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The Effects of Tropical Storm Agnes on Fishes in the James, York, and Rappahannock Rivers of Virginia

Walter J. Hoagman

Woodrow L. Wilson

The Effects of Tropical Storm Agnes on the Chesapeake Bay Estuarine System

The Chesapeake Research Consortium, Inc.

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THE CHESAPEAKE RESEARCH CONSORTIUM, INC.

The Johns Hopkins University
Smithsonian Institution
University of Maryland
Virginia Institute of Marine Science

Project Coordinator, Jackson Davis (VIMS)
Volume Coordinator, Beverly Laird (VIMS)

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Preface

During June 1972 Tropical Storm Agnes released record amounts of rainfall on the watersheds of most of the major tributaries of Chesapeake Bay. The resulting floods, categorized as a once-in-100-to-200-year occurrence, caused perturbations of the environment in Chesapeake Bay, the nation's greatest estuary.

This volume is an attempt to bring together analyses of the effects of this exceptional natural event on the hydrology, geology, water quality, and biology of Chesapeake Bay and to consider the impact of these effects on the economy of the Tidewater Region and on public health.

It is to be hoped that these analyses of the event will usefully serve government agencies and private sectors of society in their planning and evaluation of measures to cope with and ameliorate damage from estuarine flooding. It is also to be hoped that the scientific and technical sectors of society will gain a better understanding of the fundamental nature of the myriad and interrelated phenomena that is the Chesapeake Bay ecosystem. Presumably much of what was learned about Chesapeake Bay will be applicable to estuarine systems elsewhere in the world. Most of the papers comprising this volume were presented at a symposium held May 6–7, 1974, at College Park, Maryland, under the sponsorship of the Chesapeake Research Consortium,Inc., with support from the Baltimore District, U.S. Army Corps of Engineers (Contract No. DACW 31-73-C-0189). An early and necessarily incomplete assessment, *The Effects of Hurricane Agnes on the Environment and Organisms of Chesapeake Bay* was prepared by personnel from the Chesapeake Bay Institute (CBI), the Chesapeake Biological Laboratory (CBL), and the Virginia Institute of Marine Science (VIMS) for the Philadelphia District, U.S. Army Corps of Engineers. Most of the scientists who contributed to the early report conducted further analyses and wrote papers forming a part of this report on the effects of Agnes. Additional contributions have been prepared by other scientists, most notably in the fields of biological effects and economics.

The report represents an attempt to bring together all data, no matter how fragmentary, relating to the topic. The authors are to be congratulated for the generally high quality of their work. Those who might question, in parts of the purse, the fineness of the silk must keep in mind the nature of the sow's ears from which it was spun. This is not to disparage the effort, but only to recognize that the data were collected under circumstances which at best were less than ideal. When the flood waters surged into the Bay there was no time for painstaking experimental design. There were not enough instruments to take as many measurements as the investigators would have desired. There were not enough containers to obtain the needed samples or enough reagents to analyze them. There were not enough technicians and clerks to collect and tabulate the data. While the days seemed far too short to accomplish the job at hand, they undoubtedly seemed far too long to the beleaguered field parties, vessel crews, laboratory technicians, and scientists who worked double shifts regularly and around the clock on many occasions. To these dedicated men and women, whose quality of performance and perseverance under trying circumstances were outstanding, society owes an especial debt of gratitude.

It should be noted that the Chesapeake Bay Institute, the Chesapeake Biological Laboratory, and the Virginia Institute of Marine Science, the three major laboratories doing research on Chesapeake Bay, undertook extensive data-gathering programs, requiring sizable commitments of personnel and equipment, without assurance that financial support would be provided. The emergency existed, and the scientists recognized both an obligation to assist in ameliorating its destructive effects and a rare scientific opportunity to better understand the ecosystem. They proceeded to organize a coordinated program in the hope that financial arrangements could be worked out later. Fortunately, their hopes proved well founded. Financial and logistic assistance was provided by a large number of agencies

that recognized the seriousness and uniqueness of the Agnes phenomenon. A list of those who aided is appended. Their support is gratefully acknowledged.

This document consists of a series of detailed technical reports preceded by a summary. The summary emphasizes effects having social or economic impact. The authors of each of the technical reports are indicated. To these scientists, the editors extend thanks and commendations for their painstaking work.

Several members of the staff of the Baltimore District, U.S. Army Corps of Engineers, worked with the editors on this contract. We gratefully acknowledge the helpful assistance of Mr. Noel E. Beegle, Chief, Study Coordination and Evaluation Section, who served as Study Manager; Dr. James H. McKay, Chief, Technical Studies and Data Development Section; and Mr. Alfred E. Robinson, Jr., Chief of the Chesapeake Bay Study Group.

The editors are also grateful to Vickie Krahn for typing the Technical Reports and to Alice Lee Tillage and Barbara Crewe for typing the Summary.

The Summary was compiled from summaries of each section prepared by the section editors. I fear that it is too much to hope that, in my attempts to distill the voluminous, detailed, and well-prepared papers and section summaries, I have not distorted meanings, excluded useful information or overextended conclusions. For whatever shortcomings and inaccuracies that exist in the Summary, I offer my apologies.

