LARGE-SCALE EXPERIMENTAL TEST OF COPPER SULFATE AS A CONTROL FOR THE FLORIDA RED TIDE

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LARGE-SCALE EXPERIMENTAL TEST OF COPPER SULFATE AS A CONTROL FOR THE FLORIDA RED TIDE

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ABSTRACT

The first large-scale attempt at controlling the red tide was made in the autumn of 1957. About 16 square miles stretching along 32 miles of shoreline from Anclote Key to Pass-a-grille Beach, off St. Petersburg, Florida, were dusted with copper sulfate ($CuSO_4 \cdot 5H_2O$) at about 20 pounds to the acre by crop-dusting planes. The copper very quickly reduced *Gymnodinium breve*, the red tide organisms, from several million to practically none per liter relieving the area of the respiratory irritation caused by the airborne toxin of *G. breve*. In 2 out 5 areas the organisms rose again to concentrations lethal to fish in 10 to 14 days after dusting. This method is not recommended for general control, but will give temporary relief in local situations from the airborne toxin.

TABLE OF CONTENTS

TABLES

ILLUSTRATIONS

LARGE-SCALE EXPERIMENTAL TEST OF COPPER SULFATE AS A CONTROL FOR THE FLORIDA RED TIDE

Laboratory experiments, and a few field experiments (Joe O. Bell, unpublished manuscript), have indicated that the red

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Special Scientific Report--Fisheries No. 270, LARGE-SCALE EXPERIMENTAL TEST OF COPPER SULFATE AS A CONTROL FOR THE FLORIDA RED TIDE by George A. Rounsefell and John E. Evans.

In March 1958, after the completion of the manuscript of this report, a selected panel of 14 biologists versed in this field of research were invited by the Director of the Bureau of Commercial Fisheries to a symposium on red tide held at Galveston, Texas. It was the concensus of this group, after mature consideration of the copper sulfate experiment, that the combination of excessive cost, short duration of control, and possibility of harm to other marine life render application of the method inadvisable.

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a large orange target on the beach and the laboratory vessel Kingfish, which maintained by radar a stable position just offshore of the area of discolored water. After each plane load the vessel and target were moved forward.

This method was abandoned because (1) it tied up the vessel, which was needed for sampling, (2) it was difficult to use the beach target except on straight stretches of beach, and (3) many dense patches of discolored water were somewhat offshore, and did not require dusting close to the beach. After some experimentation

ILLUSTRATIONS

LARGE-SCALE EXPERIMENTAL TEST OF COPPER SULFATE AS A CONTROL FOR THE FLORIDA RED TIDE

Laboratory experiments, and a few field experiments (Joe O. Bell, unpublished manuscript), have indicated that the red tide organism, Gymnodinium breve, is easily killed by fairly low concentrations of copper ions. Because of the relatively low cost of copper sulfate crystals ($215 a ton, delivered) it was felt that copper sulfate, if it could be properly applied, might prove to be useful as a control agent.

Accordingly, when the red tide outbreak of 1957 started offshore from St. Petersburg, Florida, it was decided to make the first large-scale attempt to determine the feasibility of control (table 1, page 5; figs. 1 and 2, pages 41 and 42). The feasibility was to be gauged by:

1. Cost of control for the area covered.
2. Duration of control.
3. Whether any apparent damage to other organisms occurred.

NOTE.--This large-scale attempt at control was participated in by all members of the Gulf Fishery Investigations working on red tide. William B. Wilson, and Drs. Sammy M. Ray and David V. Aldrich from the Galveston Laboratory made the counts of G. breve in the sea-water samples, assisted by Dr. McKinley Jambor and Jean Gates. John Finucane made an aerial reconnaisance each day and developed the final dusting technique. Alexander Dragovich made the vessel surveys and collected the samples for both copper analysis and G. breve counts. Especial credit should also be given pilot William D. (Tommy) Wood who flew the Service plane and Captain John D. McCormick who operated the vessel Kingfish regardless of weather. As indicated in the text, the Florida State Board of Conservation took an active and vigorous part, and special thanks due Ernest C. Mitts, Director; Robert M. Ingle, Director of Research; and Dr. Robert F. Hutton, in charge of their St. Petersburg Laboratory.

As far as the third criterion is concerned but little information was obtained, but more concerning the effect of copper on other organisms under actual field conditions is being gathered in another experiment.

The incidence of red tide and the density of the organisms, before, during, and after the experiment, were gauged by aerial and vessel observation of dead fish and discolored water, and, more accurately, by consistent laboratory counts of the organisms from water samples collected through the period. The detailed data are contained in tables 2 to 4 (pages 6 - 24).

Despite the emergency nature of the operation numerous water samples were collected for copper analysis throughout the period (tables 4 and 5, pages 24 and 40).

DUSTING METHODS

Since there was no previous experience of large-scale dusting over water areas without discrete boundaries it was necessary to improvise and develop methods as the work proceeded. On land the crop-dusting planes can follow rows of plantings or fly straight toward a definite object, and the end of the field or area is usually clearly defined.

Our first attempt to provide a target and line of flight for the dusting planes consisted in having the planes dust between a large orange target on the beach and the laboratory vessel Kingfish, which maintained by radar a stable position just offshore of the area of discolored water. After each plane load the vessel and target were moved forward.

This method was abandoned because (1) it tied up the vessel, which was needed for sampling, (2) it was difficult to use the beach target except on straight stretches of beach, and (3) many dense patches of discolored water were somewhat offshore, and did not require dusting close to the beach. After some experimentation the best method developed was for a biologist to fly with the Service pilot over the area to be dusted about five minutes ahead of the dusting planes, and drop a 15-minute smoke bomb in the center of the area to be sprayed.

Laboratory experiments (W. B. Wilson, manuscript) showed that G. breve could be effectively killed in 1 to 3 hours by copper concentrations of 0.05 and 0.10 parts per million, equivalent to 0.8 and 1.6 microgram atoms per liter. In making calculations of the pounds of copper sulfate per acre to use in dusting, if we assume a depth of 10 feet then 20 pounds of $CuSO_4$ $5H_2O$ per acre will give 0.18 parts per million of copper or 2.9 microgram atoms per liter.

Of course, the laboratory experiments presuppose a uniformly mixed solution, so that the amount used in the field needs to be somewhat higher to allow for uneven mixing. The copper content of water samples taken soon after dusting showed that the amount used was probably close to the minimum effective dose, since the samples were consistently lower than would be expected from the calculations. Also, the average depth of the water sprayed probably was closer to 20 than to 10 feet.

On the first day the dusting planes attempted to use about 25 pounds per acre. The immediate effect on the red tide organisms was so drastic that we cut the amount back to 20 pounds per acre, which was thereafter maintained.

