24
Kings County	26	14	16	18
Halifax County	7	15	12	11
Other counties	14	22	27	26
Other provinces	10	8	6	9
U.S. and other countries	5	18	12	12
Total numbers of anglers (n)	58	1,192	2,080	2,453

If allowance is made for the differences in calendar duration of each survey (particularly the 1976 survey, since little fishing activity occurs from mid-May to mid-June at the causeway, but catch rates rise in September), it seems fair to conclude that both the estimated total angling effort and total catch declined between surveys, with a particularly sharp decrease in fishing success in 1978 (Table 15).

TABLE 15. Estimated striped bass catch, effort and catch/effort statistics, by creel survey, Annapolis River causeway.

Survey[1]	Duration	Total effort (hr)	Total catch	Av. fish per hr	Hr per fish
1975	May 13-Sep 11	9,799	478	0.049	20.5
1976	Jun 18-Sep 17	7,261	351	0.048	20.7
1978	May 15-Sep 8	5,618	116	0.021	47.6

[1]1972 survey data incomplete.

DISCUSSION AND CONCLUSIONS

This is the fourth survey of the Annapolis River striped bass angling fishery conducted since 1972, from which certain trends and characteristics of the fishery have become evident. Although angling occurs from ice-out in the spring to freeze-up in the winter, the fishery is concentrated upriver, between Round Hill and Hebb's Landing, during the April-June period (prior to implementation of the April 1-June 30 closure in 1976 the fishery extended upstream from Bridgetown), and at the Annapolis Royal causeway during the summer and autumn.

The proportions of anglers, by origin, have fluctuated within narrow limits in recent years. Thus, in 1978, the majority (58%) of anglers were of non-local origin and most of these were from other counties within Nova Scotia. About 21% of visitors were from other provinces and countries, a figure similar to the mean of the previous three surveys (20%). Potential biases of the "length of stay" and "frequency of use" types (Sinclair and Morley 1975) should be absent from this survey, since anglers were sampled in proportion to their frequency of occurrence. No attempt was made to estimate the "true" number of individual anglers participating in the fishery. Observations indicate that a moderate number of local anglers engage actively in the fishery, while greater numbers of non-local anglers make fewer trips per individual.

As in previous years, most anglers failed to catch a striped bass on any given trip. Less than 2% of anglers had caught a fish when interviewed and an average of about 50 hours was spent fishing for each fish caught. Anglers fished most actively during daylight hours, with the peak of activity occurring in the early evening at both upriver and causeway sites. Catches were best in the early morning. The upriver fishery continued as the preserve of local anglers, who enjoyed catch rates much higher than those of anglers fishing at the causeway.

Live alewives were the most successful and frequently used bait at the upriver sites, as were bucktails at the causeway. Jessop and Doubleday (1976) noted that the frequency of use and success of bait types is related to environmental conditions at the fishing sites. Comparisons with previous surveys also show similarities between years in the seasonal cycles of catch and effort at the causeway and at the upriver sites. At the causeway the peak catches in June and September presumably reflect the movements of the striped bass to the area, while the peak of angling effort reflects the influx of summer tourists. The trend towards greater fishing activity on weekends on holidays than on weekdays is also confirmed. This trend is consistent with the observation that fishing activity reflects the availability of leisure time.

The use of a two-strata, random sampling scheme, shorter, more frequent sampling periods and observed catch and effort data resulted in unbiased estimates of total angling catch and effort that are less variable than in previous surveys. The estimates can be accepted with confidence for the periods to which they apply. However, as in other years, the lack of sampling at the causeway between 2300 and 0500 hours, due to logistic difficulties, is a significant omission. Unofficial tallies of catch reported during this period indicate that perhaps 20%-40% of the total daily catch occurred at night. At the upriver sites, fishing after dark was rare and is of no significance.

Comparison of the creel-survey estimate of total angling catch of striped bass (upriver and causeway combined) for the period May 15-September 8 ($106 \leq 181 \leq 255$) with the number of entries in the Fishing Derby during the same period (248, pers. comm., N.S. Dept. of Tourism) provides independent evidence for the accuracy of the creel survey, since the number of entries in the Derby lies within the 95% confidence bounds of the creel survey. The fact that some fish entered in the Derby were caught during the 2300-0500 hour non-surveyed period and that some angled fish were not entered in the Derby (although a high proportion were, and angler participation was greater than in previous years) would tend to neutralize the differences between creel survey and Derby entry numbers.