Jackson Davis
Project Coordinator

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THE EFFECTS OF TROPICAL STORM AGNES ON FISHES IN THE JAMES, YORK, AND RAPPAHANNOCK RIVERS OF VIRGINIA[1]

Walter J. Hoagman[2]
Woodrow L. Wilson[2]

ABSTRACT

Intensive trawl surveys during and after Tropical Storm Agnes were mounted on the James, York, and Rappahannock Rivers to measure the effects of the floodwaters on the distribution and abundance of fish. The direct effect of Agnes on the fish populations was minor and temporary. The normal zone was extended downriver. A substantial portion of the lower-river (marine) species was also displaced downstream and into Chesapeake Bay, but had returned by the follow-up surveys. No adult mortalities due to Agnes were detected. Although we know vast quantities of fish larvae and other plankton were swept into Chesapeake Bay, the overall impact on all fish appears to have been slight.

INTRODUCTION

The Department of Ichthyology of the Virginia Institute of Marine Science mounted intensive trawl surveys in the James, York, and Rappahannock Rivers during and after Agnes to determine the impact of the floodwaters on the resident and seasonal fishes.

METHODS

The initial survey took place between 28 June and 3 July 1972, the week after Agnes flooded the upper rivers and sent massive amounts of fresh water through the lower estuaries. The sampling scheme consisted of five replicate tows at three stations with a 30-ft, semi-balloon, bottom trawl (3/4-inch-mesh codend) for 7.5 minutes each. Six additional stations per river were sampled once. All stations were between the mouth of the river and just into the normal freshwater zone, with the replicate stations taken near the mouth, near the freshwater interface, and midway between. All surveys were conducted from the R/V *Langley*. River miles are given in Fig. 1.

Followup studies were made twice. Between 8 August and 7 September 1972 the sampling scheme of the initial survey was repeated to measure the recovery of the fish populations. In addition, five replicate samples were collected at Mile 39 in the James River. Between 30 October and 8 November 1972 another survey was undertaken with single tows at eight stations in the lower James, York, and Rappahannock Rivers up to Mile 36-50.

RESULTS

The results presented here represent conditions at the time of the three surveys. The entire isohaline movement during and after Agnes is covered in other sections of this volume. Fish were counted and measured individually but, for

[1]Contribution No. 761, Virginia Institute of Marine Science
[2]Virginia Institute of Marine Science, Gloucester Point, Va. 23062

simplicity, only average lengths are presented here. All trawling was performed in waters deeper than 7 m, thus we cannot provide data on changes in fish populations in the shoal communities. Because the fresh water ran out primarily along the surface (down to 3-6 m, mainly), we suspect the shoal fishes were affected first and most: they probably sought the deeper, more saline waters adjacent to their immediate locale. Conclusions in this report are therefore limited to the mainstream bottom community.

James River

The flood crest passed Richmond on 23 June 1972. It passed down the river as a surge, depressing salinities in the lower 30 miles within two days, with the lowest salinities reported on 28 June (Chesapeake Bay Research Council 1973). A sharp halocline was established by 28 June but the salinities rebounded in the bottom waters within 10 days. The stratified condition, with fresh water at the surface (0-8 m) and much higher salinity below, disappeared as the flow weakened. By 25 August (63 days after the crest) the salinity profile at a particular station (on low slack tide) was fairly uniform without the pronounced halocline of earlier dates. There was a net downstream displacement of approximately 6-10 miles in the bottom salinities between the worse case and the normal (Fig. 2). Oxygen was adequate for fish in the James River on every survey at the stations sampled ($O_2 \geq 4.7$ ppm).

The summer fish populations of the James River follow the typical pattern of estuarine migrants in the lower reaches (e.g. spot, *Leiostomus xanthurus;* Atlantic croaker, *Micropogon undulatus;* and weakfish, *Cynoscion regalis*) with a gradual transition to resident freshwater species in the middle to upper sections (e.g. channel and white catfish, *Ictalurus punctatus* and *I. catus;* American eel, *Anguilla rostrata;* and juvenile shad, *Alosa sapidissima*). White perch *(Morone americana)* have been partially absent from the James River since 1971 (St. Pierre & Hoagman 1974) and the striped bass *(Morone saxatilis)* has been at very low abundance (Merriner & Hoagman 1974).

The freshwater species did not move downstream appreciably with the 1 ppt isohaline. White and channel catfish were equally abundant at Mile 25 during and after Agnes; none were captured at Mile 10 during Agnes, even though the salinities had fallen to tolerable levels. Juveniles of blueback herring (*Alosa aestivalis)*, American shad, and alewife *(Alosa pseudoharengus)*, which are pelagic and normally live in fresh water, were not captured at Mile 10-13 during Agnes or later. Carp *(Cyprinus carpio)* and brown bullhead *(Ictalurus nebulosus)* were not found any further downstream during Agnes than after.

Apparently the normal zones of residence for the freshwater species were maintained, even though the size of the zone had been extended downriver temporarily. The downstream extension of the freshwater zone was probably too rapid for these species to become aware of the expanded area and move into it. Since they normally live in fresh water, the additional flow provided no stimulus to leave their normal habitat.

Most species in the lower river can only tolerate particular minimum salinities. For these species, fresh water can be considered a pollutant that causes avoidance, or death if they are entrained. Being mobile, most would be expected to avoid falling salinities by moving out with the flow. Since most of these species commonly live in salinities 4 to 20 ppt in the lower rivers, the 0.5 to 5 ppt displacement (oligohaline zone) can be considered the avoidance zone.