NARRATIVE OF EXPERIMENTAL CONTROL OPERATIONS

On Thursday, September 26, dead fish in small numbers were observed in the vicinity of John's Pass and Madeira Beach, near St. Petersburg, Florida (fig. 3, page 43). The Florida State Board of Conservation and the headquarters of the Gulf Fishery Investigations in Galveston were immediately alerted.

Counts of G. breve made on the 27th from samples of water collected on the 26th showed concentrations of fish killing proportions. The staff of the Gulf Fishery Investigations immediately distributed 7,200 pounds of copper sulfate, kept on hand for experimental purposes, in a small area of high G. breve concentrations off Madeira Beach, by dragging the material behind a vessel in burlap sacks. Although the copper sulfate was obviously effective in this small area, it was at the same time apparent that such slow distribution methods would be inadequate for treating a major outbreak.

After reviewing the situation (figs. 4 and 5, pages 44 and 45) on Saturday night, the 28th, 20 tons of powdered copper sulfate were purchased. The material was ordered early Sunday morning and at 3:30 p.m. the first loads of copper sulfate were sprayed on the heavy concentrations of red tide organisms noted off Blind Pass, by two crop dusting planes hurriedly summoned from Fort Myers.

Before dusting commenced, the beaches near Blind Pass showed rows of dead fish and the airborne toxin from G. breve caused coughing and choking among residents along the beach. The spraying rapidly destroyed the organisms as shown in figures 14 to 18 (pages 54-56).

On Monday, September 30 (see fig. 6, page 46), state officials pledged immediate action to obtain release of funds to combat the outbreak, since no federal funds were available beyond those used on an emergency basis from the research budget of the federal laboratory. The State of Florida released $50,000 from the previously established Red Tide Emergency Fund and the control experiment was continued.

The Florida State Board of Conservation worked closely with the Bureau of Commercial Fisheries laboratory, not only by furnishing necessary funds, but also the vessel Punjab for water sampling, the vessel Mayan to distribute copper sulfate in waters beyond the range of the planes (note the two offshore areas off Tarpon Springs in fig. 2, page 42), and conservation agents with radio-equipped cars and walkie-talkies for maintaining close contact between vessels, scouting planes and the crop-dusting planes. The U. S. Coast Guard Air Station and the Coast Guard District Office cooperated by furnishing helicopters from the air station at St. Petersburg for spotting infested areas, and dye packs and smoke bombs used in marking the areas to be sprayed.

Control operations were completely

stopped by very heavy rains and overcast from the afternoon of September 30 to the late afternoon of October 2 (fig. 7, page 47). Unhampered, the organisms increased in numbers and spread to new areas. The airborne toxin was causing extreme discomfort along several miles of beach. When the weather cleared two more planes were summoned and all four planes sprayed on October 2, 3, and 4 (see figs. 8 and 9, pages 48 and 49).

By October 5 spraying from the north and south had restricted the heavy infestations in the area from Clearwater Beach to the north end of Honeymoon Island (fig. 10, page 50). Two planes finished dusting the heavily infested patches in this area (figs. 11 and 12, pages 51 and 52). The last inshore patch was sprayed on October 8 (fig. 13, page 53). Water samples were taken daily and coordinated with aerial observations of the affected section to quickly indicate any signs of recurrence.

Following the major spraying water samples were taken farther offshore and the October 8 samples showed high concentrations 8 miles off Belleair Beach and 10 miles northwest of Anclote Key. Another inshore concentration just off Honeymoon Island was treated on October 9 with a light copper sulfate spraying. The offshore concentrations are beyond the practical range of the small crop-dusting planes. Any far offshore control by dusting must depend either on multi-engine planes or vessels.

The areas of high infestation on various dates during this outbreak stretched along 32 miles of beaches from Anclote Key on the north, south to the Don Ce-Sar Federal Center at St. Petersburg Beach (fig. 2, page 42). The total area sprayed was approximately 16 square miles, or 10,240 acres. The attempted rate of spraying was 20 pounds per acre, and 210,000 pounds of copper sulfate was used which gives a close approximation of the desired amount.

The number of fish killed by the red tide cannot be estimated accurately, but it would certainly total in the millions. Thus a kill of one fish per square yard equals about 5,000 per acre or approximately 50,000,000 in the estimated 10,240 acres of water dusted. At times the numbers of freshly killed fish greatly exceeded this density in fair sized patches. However, due to the drifting action of the wind and the convergence of currents along tidal interfaces the dead fish soon tend to form in long dense windrows, making any accurate tallies impossible. Furthermore, the fish, such as mackerel, without swim bladders sink when killed. The fish killed were preponderately much below commercial size, and chiefly of non-commercial species.

The costs to October 9 for copper sulfate, spraying, plane charter and various miscellaneous items were approximately:

Gulf Fishery Investigations' Research Funds	$13,000
State of Florida Red Tide Emergency Fund	30,000
TOTAL COST	$43,000

Examination of figures 14 to 18 (pages 54 and 56) shows that although the spraying promptly reduced the organisms to practically nothing in the areas sprayed, the effects were not lasting. In a matter of two weeks concentrations in 2 out of 5 localities had again reached fish-killing proportions. Since the range in density of G. breve required to kill fish varies with the species of fish from a minimum of about 250,000 to 500,000 or more per liter, we have arbitrarily shown 250,000 per liter as the killing concentration in the figure.

SUMMARY

This large-scale attempt at control showed that:

1. For areas close to land (up to about 3 miles offshore) and in shallow water (up to at least 30 feet) spraying of copper sulfate crystals at about 20 pounds to the acre will destroy the red tide organisms.

2. There is a high probability that the organisms may again become numerous in such a dusted area. On the basis of this one experiment it appears that they might rebuild within 10 to 14 days.

3. The cost of this dusting was about $4 per acre. On the basis of experience gained we believe this cost can be readily reduced to $3 per acre. On the

basis of a half-mile wide strip off the beach the dusting cost about $1,000 per mile.

4. The spraying of such a restricted area cannot insure that the beaches may not receive the bodies of dead fish killed elsewhere and drifted in by tides and in-shore winds.

5. The chief benefit from this type of restricted spraying is the temporary relief from the choking and coughing caused by the airborne toxin of G. breve. This is especially bad on the beaches where it is apparently thrown into the air by the breaking surf.

CONCLUSION

In conclusion, we cannot recommend the dusting of copper sulfate as a control for a red tide outbreak of serious proportions. Until some cheaper and more effective means of control is discovered, it may serve in local situations to give immediate temporary relief from the airborne toxin.