The life history data indicate a progressive ageing of the striped bass population of the Annapolis River, thereby resulting in an imbalance in the sex ratios typical of this species during the spawning period and stream residence. Merriman (1941) observed from 10 to 50 males surrounding a single spawning female, while Trent and Hassler (1968) reported sex compositions of from 70% to 85% males among gill-netted striped bass in the Roanoke River, and Wilson et al. (1976) reported 77%-81% males in the Potomac River. In comparison, the sex composition of angled fish from the Annapolis River has ranged from 6% to 20% males in recent years, and is evidently declining. The relative lack of males may have some impact on the success of spawning as manifest in the fertilization rate, since the viability of collected eggs may have declined. Williams (1978) reported that approximately 73% of the eggs collected (n=1,419) in one sample period were viable; and in 1978, 93% of those collected (n=11,868) in several sampling periods were viable (Jessop, unpublished); but in 1979, only 42% of over 66,000 eggs were viable (Parker, R., Envir. Prot. Serv., Halifax, pers. comm.).

Although spawning occurred on a number of occasions during June in each survey year, the lack of ripe fish in the angling catch may indicate either a difficulty in assessing the maturation state (Chadwick 1965), a scarcity of mature fish ripening to spawn, or both.

The growth rate of striped bass from the Annapolis River is slower than that of striped bass from American populations (Merriman 1941) and from the Saint John River (Dadswell 1976), but exceeds that of bass from the St. Lawrence River (Magnin and Beaulieu 1967). For example, a 14-year-old striped bass from the Saint John, Annapolis and St. Lawrence rivers averages 95 cm FL and 11 kg in weight, 89 cm and 9 kg, and 75 cm and 8 kg, respectively. Over most of their range and following maturity, male striped bass weigh less than females of the same length (Merriman 1941); but in the Annapolis River, both sexes evidently have similar weights at equal lengths. Although females longer than 65 cm tended to be heavier than males of the same length, the non-significance of the trend may have been influenced by the limited numbers of male fish in each length group and the rarity of males greater than 85 cm in length. Since female striped bass typically live longer and attain larger size than do male striped bass (Merriman 1941), the absence of males after age-14 probably explains the subsequent abrupt rise in the age-weight relationship.

The cause of the reproduction failure is not definitely known, but it is generally agreed (Westin and Rogers 1978) that striped bass population levels are established during the first two months of life, a period when reproductive success is most vulnerable to environmental variation. A particularly critical period occurs between hatching and completion of the transformation from larvae to young – 21-30 days old (Smith and Wells 1977). Thus, the possibility of organochloride contamination and of water quality effects on survival were studied.

One consequence of the absence of smaller striped bass and the greater fecundity of large fish is that the bulk of egg deposition comes from the larger fish. These fish also carry the greatest burden of organochlorides in their muscle and reproductive tissue, since organochloride levels (PCB, ΣDDT) increase with fish size, with the concentration of both organochloride types showing significant correlation (Jessop and Doubleday 1976). The situation is fully discussed in Jessop and Vithayasai (1979).

Total organochloride levels (PCB, ΣDDT) in the large fish are sufficiently elevated to warrant concern about the potential for egg and larval mortality (Smith and Cole 1973; Burdick et al. 1964; Macek 1968; Johnson and Pecor (1969). Stauffer (1979) concluded, however, that DDT or PCB content at levels similar to those found in Annapolis River striped bass was unlikely to induce mortality in Lake Michigan lake trout sufficient to account for the apparent complete failure of lake trout reproduction. While between-species differences probably exist in sensitivity to organochloride contamination, Locke and Havey (1972) suggest that the wide variations in reported effects of DDT upon fish may result from a synergistic interaction of several pesticides, such as dieldrin and guthrion with DDT. No information is available on the presence of pesticides other than DDT in striped bass from the Annapolis River.