Atlantic croaker and weakfish (grey trout) moved approximately 10 miles downstream during Agnes but had returned upriver two months later (Table 1).

Table 1. Catches and mean lengths (mm) of six major fishes captured in the James (J), York (Y), and Rappahannock (R) Rivers during and after Tropical Storm Agnes. Stations with asterisks (*) had five replicate tows made. A dash (-) indicates that no tow was made.

River and Mile	White Catfish						Channel Catfish					
	28 Jun - 3 Jul		8 Aug - 7 Sep		30 Oct - 8 Nov		28 Jun - 3 Jul		8 Aug - 7 Sep		30 Oct - 8 Nov	
	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length
J-00	0		0		0		0		0		0	
05	0		0		0		0		0		0	
10*	0		0		-		0		0		-	
13	0		0		0		0		0		0	
19	2	95	6		1	175	1	232	2	275	1	437
25*	4	122	2	129	3	87	1	181	7	136	6	110
27	2	111	2	76	2	100	17	178	14	142	15	105
32	5	97	0		0		36	146	17	131	4	175
36	6	112	2	25	0		19	144	36	132	26	97
39*	-		8	90	-		-		48	167	-	
Y-00*	0		0		0		0		0		0	
05	0		0		0		0		0		0	
10	1	387	0		0		0		0		0	
15	3	230	0		0		0		0		0	
20	4	252	5	281	1	295	0		0		0	
25*	3	247	10	278	2	339	0		0		0	
30	2	116	8	200	51	215	0		0		0	
35	8	85	4	148	41	200	0		0		0	
40	3	214	38	86	13	13	0		3	128	5	177
50	0		2	232	8	151	0		4	166	3	153
R-00	0		0		0		0		0			
05*	0		0		0		0		0			
10	0		0		0		0		0			
15	0		0		0		0		0			
20*	1	276	0		0		0		0			
25	0		3	282	1	254	0		0			
30	3	171	27	180	0		0		0			
35*	8	89	4	136	7	153	0		0			
40	40	137	6	89	9	65	0		0			

Table 1. Cont'd.

River and Mile	Hogchoker						American Eel					
	28 Jun - 3 Jul		8 Aug - 7 Sep		30 Oct - 8 Nov		28 Jun - 3 Jul		8 Aug - 7 Sep		30 Oct - 8 Nov	
	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length
J-00*	111	125	69	129	8	109	0		0		0	
05	339	115	54	126	94	134	0		0		0	
10	121	114	85	120	-		2	423	1	435	-	
13	85	120	38	117	49	130	3	424	4	485	3	289
19	17	96	39	90	103	120	4	321	14	290	4	439
25	2	64	6	89	56	105	1	313	8	305	0	
27	0		2	58	103	109	0		13	291	0	
32	1	51	0		6	111	0		6	302	0	
36	1	36	0		10	99	0		1	310	0	
39*	-		2	50	-		-		13	315	-	
Y-00	102	120	0		0		0		0		0	
05	52	131	1	140	7	131	0		0		0	
10	57	117	4	130	349	134	2	447	0		1	412
15	446	102	0		155	128	1	505	3	476	1	315
20	66	109	119	134	423	136	0		13	505	0	
25	30	135	98	91	54	125	2	405	4	497	6	353
30	7	95	26	72	183	117	0		1	470	5	391
35	11	53	9	77	238	116	0		0		1	410
40	6	43	27	64	520	119	2	300	0		1	420
50*	17	37	8	70	185	105	1	373	0		0	
R-00*	9	121	95	118	3	120	0		0		0	
05	42	108	52	122	1	123	1	489	2	525	0	
10	144	107	294	121	17	125	1	499	6	516	0	
15	119	105	41	122	1	110	1	461	0		0	
20	63	88	174	124	1	78	2	519	2	564	0	
25	7	90	80	111	33	118	2	578	20	417	2	431
30	7	86	76	101	352	113	3	575	36	498	3	419
35	27	42	78	77	514	109	1	593	1	467	2	638
40*	9	73	119	61	67	88	1	357	11	272	0	

Table 1. Cont'd.

River and Mile	Spot						Atlantic Croaker					
	28 Jun - 3 Jul		8 Aug - 7 Sep		30 Oct - 8 Nov		28 Jun - 3 Jul		8 Aug - 7 Sep		30 Oct - 8 Nov	
	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length	Number per tow	Mean length
J-00*	13	188	88	177	34	159	61	144	188	185	3	117
05	2	137	3	201	22	154	59	148	102	170	33	132
10*	8	161	33	170	-		25	152	57	190	-	
13	61	151	12	180	32	141	39	143	21	152	44	119
19	0		4	127	29	130	10	87	219	143	28	99
25*	0		0		0		1	79	16	124	9	68
27	0		0		0		0		7	97	1	22
32	0		0		0		1	66	1	75	2	27
36	0		0		0		0		14	53	7	39
39*	-		0		-		-		6	94	-	
Y-00*	73	173	2	176	2	151	129	139	1	142	1	97
05	7	167	9	186	11	140	68	136	0		4	86
10*	4	168	14	138	2	131	14	121	5	178	13	128
15	30	113	8	127	4	142	38	128	0		8	96
20	1	115	190	124	2	152	51	128	26	180	39	114
25*	27	89	31	120	1	124	607	112	10	166	22	105
30	0		5	112	9	134	0		55	80	60	90
35	0		0		0		0		23	60	12	62
40	0		0		0		0		0		0	
50	0		0		0		0		0		0	
R-00	84	154	112	139	39	133	0		26	133	35	87
05*	149	111	599	137	119	137	1	146	7	115	7	95
10	34	98	310	137	302	128	0		2	184	16	126
15	125	99	50	125	9	151	21	135	0		5	85
20*	29	99	112	127	36	131	5	123	9	150	10	74
25	7	93	9	137	251	132	0		10	161	15	108
30	28	94	2	144	115	139	5	103	22	178	26	134
35*	0		35	123	23	123	0		63	108	5	91
40	0		4	87	4	124	0		36	80	10	60