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Table 1.--Copper sulfate sprayed by area and date

Area	Date sprayed	Tons of copper sulfate	Area sub-totals
Blind Pass	Sept. 29, 1957	1.5	
Do.	30	4.5	6.0
Johns Pass	Oct. 1	3.1	
Do.	2	6.3	
Do.	3	5.3	14.7
Indian Rocks	Oct. 3	17.85	17.85
Boca Ciega Bay	Oct. 3	1.8	
Do.	7	0.45	2.25
Little Pass	Oct. 3	14.55	
Do.	7	1.6	16.15
Clearwater Beach Area	Oct. 6	10.0	
Do.	7	8.4	18.4
Hurricane Pass Area	Oct. 5	10.0	10.0
North of Honeymoon Island	Oct. 3	6.0	
Do.	4	13.9	19.9
Total			104.90

Table 2.--Counts of Gymnodinium breve by locality and date

(Dates marked with asterisk denote samples collected by plane)

Area	Date (1957)	Average Count (Per liter)		Remarks
		Surface	Bottom	
John's Pass	Sept. 24	700	0 0	
Do.	26	821,000	946,000	
Do. (Treasure Is.)	28	2,490,000	1,370,000	
Do.	29	3,100,000		
Do.	30	6,730,000		
Do.	Oct. 1	209,000	164,000	Started spraying
Do. (4 miles out)	2	74,000	37,000	Finished spraying Oct. 3
Do.	4	20,000	30	
Do.	5	5,100	0	
Do.	6	0	0	
Do.	8	200	0	
Do.	10	52,000	10,000	
Do.	14	240,000	10,000	
Do.	15	100,000	60,000	
Do.	22	180,000	200,000	
Do.	15*	54,000		
Do.	18*	260,000		
Do.	21*	300,000		
Do.	24*	80,000		
Do.	28*	12,000		
Blind Pass	Sept. 26	158,000	27,300	
Do.	28	1,870,000	1,850,000	
Do.	29	16,550,000	3,880,000	Before dusting
Do.	29	40,000	313,000	Sampled while dusting
Do.	30	0	0	Finished dusting on 30th
Do. (N. of Pass)	Oct. 1	242,000	78,000	
Do. (S. of Pass)	2	2,300	0	
Do. (N. of Pass)	2	150,000	0	
Do.	4	13,000	1,400	
Do.	6	50	0	
Do.	8	0	0	
Do.	10	380,000	363,000	
Do.	14	470,000	240,000	
Do.	15	470,000	880,000	
Do.	15*	400		
Do.	22	340,000	520,000	
Do.	18*	220,000		

Table 2. (cont'd)--Counts of Gymnodinium breve by locality and date

(Dates marked with asterisk denote samples collected by plane)

Area	Date (1957)		Average Count (Per liter)		Remarks
			Surface	Bottom	
Blind Pass (cont'd)	Oct.	21*	220,000		
Do.		24*	80,000		
Do.		28*	80,000		
Madeira Beach (Redington Beach)	Sept.	24	255	0	
Do.		26	560,000	670,000	
Do.		27	537,000	576,000	
Do.		28	729,000	760,000	
Do.	Oct.	1	8,200	0	Started spraying
Do.		2	910,000	51,000	
Do.		3	87,000	1,600	Finished spraying
Do.		5	0	0	
Do.		6	0	0	
Do.		8	200	0	
Do.		10	28,000	2,000	
Do.		14	160,000	160,000	
Do.		15	54,000	280,000	
Do.		22	80,000	320,000	
Indian Rocks Beach	Sept.	24	300	0	
Do.		26	208	60	
Do.	Oct.	1	1,351,000	846,000	
Do.		2	358,000	100	
Do. (4 miles off)		3	480,000		Sprayed on 3rd
Do.		4	0	0	
Do.		5	100	0	
Do.		6	150	50	
Do.		8	87,000	62,000	
Do.		10	84,000	42,000	
Do.		14	53,000	40,000	
Do.		15	27,000	25,000	
Do.		22	130,000	90,000	
Little Pass	Oct.	2	5,957,000	293,000	
Do.		3	2,630,000		Before dusting
Do.		3	0		After dusting
Do.		4	0	0	
Do.		5	51,400	24,300	
Do.		6	430,000	310,000	
Do.					Sprayed small patch

Table 2. (cont'd)--Counts of Gymnodinium breve by locality and date

(Dates marked with asterisk denote samples collected by plane)

Area	Date (1957)		Average Count (Per liter) Surface	Bottom	Remarks
Little Pass and Belleair Beach	Oct.	8	440,000	132,000	
Do.		10	185,000	88,000	
Do.		14	109,000	57,000	
Do.		15	48,000	81,000	
Do.		18*	120,000		
Do.		21*	0		
Do.		22	280,000		
Do.		24*	140,000		
Do.		28*	2,000		
Clearwater Beach	Oct.	2	119,000	100	
Do.		4	15,000	0	Partially sprayed on 3rd
Do.		5	0	0	
Do. (Big Pass)		8	380,000	300,000	
Do. (Big Pass)		10	10,000	6,000	
Do. (Big Pass)		14	460,000	58,000	
Do. (Big Pass)		15	120,000	128,000	
Do. (Big Pass)		18*	100,000		
Do. (Big Pass)		21*	24,000		
Do. (Big Pass)		22	94,000	62,000	
Do. (Big Pass)		24*	4,000		
Do. (Big Pass)		28*	100		
Hurricane Pass & Honeymoon-Island	Oct.	4	960,000		
Do.	Oct.	5	43,700	531,200	
Do.		6	985,000	389,000	
Do.		8	264,000	93,000	
Do.		10	104,000	88,000	
Do.		14	480,000	163,000	
Do.		15	850,000	530,000	
Do.		18*	71,700		
Do.		21*	18,000		
Do.		22	21,000	116,000	
Do.		24*	62,000		
Do.		28*	0		

Table 2. (cont'd)--Counts of Gymnodinium breve by locality and date

(Dates marked with asterisk denote samples collected by plane)

Area	Date (1957)	Average Count (Per liter)		Remarks
		Surface	Bottom	
Anclote Key	Oct. 4	1,838,000		Sprayed on 4th
Do.	6	100	100	
Do.	8	120,000	44,000	
Do.	14	8,000	4,000	
Do.	15	200,000	200,000	
Do.	18*	1,600		
Do.	22	480,000	140,000	
Do.	24*	6,000		
Do.	28*	0		

Table 3.--Daily counts of *Gymnodinium breve* by locality

Date	Locality	No. of Samples	Average Count (Per liter) Surface	Average Count (Per liter) Bottom	Minimum-Maximum Surface	Minimum-Maximum Bottom
Sept. 23	Inside John's Pass	1	14,000			
	Inside Blind Pass	1	100			
	S. W. Pass-a-Grille	1	1,000			
Sept. 24	S. W. Pass-a-Grille	2	0	0		
	Egmont Channel	1	11,900	0		
	5 mi. W. of Pass-a-Grille	1	136,000	7,500		
	Off John's Pass	2	700	0	500-900	
	Off Redington Beach	2	255	0	200-310	
	2 mi. of Indian Rocks	1	0	0		
	$1\frac{1}{2}$ mi. E. Indian Rcks. buoy	1	600			
Sept. 26	$\frac{1}{4}$ mi. off Blind Pass	1	158,000	27,300		
	Off John's Pass	3	821,000	946,000	140,000-2,130,000	276,000-2,220,000
	Madeira Beach	1	1,450,000			
	Close to shore Madeira Beach	1	4,500			
	$2\frac{1}{2}$ mi. N. W. of Madeira Tank	1	230,000	670,000		
	Indian Rocks area	5	208	60	0-1,000	0-300
Sept. 27	Off Madeira Beach - (4 sq. miles)	40	537,000		0-1,800,000	
	Do.	14		576,000	0-1,510,000	
	Table 3 Section (2)					
Sept. 28	7/8 mi. off Blind Pass	1	1,870,000	1,850,000		
	Off center Treasure Island	1	2,490,000	1,370,000		
	Off Madeira Beach - (4 sq. miles)	67	729,000		0-2,610,000	
	Do.	37		760,000		0-2,910,000