Sublethal levels of organochlorides may also affect larval fish behaviour (Dill and Saunders 1974), growth and development (Mauck et al. 1978), and enzymatic activity (Campbell et al. 1974) sufficiently to impair the response of the organism to environmental conditions or hazards, which might result in abnormal mortality. It should be noted that these results were obtained from chronic exposure studies, which likely resulted in body burdens of organochlorides much higher than observed in Annapolis River striped bass.

In contrast, the bulk of eggs laid by the successfully reproducing striped bass populations of the Shubenacadie (Jessop and Vithayasai 1979) and Kouchibouguac rivers (Jessop, unpublished) derive from smaller fish less burdened by organochlorides. Both stocks have been intensively exploited by commercial fisheries, resulting in population age and size structures where few fish in the catch exceed age-10 and 8 kg in weight, while most are 3-7 years of age and 1.0-4.5 kg in weight.

Water quality parameters such as dissolved oxygen, pH and total dissolved solids have been investigated on several occasions and found to be within acceptable limits (Inland Waters Branch, pers. comm.; Baker, J., N.S. Dept. of Envir., pers. comm. 1975; Williams 1978). Williams (1978) confirmed that some of the striped bass eggs collected in the river were viable by hatching a small number in the laboratory and by obtaining three larvae during extensive field sampling. However, a 1979 study of the effects of water origin and quality on striped bass egg hatchability and larval survival concluded that, while the eggs and larvae were indeed viable under laboratory conditions with suitable water quality, their very low survival rate in the river may result from low pH (Parker, R., Envir. Prot. Ser., pers. comm., 1979).

Approximately 42% of over 67,800 eggs from the Annapolis River were viable when collected. The hatch rate of 5,300 eggs used experimentally was 46%. Larval survival was 3% to 3 weeks post-hatch and 1.3% to 9 weeks post-hatch. The viability and hatch rates are comparable to those achieved several years ago by some striped bass hatcheries in the United States, but improved techniques such as formalin treatment now result in fertilization rates of 80%-85%, hatch rates of 95%-100% and survival to 5 days of about 75% (Mitchell, K., Brookneal Hatchery, Virginia, pers. comm., 1979).

Daily measurements of pH ranged from under 6.0 to slightly more than 7.0 during June, the spawning period. Bowker et al. (1969) reported that pH ranges from 6.6 to 9.0 were satisfactory for hatching, while Bonn et al. (1976) advise that the pH is optimum between 7.0 and 9.5, with mortality among fry sometimes occurring at a pH below 6.8. Yolk-sac larvae survival varies in response to interacting levels of pH, temperature and total dissolved solids (TDS), with the optimum at a pH of 7.5, temperature of 18°C and TDS of 186 mg/l NaCl (Davies 1973).

The pH values observed at five stations tended to increase with distance downstream of the limit of saltwater intrusion (near Bridgetown) and may result from the buffering action provided by increased mixing of the underlying saline layer, since total dissolved solids (TDS) in the freshwater layer increased concurrently. A decrease in pH was also observed in association with increased runoff following precipitation, which has an average pH of 4.9 in southern Nova Scotia during April through June (Watt, W., Fisheries and Marine Service, pers. comm., 1979). Additional field and laboratory studies will be conducted in 1980 to resolve the influence of pH on striped bass spawning success.

In the Shubenacadie River, where successful spawning occurs, pH values averaged 6.5 (ranges 6.3-7.0) when taken irregularly between June and September (Dr. Wiles, M., St. Mary's University, Halifax, pers. comm., 1979). No pH data are available for the Kouchibouguac or Richibucto rivers of northeastern New Brunswick.

The chlorinated sewage outfall from the Bridgetown sewage treatment plant empties into the Annapolis River in an area of known spawning activity, but tests in 1978 established that the residual chlorine levels were undetectable within a short distance of the outfall (Trider, G., Envir. Prot. Serv., Halifax, pers. comm.) and thus are of no threat to striped bass eggs or larvae (Middaugh et al. 1977). The effluent from the United Elastics Ltd. plant about 5 km downstream from Bridgetown has also been analyzed and found to be of little concern.