Table 1. Cont'd.

River and Mile	Weakfish: 28 Jun - 3 Jul Number per tow	28 Jun - 3 Jul Mean length	8 Aug - 7 Sep Number per tow	8 Aug - 7 Sep Mean length	30 Oct - 8 Nov Number per tow	30 Oct - 8 Nov Mean length
J-00*	4	170	54	195	28	117
05	5	162	10	67	45	121
10*	2	164	21	85	0	
13	0		12	106	9	134
19	0		4	156	0	
25*	0		7	31	0	
27	0		1	27	0	
32	0		4	28	0	
36			3	28	0	
39			0			
Y-00*	6	193	1	76	0	
05	1	189	0		0	
10*	0		1	91	0	
15	1	200	0		3	174
20	0		7	89	1	105
25*	0		3	202	0	
30	0		27	88	0	
35	0		0	91	0	
40	0		0		0	
50	0		0		0	
R-00	14	206	71	99	2	122
05*	1	167	22	133	3	124
10	0		3	73	124	111
15	1	174	7	199	3	106
20*	1	38	15	107	1	147
25	0		3	137	8	151
30	0		12	126	28	123
35*	0		27	107	3	142
40	0		0		0	

At Mile 25 the Agnes survey captured none of these species, although two months later 80 croakers and 34 weakfish were taken in five replicate tows. Maximum abundance of these fish was within the lower 10 miles during both surveys, but the fresh water at Mile 19 on 18 and 29 June (Fig. 2) may account for their absence upriver. Hogchoker were displaced but not to the extent of croaker or weakfish. Silver perch were not captured at Mile 10 during Agnes but were present up to Mile 19 during the first follow-up survey. Between Mile 10 and the mouth (Mile 0) no detectable displacement of fishes occurred.

By 2 November 1972, the distribution of croaker, spot, hogchoker, silver perch, and bay anchovy was essentially the same as during the follow-up survey in August. The freshwater species were distributed as in previous surveys, with channel catfish and white catfish first appearing at Mile 19 and increasing in abundance upriver.

At Miles 0 and 10 on 28 and 29 June there were 107 spot, 431 croaker, and 27 weakfish captured with the 10 tows. On 8-10 August at the same stations there were 604 spot, 1,223 croaker and 376 weakfish captured. This represents a fourfold increase of these species after the flood in the lower river. Crowding in the lower river during Agnes would have shown a reverse pattern. Time of year and variability at stations may account for part of this increase, but it seems a substantial portion of the populations was actually "moved" out of the James during Agnes, and not merely crowded together downstream. We did not sample outside of the lower James River during Agnes, or the follow-ups, so we cannot demonstrate this effect except circumstantially. The mean lengths during Agnes, and from the follow-up surveys, indicate no substantial recruitment of the youngest year-classes to the river populations.

The flood waters, being of lesser density, overlaid the denser water of the lower James River. The sharp halocline (in vertical profile) continued to at least 19 July (Chesapeake Bay Research Council 1973). This fresher water affected the shoals first and would be expected to move the euryhaline fishes into deeper and saltier waters. The trawl catches during Agnes would have been greater at equivalent stations if this were the only displacement, because during the follow-up surveys the shoals had returned to normal salinity and the fishes would be redispersed. Since the Agnes catches were far less, and spot, croaker, and weakfish were downstream, it seems the flood water not only caused the fish to move downstream, but additionally caused a pronounced movement out of the river.

York River

The York River with its much smaller watershed did not have the equivalent freshwater input as the James River. However, being much smaller overall, the proportional impact was the same as or greater than in the James River. The initial flood surge displaced the 1 to 5 ppt isohaline to the maximum, eight days after the crest passed the fall line on 23-26 June 1972. We trawled the York on 29 and 30 June. At this time the fresh water had diluted the entire river and the normal bottom salinities were displaced approximately 12 miles downriver (Fig. 3) Vertical stratification, while evident, was not as intense as in the James River.

The fish populations in the York River reacted similarly to those in the James River. The freshwater species were captured somewhat lower in the river than normal, as shown by the distribution of white catfish and hogchoker (Table 1). There was no mass movement detectable. The euryhaline species in the lower salinity zones between Miles 15 and 28 moved downriver in response to the decreased salinities.