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter) Surface	Average Count (Per liter) Bottom	Minimum-Maximum Surface	Minimum-Maximum Bottom
Sept. 29	Off Blind Pass - (while dusting)	7	40,000	313,000	0-190,000	0-940,000
	Do. (outer edge of dusted area)	1	60,000	390,000		
	Just N. of Blind Pass	2	16,550,000		3,100,000-30,000,000	
	Do.	2	3,880,000			2,820,000-4,940,000
	Off John's Pass	1	3,100,000			
Sept. 30	Off Blind Pass - (area dusted 29th)	14	0			
	Do.	8	0	0		
	Off entrance to John's Pass	2	6,730,000		460,000-13,000,000	
	(Table 3 Section 3)					
Oct. 1	3-4 offshore Indian Rocks	4	1,334,000		406,000-2,090,000	
	Do.	4		762,000		239,000-2,090,000
	Close to beach at Indian Rocks	1		1,180,000		
		2	1,385,000		1,380,000-1,390,000	
	½ mi. N. W. Madeira Beach Tank	1	8,200	0		
	Off John's Pass area	4		164,000		8,300-438,000
		6	209,000		0-790,000	
	¼ mile off Blind Pass	1	242,000			
	Do.	2		78,000		11,000-145,000
Oct. 2	2/4 mile S. of Blind Pass	1	2,300	0		

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter) Surface	Average Count (Per liter) Bottom	Minimum-Maximum Surface	Minimum-Maximum Bottom
Oct. 2	¼ mile W. Bellaire Tank	1	105,000	75,000		
	4 miles off John's Pass - sea buoy	1	74,000	37,000		
	¼ mile W. Madeira Beach - Tank	1	910,000	51,000		
	¼ mile N. of Blind Pass	1	150,000	0		
	Little Pass area - (Clearwater)	3	5,957,000	293,000	250,000-17,000,000	129,000-380,000
	Indian Rocks area	2	358,000	<100	275,000-500,000	0- <100
	Clearwater Beach	1	119,000	<100		
	¼ mile W. Don-ce-Sar	1	0	0		
		3	6,000		0-18,000	
	Mullet Key Close to Shore	1		0		
	Off Egmont Key	1	0	0		
Oct. 3	Off Madeira Beach Tank to Indian Rocks Tank	3	87,000	1,600	1,100-240,000	0-4,900
	½ mile off Little Pass	1	2,630,000			
	4 miles off Indian Rocks (sea buoy)	1	480,000			
	Entrance to Little Pass (after dusting)	3	0	0		
	¼ to 3/4 mi. E. of Bellair	4	135,000		0-540,000	
	Beach Tank (after dusting)	3		0		
	S. end Pass-a-Grille	1	0	0		
	1 mile W. Mullet Key	1	100,000	0		
	1 mile W. Egmont Key	1	130,000	530,000		

Table 3. (cont'd)--Daily counts of *Gymnodinium breve* by locality

Date	Locality	No. of Samples	Average Count (Per liter) Surface	Average Count (Per liter) Bottom	Minimum-Maximum Surface	Minimum-Maximum Bottom
	(Table 3 Section 5)					
Oct. 4	$\frac{1}{4}$ mile off John's Pass area	2	0	0		
	$\frac{1}{4}$ mile off below Indian Rocks	2	0	0		
	Indian Rocks to Belleair Beach	2	0	0		
	Belleair Beach to Little Pass	2	0	0		
	Off entrance to Little Pass	1	0	0		
	Off Clearwater Beach Island	3	15,000		0-34,000	
	Do.	2		0		
	$1\frac{1}{2}$ mile off Hurricane Pass	1	960,000			
	0-6 miles off Anclote Key	4	1,838,000		0-3,310,000	
	Off Blind Pass area	5	13,000	1,400	4,300-28,000	0-6,000
	Off John's Pass area	5	21,000	40	0-95,000	0-200
Oct. 5	Off Little Pass	3	51,400	24,300	200-148,000	0-73,000
	Indian Rocks Beach area	5	100	0	0-300	
	Off Madeira Beach	3	0	0		
	John's Pass area	1	5,100	0		
	10-19 miles off Little Pass	2	311,000	16,500	11,000-610,000	
						100-33,000
	Belleair Beach	1	0	0		
	Off Clearwater Beach	1	0	0		
	At entrance to Big Pass	1	260,000	21,000		
	W. of Honeymoon Island	5	43,700	531,200	0-1,570,000	0-2,190,000
	2 miles W. of Caladesi Island	1	0	0		

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter) Surface	Average Count (Per liter) Bottom	Minimum-Maximum Surface	Minimum-Maximum Bottom
Oct. 6	Off Blind Pass	2	50	0	0-50	
	Off John's Pass	1	0	0		
	Off Madeira Beach	2	0	0		
	Off Indian Rocks Beach	2	150	50	100-200	0-100
	Off Belleair Beach	1	96,000	7,000		
	Off Little Pass	1	430,000	310,000		
	Off Big Pass	1	130,000	103,000		
	Off Hurricane Pass	1	640,000	17,000		
	N. end Honeymoon Island	1	1,330,000	760,000		
	Anclote Key Sea Buoy	1	100	100		
Oct. 8	3/4 mi. off Blind Pass	2	0	0		
	3/4 mi. off John's Pass	1	200	0		
	3/4 mi. off Maderia Beach	1	200	0		
	3/4 mi. off Indian Rocks Beach	S(4) B(2)	87,000	62,000	40,000-126,000	52,000-72,000
	3/4 mi. off Belleair Beach	1	540,000	136,000		
	3/4 mi. off Little Pass	1	340,000	28,000		
	3/4 mi. off Big Pass	1	380,000	380,000		
	3/4 mi. off Hurricane Pass	1	480,000	140,000		
	3/4 mi. N. end of Honeymoon Island	1	48,000	46,000		
	3/4 mi. Anclote Key sea buoy	1	120,000	44,000		
Oct. 9	Boca Ciega Bay Marker #2G off Long Key	1	8,400			
	Boca Ciega Bay Marker #12	1	1,600			
	Boca Ciega Bay Marker #6	1	400			