Williams (1978) suggested that the highly stratified nature of the estuary may result in larval mortality, following ova exposure to bottom salinities that range from 15‰ to 20‰ at the lower boundary of the spawning zone during the spawning period (Albrecht 1964). Otwell and Merriner (1975), however, reported larval mortalities of about 24% at salinities of 20‰, while Westin and Rogers (1978) observed good survival and development of prolarvae and postlarvae at 5‰-15‰ and 16°-20°C, and at 25‰ and above 21°C, respectively. Although a thermocline is associated with the halocline and water temperature generally decreased with increasing salinity, the potential for thermal shock or temperature x salinity interaction is probably minor, since the surface to bottom temperature differential in the spawning and larval drift areas as observed by Williams (1978) seldom exceeded 5°C, with a minimum bottom temperature of

15°C (Otwell and Merriner 1975). In any case, penetration of the halocline by eggs (and probably prolarvae also) seems unlikely, given that the density of the egg is lower than that of the saline layer at the observed temperatures and salinities (Smith and Wells 1977) and the suspensive action of turbulence in the freshwater layer. The mobility and avoidance behavior of older larvae should serve to minimize any adverse effects. In addition, the occurrence of successful reproduction in the 12-year period between completion of the Annapolis Royal causeway in 1960 and the most recent successful year-class in in 1971, for most of which time the salinity profile of the estuary was presumably much as it is today, suggests that salinity is not the critical factor.

Investigations of the cause of the decline in the Annapolis River striped bass stock will continue, with additional protective measures taken as appropriate.

APPENDIX A

ANGLING BY BOAT

The sampling design employed in the creel survey of the shore-based fishery was not, of course, suitable for the boat fishery due to its mobility and difficulty of observation from shore, so that no estimates can be made of total catch and effort by boating anglers. Consequently, complete information is unavailable for all boat-based anglers observed. The following analysis is intended only to summarize observations made incidentally to the shore-based survey.

A total of 149 anglers was observed fishing from boats during 61 of the 523 two-hour sample periods. The mean number of fishermen per sample was 2.44 (range 1-7). Three striped bass were observed caught during 165.52 hours of angling for a catch rate of 0.02 fish per hour.

Boat-fishing activity was greatest upriver during May and June and, in the causeway area (primarily upstream of the causeway), it peaked in August, as shown by the following table.

Month	Upriver Anglers	Upriver Catch	Causeway Anglers	Causeway Catch
May	7	2	16	0
Jun	5	0	17	0
Jul	–[1]	–	37	0
Aug	–	–	57	1
Sep	–	–	9	0
Total	13	2	136	1

[1]Observations ceased due to lack of fishing activity.

Residence information could be obtained for only 56% of the anglers observed.

All boat-based anglers interviewed (8 of 13 observed) while fishing upriver were Nova Scotia residents, of which 75% were Annapolis County residents. Of 89 fishermen interviewed at the causeway, 85% were provincial residents and 25% were Annapolis County residents.

Bait preferences were difficult to determine, since fishermen often used several baits during a trip. Interviews with 95 anglers established that 44% used plugs, 31% used lures or other baits, 18% used a combination of plugs and lures and 7% used whole, usually live, alewives. Both observed catches upriver were made with alewives.

APPENDIX B

MEAN NUMBER OF ANGLERS AND STRIPED BASS CATCH RATE, BY WEEK, AT THE CAUSEWAY AND UPRIVER SITES, ANNAPOLIS RIVER CREEL SURVEY, 1978