Large numbers of croaker and spot were captured at Mile 25 during Agnes and again during the follow-up of 21-23 August. Their average lengths, however, show that it was only the very young that remained in the lowered salinity after Agnes. At Mile 25 the spot were 89 mm, and the croaker 112 mm. Two months later the respective length were 120 mm and 166 mm, too much for growth alone. The average size for both croaker and spot increased downriver during Agnes (Table 1), and it is these fish that probably repopulated the middle York River over the following two months. Weakfish were not captured above Mile 15 during Agnes, but were fairly abundant between Miles 20 and 35 two months later.

Catches at Miles 0 and 10 during 21-23 August must be omitted from evidence used to demonstrate displacement because the oxygen was nearly depleted near bottom. On 3-8 November oxygen was normal at these stations for mid-fall and the fish were again present.

Rappahannock River

The "worst case" condition occurred on 10 July 1972, 18 days after Agnes crested at the fall line. The 1 ppt isohaline (at low slack water) intersected bottom at Mile 34, 5 ppt at Mile 23, and 8 ppt at Mile 6 (Chesapeake Bay Research Council 1973). The initial displacement occurred 2 days after the flood crested at the fall line on 22 June. A layer of extremely fresh water 5-10 m deep established a pronounced halocline in the lower river, with fresh water (surface readings) extending below Mile 15. Recovery was slowed by a 10 m sill which blocked the mouth to high salinity bay water.

Salinity data collected during bottom trawling show there was fresh water at Mile 35 several days after Agnes (Fig. 9). Before Agnes and during 6-7 September, the salinity was about 2.5 ppt at Mile 35, depending on tide. During the first follow-up, 1 ppt extended above Mile 40. Oxygen was low (2-3 ppm during Agnes and the first follow-up between Miles 5 and 25, but spot, hogchocker, and weakfish were still abundant.

The fish catches at Mile 35 during Agnes, contained few of the euryhaline varieties such as spot, croaker, and weakfish; but after 2 months they had repopulated the area up to Mile 40 (Table 1). As in the James River, the overall catch during the effects of Agnes was much less than during the follow-up surveys, suggesting that they were displaced out of the river temporarily. Average lengths indicated no tendency for a size selective migration to the lower river, as found in the York. Eels and hogchokers were found at most stations during the two major surveys.

The lower river contained fair quantities of all expected species during the 30-31 October survey (Table 1). These fish were distributed nearly uniformly up to Mile 30 where the bottom salinity was 5.3 ppt. The salinity fell to 0 ppt at mile 40 and the euryhaline species declined in abundance.

CONCLUSIONS AND DISCUSSION

In all rivers sampled, the yearling and older fishes that normally occupy salinities 3 ppt and higher were displaced downstream by the flood waters of Agnes. This displacement was 8-14 miles and extended throughout the river, apparently resulting in a portion of the population being "forced" out of the rivers. Increased concentration of fish in the lower portions of the rivers was not detected.

The direct effect of the Agnes flood waters on the fish populations seems to have been minor and temporary. Dead or sick fish were not captured and no fish kills were apparent from surface observations. Freshwater species moved downstream somewhat but not to the extent possible based on the changed salinity structure. The shoal-water fish probably moved first into deeper water, then downstream as the channel water became fresher.

The effects on larval fish have not yet been determined. A special study using suspended plankton nets in mainstream during Agnes (Hoagman, unpublished data) showed large quantities of fish larvae and other plankton were swept out of the James and Rappahannock Rivers into Chesapeake Bay. When these samples are processed, a better assessment of the indirect effects on the nurseries and direct effects on the larvae will be more clearly known.

When Hurricane Camille flooded the James River in late August 1969 the fish reacted as in this study. Camille caused the James to crest at 24.9 ft in Richmond, 11.6 ft less than Agnes. The maximum discharge was 282,000 cfs for Camille compared to 319,000 cfs for Agnes.

VIMS made trawl surveys of the James River before, during, and after Camille. The survey used surface, bottom, and midwater trawls from Mile 0 to Mile 80 near Richmond. Replicate bottom tows were not taken, and Miles 10, 15, and 20 were not sampled during the flood. The surface-trawl catches of juvenile alewife, blueback herring, and American shad showed a pronounced downstream movement of these pelagic species. Before the flood they were concentrated between Miles 46-65, but during the flood they were most abundant between Mile 25 and Mile 40 (St. Pierre et al. 1970).

Displacement of the lower river species between Miles 6 and 24 was unproven for Camille because these stations were not occupied. Three to four weeks after Camille, the fish populations of the central James returned to the pre-flood distribution, but the catches were less at 8 bottom and 16 midwater stations over a 50 mile stretch of river.

Of two other reports on the effects of hurricanes on fishes, Hubbs (1962) considered that the small pools he investigated in Texas were drastically changed; whereas Tabb and Jones (1962) believe no permanent damage was done to the fish populations in north Florida Bay by Hurricane Donna. The temporary effects of Donna were widespread and the changes in environment caused considerable fish movement.

For the freshwater and euryhaline species, it appears no real damage (i.e., reduction in abundance due to death) was done to the stocks because of Agnes. The temporary displacement had little effect on the commercial and sportfishing activities of the lower rivers. The estuarine nursery grounds were repopulated within several weeks. Unless the ichthyoplankton were seriously affected, the overall impact of Agnes on the fish populations in Virginia seems to have been negligible.