Table 3. (cont'd)--Daily counts of *Gymnodinium breve* by locality

Date	Locality	No. of Samples	Average Count (Per liter) Surface	Bottom	Minimum-Maximum Surface	Bottom
Oct. 9	Boca Ciega Bay Marker #2 inside John's Pass	1	200			
	Boca Ciega Bay Marker #12 off Maderia Beach	1	200			
	Boca Ciega Bay Marker #16	1	0			
	Boca Ciega Bay Marker #18	1	0			
	Boca Ciega Bay Marker #22	1	0			
	Boca Ciega Bay Marker #26	1	0			
	Boca Ciega Bay off Reddington Beach	1	0	0		
Oct. 10	3/4 mi. off Blind Pass	2	380,000	363,000	280,000-480,000	146,000-580,000
	3/4 mi. off John's Pass	1	52,000	10,000		
	3/4 mi. off Maderia Beach	1	28,000	2,000		
	3/4 mi. off Indian Rocks	1	84,000	42,000		
	3/4 mi. off Belleair Beach	1	140,000	84,000		
	3/4 mi. off Little Pass	1	130,000	92,000		
	3/4 mi. off Big Pass	1	10,000	6,000		
	3/4 mi. off Hurricane Pass	1	104,000	88,000		
	1 mi. E. of entrance marker Pass-a-Grille	1	36,000	18,000		
	1/5 mi. due W. Venice Jetty	1	0	0		
	$\frac{1}{4}$ mi. due W. Midnight Pass	1	0	0		
Oct. 11	Buoy #2 Egmont Channel	1	360,000	300,000		
	1 mi. E. Buoy #1 Egmont Channel	1	1,780,000	320,000		
	Buoy #1 Egmont Channel	1	480,000	340,000		

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter) Surface	Average Count (Per liter) Bottom	Minimum-Maximum Surface	Minimum-Maximum Bottom
Oct. 11	$1\frac{1}{2}$ mi. E. Buoy #1 Edmont Channel	1	30,000,000 50,000,000 Est.	5,000,000 Est.		
Oct. 12	3 mi. 240° of Buoy #2	1	1,720,000	1,500,000		
	2 mi. E. of Whistle Buoy	1	2,380,000	680,000		
	1 mi. W. of Whistle Buoy	1	480,000	620,000		
	Marker #3 Pass-a-Grille Channel	1	240,000	300,000		
	$\frac{1}{2}$ mi. from beach 150° from Egmont Light House	1	0	0		
	$\frac{1}{4}$ mi. from beach 160° from Egmont Light House	1	300,000	260,000		
Oct. 13	Buoy #2 Egmont Channel	1	0	0		
	180° from Buoy #2 about 5 mi.	1	700,000	200,000		
	180° from Buoy #2 about 10 mi.	1	50,000	70,000		
	180° from Buoy #2 about 12 mi.	1	150,000- 200,000 Est.	25,000- 30,000		
	180° from Buoy #2 about 12 mi.	1	30,000- 40,000	50,000- 60,000		
	$3\frac{1}{2}$ mi. WNW of Bean Pt. Anna Maria Island	1	25,000	200,000		
	Do. (in tidal interphase)	1	0	100,000		
	Do. (W. of tidal interphase)	1	200,000- 300,000	250,000- 500,000		

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter)		Minimum-Maximum	
			Surface	Bottom	Surface	Bottom
Oct. 14	3/4 mi. off Blind Pass	2	470,000	240,000	260,000-680,000	240,000-
	3/4 mi. off John's Pass	1	240,000	10,800		
	3/4 mi. off Maderia Beach	1	160,000	160,000		
	3/4 mi. off Indian Rocks Island	2	53,000	40,000	46,000-60,000	40,000
	3/4 mi. off Belleaire Beach	1	46,000	30,000		
	3/4 mi. off Little Pass	1	172,000	84,000		
	3/4 mi. off Big Pass	1	460,000	58,000		
	3/4 mi. off Hurricane Pass and Honeymoon Island	2	480,000	163,000	480,000	106,000-220,000
	3/4 mi. off Anclote Key	1	8,000	8,000		
Oct. 15 (plane)	Tampa Bay Bridge	1	<100			
	Manateer	1	0			
	Buttonwood Tanks	1	0			
	Fishery Port	1	200			
	Midnight Pass	1	0			
	Head Lemon Bay	1	0			
	Lemon Bay Bridge	1	0			
	Head Gasparilla Bay	1	0			
	Captiva Pass	1	0			
	Redfish Pass	1	0			
	Pine Island Sound	1	0			
	San Carlos Bay	1	80,000			
	Big Carlos Pass	1	<100			
	Big Hickory Pass	1	0			
	Little Marco Pass	1	0			

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter)		Minimum-Maximum	
			Surface	Bottom	Surface	Bottom
Oct. 15 (plane)	Big Marco Pass	1	0			
	Caxambus Pass	1	0			
	Rookery Bay	1	0			
	Gordon Pass	1	0			
	Stump Pass	1	0			
	Off Sarasota Pier	1	0			
	Long Boat Pass	1	280,000			
	Tampa Bay Buoy #2A	1	100			
	Pass-a-Grille (Shell Island)	1	6,000			
	John's Pass	1	54,000			
	Blind Pass	1	400			
Oct. 15	3/4 mi. off Blind Pass	2	470,000	880,000	320,000-620,000	860,000-900,000
	3/4 mi. off John's Pass	1	100,000	60,000		
	3/4 mi. off Maderia Beach	1	54,000	280,000		
	3/4 mi. off Indian Rocks Beach	2	27,000	25,000	20,000-34,000	22,000-28,000
	3/4 mi. off Belleair Beach	1	62,000	60,000		
	3/4 mi. off Little Pass	1	34,000	102,000		
	3/4 mi. off Big Pass	1	120,000	128,000		
	3/4 mi. off Hurricane Pass and Honeymoon Island	2	850,000	530,000	680,000-1,020,000	340,000-720,000
	3/4 mi. off Anclote Key	1	200,000	200,000		