Date	No. of samples	Mean no. of anglers	SD	Catch per hr
Upriver				
May 16-21	12	0.73	0.809	0.000
May 22-28	5	1.80	2.683	0.224
May 29-Jun 4	16	4.73	3.529	0.107
Jun 5-11	7	3.57	5.598	0.081
Jun 12-18	14	1.21	1.139	0.000
Jun 19-25	7	0.33	0.408	0.000
Jun 26-30	10	0.00	–	0.000
Causeway				
May 15-20	23	1.74	2.335	0.000
May 21-27	21	2.43	3.330	0.023
May 28-Jun 3	25	2.52	2.230	0.000
Jun 4-10	26	2.50	1.779	0.052
Jun 11-17	28	4.64	3.652	0.000
Jun 18-24	27	5.30	3.721	0.056
Jun 25-Jul 1	27	5.89	4.615	0.037
Jul 2-8	25	9.40	5.424	0.026
Jul 9-15	28	7.46	4.599	0.005
Jul 16-22	28	8.68	4.234	0.012
Jul 23-29	28	5.86	2.902	0.018
Jul 30-Aug 5	28	5.82	3.689	0.013
Aug 6-12	28	6.29	3.722	0.022
Aug 13-19	27	4.59	2.859	0.009
Aug 20-26	28	5.39	3.108	0.026
Aug 27-Sep 2	28	6.68	3.692	0.005
Sep 3-8	24	6.33	4.517	0.035

APPENDIX C

CHECK FOR INTERNAL CONSISTENCY OF THE DATA

As noted in Jessop and Vithayasai (1979), a randomly chosen interview period of duration $\underline{h}$ (h=2 hr) may intersect an angler's fishing time $\underline{t}$ in any four distinct ways, according to whether the angler arrived before or after the start of the interview period and whether the angler's fishing effort terminated before or after the end of the interview period. The observed data in these four categories for each fishing location (Tables C-1 and C-2), summarize (a) numbers of anglers, (b) total fishing time (in minutes) and (c) the sum of squares of fishing time.

Within these tables, the roughly approximate equalities observable between row and column totals, particularly in the total fishing time and sum of squares of fishing time, are predictable from theoretical considerations (Appendix C, Jessop and Vithayasai 1979), and thus provide an indication of validity of the planning and execution of the creel survey. More stringent tests of validity are revealed by additional relationships between the tables. In Tables C-1 and C-2, Section (b), the grand totals, when divided by h=120 minutes (9,168/120=76.4 and 146,741/120=1,222.8), are expected to approximate the total angler count in the first row or second column of Section (a). In each case, there is rather close agreement. Section (c) of the tables is less obviously related to Section (b), and requires that:

$$\left[\frac{3}{2}(181{,}070+190{,}699) + (432{,}000+30{,}835)\right] \div 120$$

= 8,504.1 (from Table C-1[c])

= 2,390+3,600+2,517

= 8,507 (from Table C-1[b]), and

$$\left[\frac{3}{2}(3{,}361{,}919+2{,}898{,}525)+(4{,}564{,}800+1{,}013{,}399)\right] \div 120$$

= 124,740.5 (from Table C-2[c])

= 47,231+38,040+42,329

= 127,600 (from Table C-2[b]).

The similarity of these numbers agrees with the predicted internal consistency, thus adding to the credibility of the estimates of total fishing effort and catch.

TABLE C-1. **Summary of observed angler numbers and fishing time at the upriver sites, according to arrival and departure before and after the interview period, Annapolis River creel survey, 1978.**

(a) Angler count

Angler arrival	Angler departure: Before end of period	Angler departure: After end of period	Total
Before start of period	37	30	67
After start of period	18	47	65
Total	55	77	132

(b) Total fishing time (minutes)

Angler arrival	Angler departure: Before end of period	Angler departure: After end of period	Total
Before start of period	2,390	3,600	5,990
After start of period	661	2,517	3,178
Total	3,051	6,117	9,168

(c) Sum of squares of fishing time ($min.^2$)

Angler arrival	Angler departure: Before end of period	Angler departure: After end of period	Total
Before start of period	181,070	432,000	613,070
After start of period	30,835	190,699	221,534
Total	211,905	622,699	834,604

TABLE C-2. Summary of observed angler numbers and fishing time at the Annapolis Royal causeway, according to arrival and departure before and after the interview period, Annapolis River creel survey, 1978.