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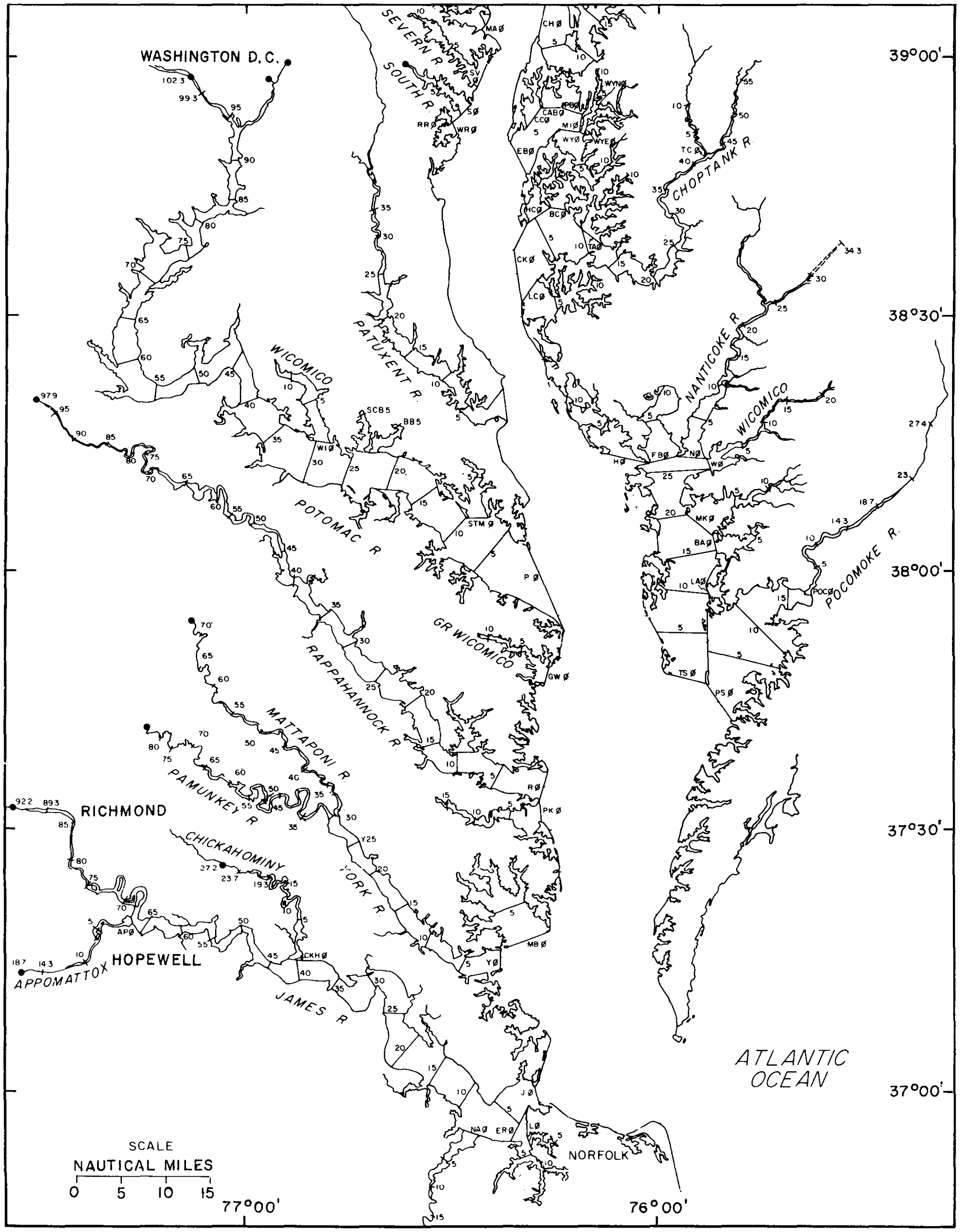

Figure 1. Locator map of study area with river miles indicated.