Table 3. (cont'd)--Daily counts of *Gymnodinium breve* by locality

Date	Locality	No. of Samples	Average Count (Per liter)			Minimum-Maximum		
			Surface	Bottom		Surface	Bottom	
			Surface	Midepth	Bottom	Surface	Midepth	Bottom
Oct. 16 and 17	24 hour tidal study 1 mile west of Don Cesar	72	1,103,250	1,037,333	1,703,833	160,000-3,300,000	74,000-3,400,000	92,000-6,340,000
Oct. 18 (plane)	Fishery Pt.	1	0					
	New Pass	1	0					
	Long Boat Pass	1	340,000					
	Blind Pass	1	220,000					
	Anclote Key	1	1,600					
	Honeymoon Island (north end)	1	140,000					
	Hurricane Pass	1	3,400					
	Big Pass	1	100,000					
	Little Pass	1	120,000					
	Johns Pass	1	260,000					
Oct. 21 (plane)	Big Carlos Pass	1	0					
	Big Hickory Pass	1	0					
	Gordon Pass	1	0					
	Big Marco Pass	1	0					
	Caxambus Pass	1	0					
	Rookery Bay	1	0					
	San Carlos Bay	1	440,000					
	Pine Island Sound	1	300,000					
	Red Fish Pass	1	0					
	Gasparilla Sound	1	0					
	Head of Gasparilla Bay	1	0					
	Stump Pass	1	0					
	Lemon Bay Bridge	1	0					
	Midnight Pass	1	0					

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter) Surface	Average Count (Per liter) Bottom	Minimum-Maximum Surface	Minimum-Maximum Bottom
Oct. 21 (cont'd) (plane)	Button Wood Harbor	1	100			
	Long Boat Pass	1	220,000			
	Tampa Bay Buoy 2A	1	<100			
	Pass-a-Grille (Shell Island)	1	580,000			
	Honeymoon Island (north end)	1	18,000			
	Big Pass	1	24,000			
	Little Pass	1	0			
	Johns Pass	1	300,000			
	Blind Pass	1	220,000			
	Vena Delmar Bridge	1	400,000	540,000		
	Inside Pass-a-Grille Pass	1	222,000	540,000		
Oct. 22	½ mile off Blind Pass	2	340,000	520,000	260,000-420,000	500,000-540,000
	½ mile off Johns Pass	1	180,000	200,000		
	½ mile off Maderia Beach	1	80,000	320,000		
	½ mile off Indian Rocks Beach	2	130,000	90,000	120,000-140,000	80,000-100,000
	½ mile off Bellaire Beach	1	280,000	220,000		
	½ mile off Little Pass	1	280,000	100,000		
	½ mile off Big Pass	1	94,000	62,000		
	½ mile off Hurricane Pass and Honeymoon	2	21,000	116,000	8,000-34,000	72,000-160,000
	½ mile off Anclote Key	1	480,000	140,000		
Oct. 23	Buoy No. 2	1	600,000	180,000		
	Egmont Channel Black Bell	1	280,000	140,000		
	Long Boat Pass	1	280,000	80,000		
	Off New Pass	1	300,000	160,000		
	Big Sarasota Pass	1	6,000	2,000		
	Midnight Pass	1	0	0		
	Venice Inlet	1	10,000	200		

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter) Surface	Average Count (Per liter) Bottom	Minimum-Maximum Surface	Minimum-Maximum Bottom
Oct. 23	Stump Pass	1	400	200		
(contd)	Gasparilla Pass	1	0	0		
	Boca Grande Pass	1	0	0		
	Captiva Pass	1	0	0		
	Red Fish Pass	1	200,000	120,000		
	Pine Island Sound	1	720,000	300,000		
	Black Can San Carlos	1	980,000	2,380,000		
	Off Big Hickory Pass	1	48,000	10,000		
	Gordon Pass	1	0	0		
	3 miles west of Don Cesar	1	80,000	420,000		
	Off foot at Mullet Key	1	200,000	420,000		
	Inside Gordon Pass	1	180,000	280,000		
	South side of Shell Island	1	260,000	340,000		
Oct. 24	3 miles west of Naples	1	180,000	120,000		
	6 miles west of Clam Pass	1	60,000	60,000		
			Surface	Middepth Bottom		
	3 miles south of Sanibel	1	7,400,000	4,320,000 2,000,000		
	5 miles west of Captiva	1	100,000	40,000		
	5 miles west of Red Fish Pass	1	180,000	40,000		
	Off Boca Grande Pass	1	0	0		
	10 miles 330° from 71A(1)	1	<100/L	<100/L		
	20 miles 330° from 71A(2)	1	2,000/L	400/L		
	10 miles on 340° from (2)	1	200	0		
	Red Blinker #28 Sarasota Bay	1	0	0		
	Inside Long Boat Pass	1	88,000	76,000		
	Buoy No. 1 Anna Maria	1	240,000	480,000		

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter)		Minimum-Maximum	
			Surface	Bottom	Surface	Bottom
Oct. 24	Tampa Bay Sunshine Skyway	1	96,000			
(plane)	Manatee R.	1	100			
	Tampa Bay Buoy No. 2	1	100			
	Long Boat Pass	1	160,000			
	Button Wood Harbor	1	40,000			
	New Pass	1	80,000			
	Fishery Pt.	1	<1,000			
	Sarasota Pier	1	60,000			
	Anclote	1	6,000			
	Honeymoon Island	1	120,000			
	Hurricane Pass	1	4,000			
	Big Pass	1	4,000			
	Little Pass	1	140,000			
	Johns Pass	1	80,000			
	Blind Pass	1	80,000			
	Pass-A-Grille	1	240,000			
Oct. 28	Little Marco Pass	1	86,000			
(plane)	Caxambus Pass	1	600			
	Big Marco Pass	1	8,000			
	Rookery Bay	1	200			
	Gordon Pass	1	180,000			
	Big Hickory Pass	1	0			
	Big Carlos Pass	1	260,000			
	San Carlos Bay	1	740,000			
	Pine Island Sount Buoy No. 16	1	180,000			
	Red Fish Pass	1	1,140,000			
	Captiva Pass	1	820,000			

Table 3. (cont'd)--Daily counts of Gymnodinium breve by locality

Date	Locality	No. of Samples	Average Count (Per liter)		Minimum-Maximum	
			Surface	Bottom	Surface	Bottom
Oct. 28	Gasparilla Sound Marker #8	1	<100/L			
(plane)	Head of Gasparilla Sound	1	200/L			
(cont'd)	Stump Pass	1	0			
	Lemon Bay Bridge	1	0			
	Midnight Pass	1	100/L			
	Fishery Pt.	1	4,000/L			
	New Pass	1	100/L			
	Button Wood Harbor	1	0			
	Long Boat Pass	1	12,000			
	Tampa Bay Buoy #2A	1	2,000			
	Manatee R.	1	2,000			
	Tampa Bay Sunshine Skyway	1	110,000			
	Pass-a-Grille	1	120,000			
	Blind Pass	1	80,000			
	Johns Pass	1	12,000			
	Little Pass	1	2,000			
	Big Pass	1	<100			
	Hurricane Pass	1	0			
	Honeymoon Island	1	0			
	Anclote	1	0			

Table 4.--Daily summary of Gymnodinium breve and copper concentration by area
(Average *Gymnodinium breve* per liter and µg At/L copper)