	(a) Angler count		
	Angler departure		
Angler arrival	Before end of period	After end of period	Total
Before start of period	834	317	1,151
After start of period	465	839	1,304
Total	1,299	1,156	2,455

	(b) Total fishing time (minutes)		
	Angler departure		
Angler arrival	Before end of period	After end of period	Total
Before start of period	47,231	38,040	85,271
After start of period	19,141	42,329	61,470
Total	66,372	80,369	146,741

	(c) Sum of squares of fishing time ($min.^2$)		
	Angler departure		
Angler arrival	Before end of period	After end of period	Total
Before start of period	3,361,919	4,564,800	7,926,719
After start of period	1,013,399	2,898,525	3,911,924
Total	4,375,318	7,463,325	11,838,643

ACKNOWLEDGEMENTS

The author wishes to thank Mr. D.A. Swetnam for his able assistance in the collection and analysis of the data; also Mr. D. Ryan and Ms. D. Witter for their efforts in the field.

REFERENCES

Albrecht, A.B. 1964. Some observations on factors associated with survival of striped bass eggs and larvae. Calif. Fish Game, 50(2):100-113.

Bonn, E.W., W.M. Bailey, J.D. Bayless, K.E. Erickson, R.E. Stevens (ed.). 1976. Guidelines for striped bass culture. Sponsored by the Striped Bass Committee of the Southern Division, American Fisheries Society.

Bowker, R.G., D.J. Baumgartner, J.A. Hutcheson, R.H. Ray and T.L. Wellborn, Jr. 1969. Striped bass, *Morone saxatilis* (Walbaum) 1968 report on the development of essential requirements for production. U.S. Fish and Wildl. Serv. Publ. 112 p.

Burdick, G.E., E.J. Harris, H.J. Dean, T.M. Walker, J. Skea and D. Colby. 1964. The accumulation of DDT in lake trout and the effect on reproduction. Trans. Amer. Fish. Soc., 93(2):127-136.

Campbell, R.D., T.P. Leadem and D.W. Johnson. 1974. The *in vivo* effect of p, p' DDT on Na^{+}-K^{+}-activated ATPase activity in rainbow trout *(Salmo gairdneri)*. Bull. Envir. Contam. Toxicol., 11(5): 425-428.

Chadwick, H.K. 1965. Determination of sexual maturity in female striped bass *(Roccus saxatilis)*. Calif. Fish and Game, 51(3):202-206.

Cochran, W.G. and G.M. Cox. 1957. Experimental designs, 2nd ed. John Wiley and Sons, New York. 611 p.

Daborn, G.R. 1978. Spawning of the striped bass, *Morone saxatilis* (Walbaum), in the Annapolis River, Nova Scotia, 1976 and 1977. Summary Rept., Contract OSU5-0163 between Acadia University and Fisheries and Marine Service, Envir. Can. 31 p.

Dadswell, M.J. 1976. Notes on the biology and research potential of striped bass in the Saint John estuary. *In* Baseline Survey and Living Resource Potential Study of the Saint John River Estuary. Vol. 3, Fish and Fisheries. The Huntsman Marine Laboratory, St. Andrews, New Brunswick.

Davies, W.D. 1973. The effects of total dissolved solids, temperature and pH on the survival of immature striped bass: a response surface experiment. Prog. Fish. Cult., 35(3):157-160.

Dill, P.A. and R.C. Saunders. 1974. Retarded behavioral development and impaired balance in Atlantic salmon *(Salmo salar)* alevins hatched from gastrulae exposed to DDT. J. Fish. Res. Bd. Canada, 31(12):1936-1938.

Jessop, B.M. 1976. Physical and biological survey of the Annapolis River, 1975. Dept. of the Environment, Fisheries and Marine Service, Resource Branch. Data Record Series No. MAR/D-76-8. v + 29 p.

Jessop, B.M. and W.G. Doubleday. 1976. Creel survey and biological study of the striped bass fishery of the Annapolis River, 1975. Department of the Environment, Fisheries and Marine Service, Resource Branch. Technical Report Series No. MAR/T-76-3. vii + 47 p.

Jessop, B.M. and C. Vithayasai. 1979. Creel surveys and biological studies of the striped bass fisheries of the Shubenacadie, Gaspereau and Annapolis rivers, 1976. Department of Fisheries and Oceans, Resource Branch. Fish. Mar. Serv. MS Rep. No. 1532. ix + 32 p.

Johnson, H.E. and C. Pecor. 1969. Coho salmon mortality and DDT in Lake Michigan. Trans. North Amer. Wildl. and Nat. Res. Conf., 34:159-166.