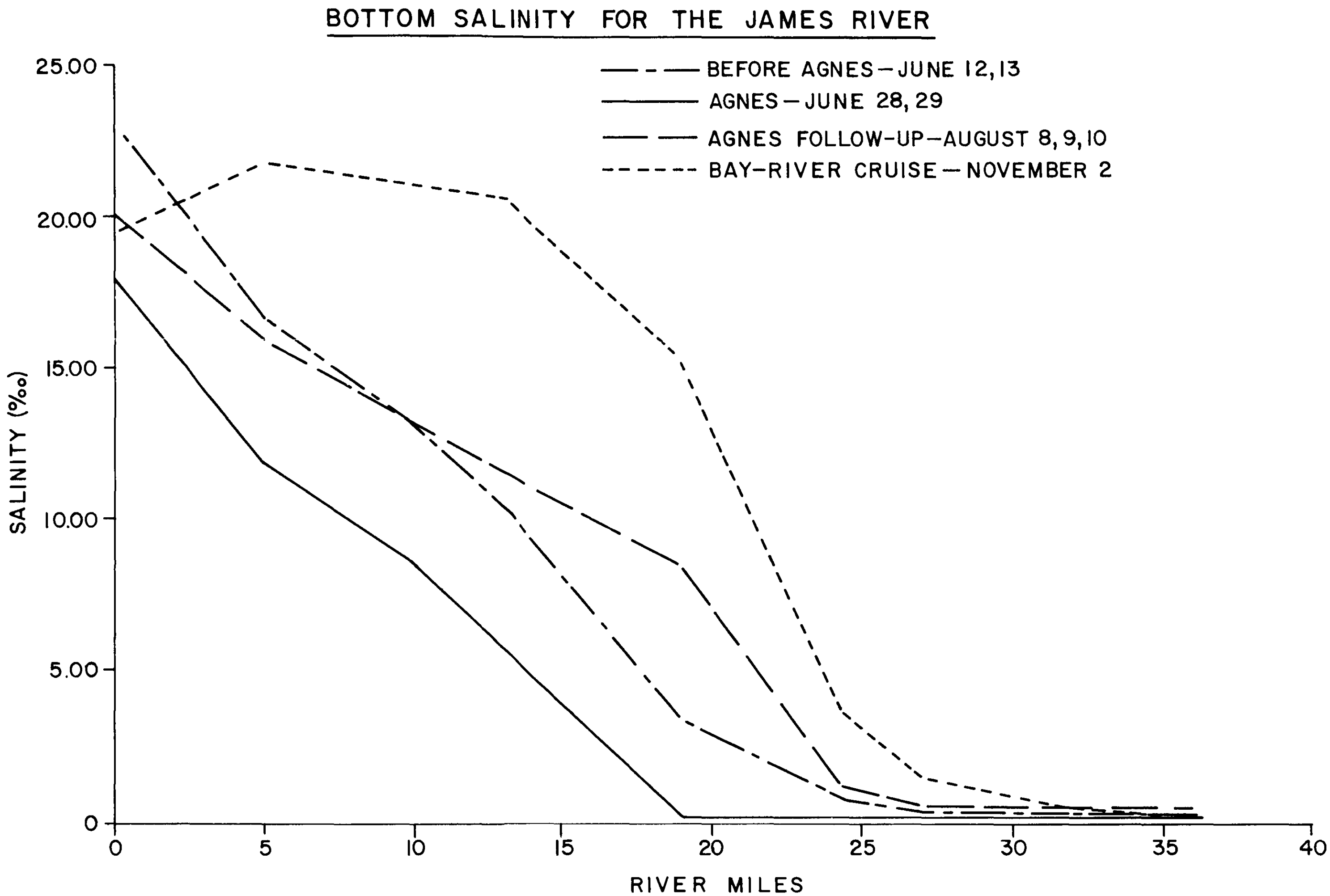

Figure 2. James River bottom salinity during trawling operations before, during, and after Agnes. Mainstream only.