Locality	Date	No. samples Surface	No. samples Bottom	Avg. G. breve count Surface	Avg. G. breve count Bottom	Average copper concentration Surface	Average copper concentration Bottom
Johns Pass	Sept. 27	98	33	349,367	386,706	.21	.26
	28	66	35	718,181	782,257	.10	.08
	29	1	0	3,100,000	-	-	-
	30	2	0	6,730,000	-	.14	-
	Oct. 1	6	6	212,000	10,916	.39	1.09
	2	2	2	429,000	44,000	.07	.11
	3	3	2	86,000	0	.90	.33
	4	5	5	0	0	.25	.29
	5	2	2	2,500	0	.31 (1)	.07
	6	3	3	0	0	.12 (2)	.10
	7	3	3	0	0	.09	.24 (2)
	8	3	3	200	0	.13	.16 (2)
	10	4	4	2,250	3,650	.24	.10 (3)
Blind Pass	Sept. 28	2	2	2,189,000	1,610,000	.04	.08
	29	9	8	38,111	322,500	.80 (7)	.43 (5)
	30	13	8	0	0	2.40 (12)	1.03 (7)
	Oct. 1	2	2	121,000	77,800	-	.62
	2	3	3	50,666	0	.06	.02 (2)
	4	5	5	13,400	1,400	.16 (3)	.05 (2)
	6	2	2	50	0	.09	.05
	7	2	2	0	0	.27 (1)	.18
	8	3	3	60	0	.11	.06
	10	4	4	194,000	182,000	.11	.12 (3)
Indian Rocks	Oct. 1	6	5	1,351,000	845,000	.06 (5)	.09
	2	4	4	256,000	158,000	.04	.18 (3)
	3	1	2	0	2,450	.73	.95
	4	2	2	0	0	.30	.24
	5	7	6	57	0	.21	.18
	6	3	3	3,300	2,366	.07	.14
	7	3	3	239,633	11,766	.09	.21 (1)
	8	4	4	222,000	100,000	.12	.28
	10	4	4	104,500	77,500	.13	.18
Clearwater Beach	Oct. 2	6	5	3,419,000	152,200	.12 (5)	.06 (4)
	3	3	3	0	0	1.76	.57
	4	3	3	11,333	0	.29	.32

( ) Shows No. of Cu. samples if different from totals in column three

Table 4. (cont'd)--Daily summary of Gymnodinium breve and copper concentration by area
(Average *Gymnodinium breve* per liter and ug At/L copper)

Locality	Date	No. samples		Avg. *G. breve* count		Average copper concentration	
		Surface	Bottom	Surface	Bottom	Surface	Bottom
Clearwater	Oct. 6	5	5	31,400	14,600	.28(4)	.14
Beach(cont'd)	6	1	1	430,000	310,000	.07	.16
	7	1	1	240,000	43,000	.21	.13
	8	2	2	321,000	14,900	.12	.23
	10	2	2	345,000	47,300	.13	.10
Clearwater	Oct. 4	5	0	1,664,000	-	.14	-
Beach to	5	3	1	1,340,000	3,000	.11	.09
Anclote Key	6	4	4	525,000	220,000	.11	.14
	7	3	3	155,666	109,333	.17	.13(2)
	8	13	13	275,230	7,253	.11(12)	.11(11)
	10	6	6	117,666	60,166	.07	.06(5)
Blind Pass (Before Spray)	Sept. 29	2	2	16,550,000	4,020,000	-	-
Clearwater Beach to Anclote Key (Before Spray)	Oct. 5	3	1	1,340,000	3,000	.11	.09

( ) Shows No. of Cu. samples if different from total in column three

Table 5.--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Johns Pass	Sept. 27	0831	S	.13	28.5	1,190,000
		0831	B	.13		1,040,000
		0840	S	.12	28.5	1,120,000
		"	B	1.50		0
		0843	S	.16	28.3	1,230,000
		"	B	.11		1,030,000
		0847	S	.01	28.4	590,000
		"	B	.07		520,000
		0851	S	.06	28.3	1,430,000
		"	B	.04		550,000
		0854	S	.09	28.1	1,580,000
		"	B	.11		520,000
		0857	S	.07	28.0	1,590,000
		"	B	.25		1,510,000
		0901	S	.02	28.1	1,020,000
		"	B	.16		212,000
		0905	S	2.78	28.2	0
		"	B	.06		520,000
		0839	S	.64		0
		0841	S	.51		0
		"	B	.22		252,000
		0845	S	.17		47,000
		0847	S	.14		45,000
		0849	B			310,000
		0851	S	.40		0
		0853	S	.17		315,000
		0854	S	.12		820,000
		0856	S	.10		360,000
		"	B	.09		214,000
		0900	S	.29		1,250,000
		0901	S	.07		142,000
		0902	S	.06		542,000
		0904	S	.12		1,080,000
		"	B	.05		1,260,000
		0905	S	.06		489,000
		0906	S			460,000
		0907	S	.12		365,000
		0909	S	.12		211,000
		"	B	.07		142,000
		0930	S	.30	28.9	574,000
		0934	S	.08		557,000

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Johns Pass	Sept. 27	0936	S	.27		254,000
(cont'd)		0939	S	.08		176,000
		0941	S	.08	29	43,000
		0943	S	.04		384,000
		0946	S	.08		129,000
		0948	S	.26		108,000
		0950	S	.07	28.9	63,000
		0952	S			149,000
		0954	S	.07		287,000
		0955	S	.08		331,000
		0957	S	.12	28.7	359,000
		1001	S			175,000
		1003	S	.05		1,800,000
		1005	S			195,000
		1152	S	.09		187,000
		1155	S	.27		5,000
		1157	S	.09		570,000
		1159	S		28.5	208,000
		"	B	.05		107,000
		1202	S	.07		169,000
		1203	S	.09		259,000
		1205	S	.05		190,000
		1206	S	.06		219,000
		1206	B	.05		101,000
		1207	S	.23		230,000
		1208	S	.13		256,000
		1209	S	.45		0
		1210	S	.26		1,890,000
		"	B	.18		0
		1215	S	.67		0
		1217	S	.66		110,000
		1219	S	.06		217,000
		"	B			770,000
		1244	S	.30	28.2	68,000
		1246	S	.10		85,000
		1248	S	.12		208,000
		1251	S			212,000
		1253	S	.24	28.7	
		1255	S	.08		408,000
		1256	S	.18		280,000
		1259	S	.14		291,000
		1301	S	.08	28.7	650,000