Locke, D.O. and K. Havey. 1972. Effects of DDT upon salmon from Schoodic Lake, Maine. Trans. Amer. Fish. Soc., 101(4): 638-643.

Macek, K.J. 1968. Reproduction in brook trout *(Salvelinus fontinalis)* fed sublethal concentrations of DDT. J. Fish. Res. Bd. Canada 25(9):1787-1796.

Magnin, E. and G. Beaulieu. 1967. Le bar, *Roccus saxatilis* (Walbaum), du Fleuve Saint-Laurent. Natur. Can., 94:539-555.

Mauck, W.L., P.M. Mehrle and F.L. Mayer. 1978. Effects of the polychlorinated biphenyl Aroclor 1254 on growth, survival, and bone development in brook trout *(Salvelinus fontinalis)*. J. Fish. Res. Bd. Canada, 35(8):1084-1088.

Merriman, D. 1941. Studies on the striped bass *(Roccus saxatilis)* of the Atlantic coast. Bull. U.S. Fish. Wildl. Serv. 35. 41 p.

Middaugh, D.P., J.A. Couch and A.M. Crane. 1977. Responses of early life history stages of the striped bass, *Morone saxatilis*, to chlorination. Chesapeake Sci., 18(1):141-153.

Nikolsky, G.V. 1963. The ecology of fishes. Academic Press, London and New York. 352 p.

Otwell, W.S. and J.V. Merriner. 1975. Survival and growth of juvenile striped bass, *Morone saxatilis*, in a factorial experiment with temperature, salinity and age. Trans. Amer. Fish. Soc., 104 (3):560-566.

Penney, G.H. 1973. A preliminary investigation of the striped bass, *Roccus saxatilis*, fishery resource in the Annapolis River system, and the general distribution of striped bass in other areas in southwestern Nova Scotia. Can. Dept. of Fisheries and Forestry, Resource Development Branch, Halifax, N.S. Man. Rept. No. 73-4. 35 p.

Smith, W.G. and A. Wells. 1977. Biological and fisheries data on striped bass, *Morone saxatilis* (Walbaum). U.S. Nat. Mar. Fish. Serv., Northeast Fisheries Center, Sandy Hook Laboratory. Tech. Ser. Rept. No. 4. 42 p.

Sinclair, W.F. and R.W. Morley. 1975. Statistical bias in on-site surveys: the severity of the problem and its potential for solution. J. Fish Res. Bd. Canada, 32:2520-2524.

Smith, R.M. and C.F. Cole. 1973. Effects of egg concentrations of DDT and dieldrin on development in winter flounder (*Pseudopleuronectes americanus*). J. Fish. Res. Bd. Canada, 30:1894-1898.

Smitheringale, W.G. 1973. Geology of parts of Digby, Bridgetown and Gaspereau Lake map-areas, Nova Scotia. Geol. Surv. Can. Mem. 375. 78 p.

Stauffer, T.M. 1979. Effects of DDT and PCB's on survival of lake trout eggs and fry in a hatchery and in Lake Michigan, 1973-76. Trans. Amer. Fish. Soc., 108(2):178-186.

Trent W.L. and W.W. Hassler. 1968. Gill net selection, migration, size and age composition, sex ratio, harvest efficiency, and management of striped bass in the Roanoke River, North Carolina. Ches. Sci., 9(4):217-232.

Westin, D.T. and B.A. Rogers. 1978. Synopsis of biological data on the striped bass, *Morone saxatilis* (Walbaum), 1792. Univ. of Rhode Is. Marine Tech. Rept. No. 67. 154 p.

Williams, R.R.G. 1978. Spawning of the striped bass, *Morone saxatilis* (Walbaum), in the Annapolis River, Nova Scotia. M.Sc. Thesis, Acadia Univ., Wolfville, Nova Scotia. 164 p.

Wilson, J.S., R.P. Morgan, II, P.W. Jones, H.R. Lunsford, Jr., J. Lawson and J. Murphy. 1976. Potomac River fishery study - striped bass spawning stock assessment. Final Rept., 1975. Ches. Biol. Lab. UMCEES Ref. No. 76-14. 61 p. + tables.