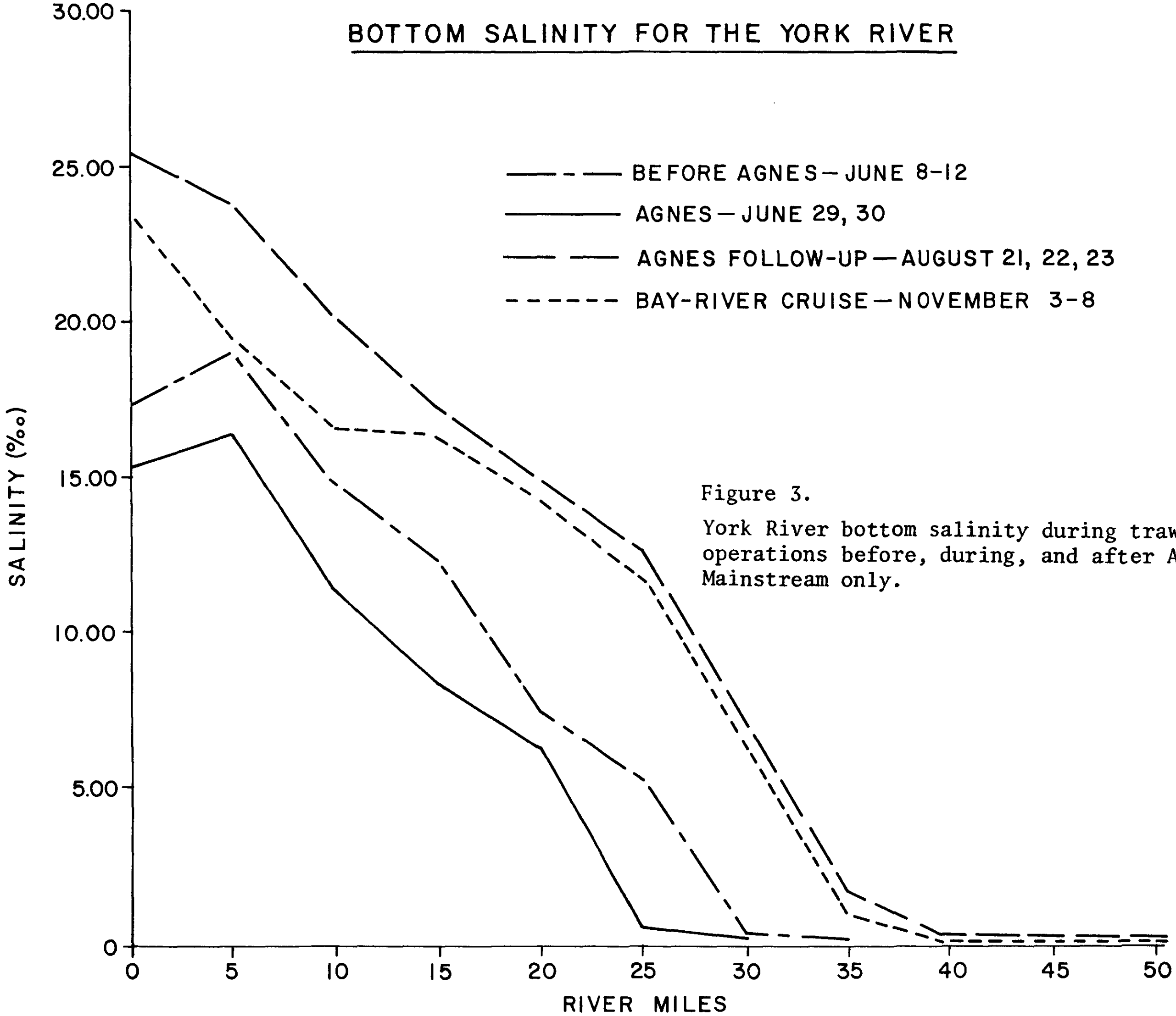

Figure 3.

York River bottom salinity during trawling operations before, during, and after Agnes. Mainstream only.

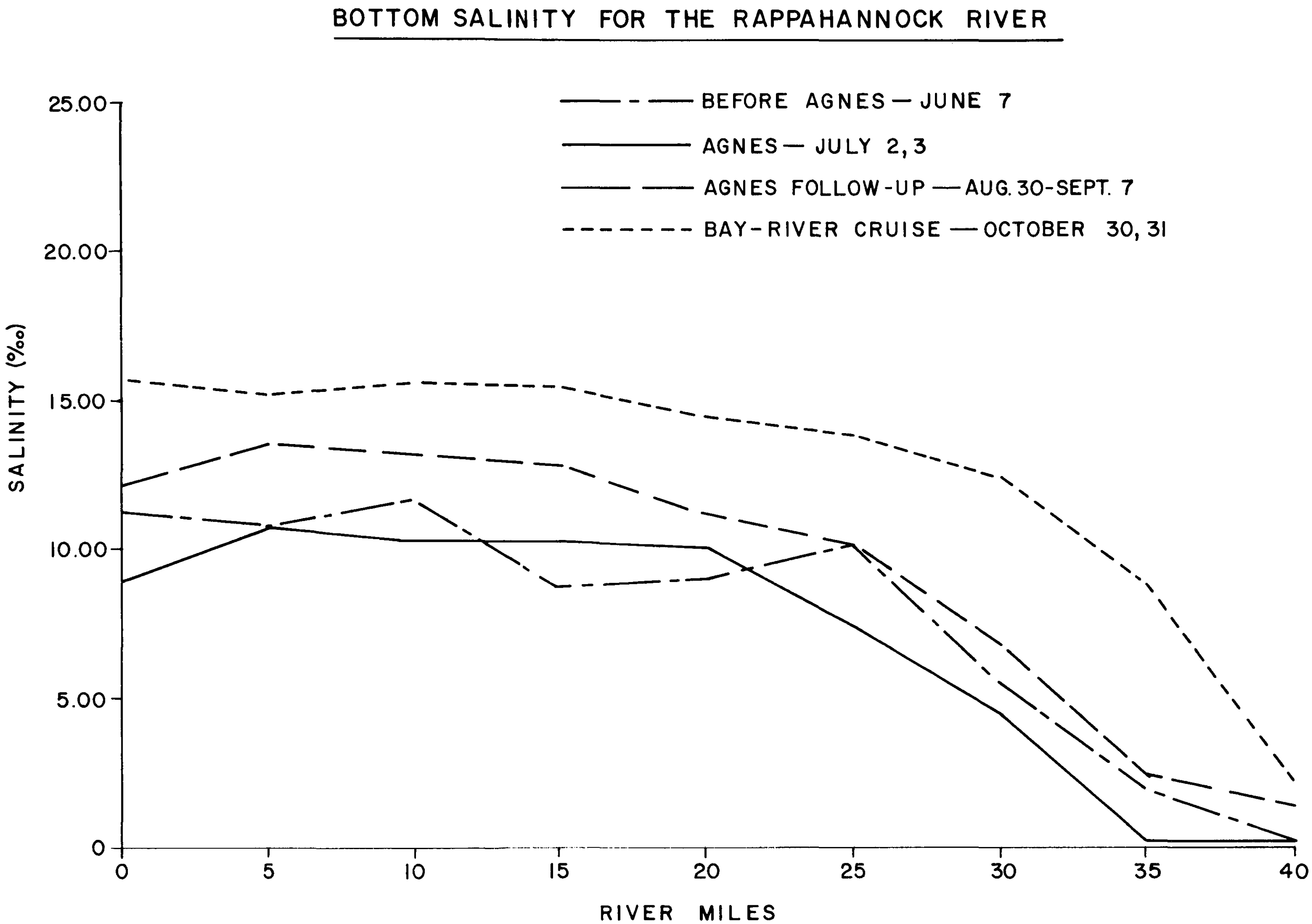

Figure 4. Rappahannock River bottom salinity during trawling operations before, during, and after Agnes. Mainstream only.