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Johns Pass	Sept. 27	1303	S	.22		700,000
(cont'd)		1305	S	.28		0
		1307	S	.48		0
		1309	S		28.8	413,000
		1311	S	.16		231,000
		1313	S			127,000
		1315	S	.23		7,100
		1317	S	.04	28.9	273,000
		1113	S			0
		"	B	.19		340,000
		1120	S	.07		0
		1225	S			620,000
		"	B	.07		73,000
		1229	S	.62		1,200
		1132	S	.08		10,000
		"	B	.07		133,000
		1136	S	.05		530,000
		1144	S			0
		"	B	.13		320,000
		1148	S	.78		0
		1156	S	.33		12,000
		"	B	.17		117,000
		1217	S	.12		0
		"	B	.27		210,000
		1230	S	.46		0
		1241	S	.02		59,000
		"	B	.04		400,000
		1255	S	.12		171,000
		"	B	.01		134,000
		1308	S	.06		660,000
		1313	S	.10		210,000
		"	B	.04		460,000
		1320	B	.09		600,000
		1325	S	.95		0
		"	B	.64		0
		1327	S	.17		0
		1336	S	.03		209,000
		"	B	.28		98,000
		1340	S	.09		23,000
		1342	S	.06		180,000
		"	B	.07		158,000

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Johns Pass	Sept. 27	1345	S	.04		460,000
(cont'd)		1348	S	.15		380,000
		"	B	.09		270,000
		1352	S	.09		1,200,000
		1356	S	.33		600,000
		"	B	.19		277,000
		1400	S	.35		0
	Sept. 28	1014	S	.27		1,210,000
		"	B	.06		860,000
		1016	S	.10		1,950,000
		1018	S	.38		1,630,000
		"	B	.25		2,840,000
		1020	S			1,630,000
		1022	S			
		"	B	.22		1,240,000
		1023	S	.28		1,170,000
		1025	S	.14		1,520,000
		"	B	.05		1,310,000
		1026	S	.12		760,000
		1028	S			1,240,000
		1030	S	.54		1,020,000
		"	B	Broken		1,120,000
		1032	S	.26		960,000
		"	B			1,640,000
		1034	S	.31		1,810,000
		1036	S			1,530,000
		1036	B	.27		431,000
		1037	S	.03		620,000
		1039	S	.09		323,000
		"	B			610,000
		1041	S			2,610,000
		1042	S	.03		770,000
		"	B	.02		0
		1044	S	.22		570,000
		1046	S	.04		740,000
		"	B	.06		2,910,000
		1048	S	.04		266,000
		1050	S	.03		159,000
		"	B	.11		510,000
		1052	S	.29		530,000
		1053	S	.10		560,000
		"	B	.05		

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Johns Pass	Sept. 28	1101	S	.06		810,000
(cont'd)		"	B	.08		420,000
		1103	S	.07		610,000
		1104	S	.05		470,000
		"	B	.04		480,000
		1107	S	.01		640,000
		1108	S	.02		480,000
		"	B	.07		510,000
		1111	S	.39		490,000
		1113	S	.08		520,000
		"	B	.07		226,000
		1115	S			199,000
		1116	S	.07		219,000
		"	B	.02		850,000
		1118	S	.12		1,580,000
		1120	S	.08		480,000
		"	B			226,000
		1122	S	.05		3,000
		1124	S	.14		596,000
		"	B	.12		219,000
		1127	S	.12		260,000
		1128	S	.05		235,000
		"	B	.02		206,000
		1130	S	.09		333,000
		1131	S	.14		18,000
		"	B			220,000
		1133	S	.09		280,000
		1135	S	.05		
		"	B	.14		134,000
		1137	S	.05		244,000
		1139	S	.05		327,000
		"	B	.05		770,000
		1141	S	.07		274,000
		1143	S	.07		570,000
		"	B	.03		600,000
		1145	S	.04		520,000
		1146	S	.05		540,000
		"	B	.06		410,000
		1148	S	.02		260,000
		1150	S	.05		530,000
		"	B			215,000

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Johns Pass	Sept. 28	1152	S	.04		270,000
(cont'd)		1155	S	.05		540,000
		"	B	.01		510,000
		1157	S	.05		245,000
		1159	S	.07		1,480,000
		"	B			730,000
		1201	S			
		1203	S	.02		617,000
		"	B			480,000
		1205	S	.16		750,000
		1207	S	.00		570,000
		"	B	.05		400,000
		1209	S			670,000
		1210	S			460,000
		"	B	.03		210,000
		1213	S	.10		470,000
		1215	S	.07		690,000
		"	B			1,700,000
		1217	S	.08		1,660,000
		1220	S	.04		460,000
		"	B	.16		2,250,000
		1222	S	.07		630,000
		1224	S	.03		590,000
		"	B	.04		430,000
		1227	S			505,000
		1228	S	.08		700,000
		"	B	.08		390,000
		1230	S	.06		0
		1232	S	.09		587,000
		"	B	.08		1,340,000
	Sept. 29	1215	S			3,100,000
	Sept. 30	1410	S	.13		13,000,000
		1423	S	.14		460,000
	Oct. 1	x0720	S	.43	28.1	7,600
		x "	B	.21	27.9	8,300
		1100	S	.24		55,000
		"	B	.21		10,100

x = Before dust

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Johns Pass	Oct. 1	1120	S	.10		410,000
(cont'd)		"	B	4.19		438,000
		1125	S	.36		0
		"	B	.34		199,000
		1500	S	.47		8,200
		"	B			0
		1512	S	.29		790,000
		"	B			0
		1519	S	.50		0
		"	B			0
	Oct. 2	1145	S	.07	26.8	74,000
		"	B	.07	27.0	37,000
		*1155	S		27.0	910,000
		* "	B	.15	27.2	51,000
	Oct. 3	940	S	.36	27	19,000
		945	B	.34	27	0
		950	S	.82	27	1,100
		"	B	.36	26.8	0
		*955	S	1.52	27	240,000
	Oct. 4	1059	S	.29	27.5	0
		"	B	.31	27.1	0
		1101	S	.28	27.5	0
		"	B	.25	27.1	0
		1109	S	.30	27	0
		"	B	.47	26.4	0
		1114	S	.21	27	0
		"	B	.21	26.9	0
		1119	S	.19	27.1	0
		"	B	.21	26.9	0
		1315	S			6,000
		"	B	.13		0
		1320	S	.08		4,600
		"	B			0
		1335	S			95,000
		"	B	.11		200
		1345	S	.19		3,600
		"	B			0
		1405	S			0
		"	B			0

* = Outside dust area

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Johns Pass	Oct. 5	1035	S	.31	28	0
(cont'd)		"	B	.12	27.5	0
		1526	S		28	5,000
		"	B	.04	27.5	0
	Oct. 6	1205	S	.07	27.7	0
		"	B	.08	27.7	0
		1217	S	.17	27.1	0
		"	B	.10	27.1	0
		1226	S		27	0
		"	B	.12	27	0
	Oct. 7	1105	S	.20	26.5	0
		"	B	.21	26.5	0
		1116	S	.17	26.5	0
		"	B		26.3	0
		1125	S		26.5	0
		"	B	.27		0
	Oct. 8	1047	S	.08	26.5	200
		"	B		26.6	0
		1029	S	.22	26	200
		"	B	.12	26	0
		1040	S	.11	26	200
		"	B	.21	26	0
	Oct. 10	1525	S	.17	26	10,000
		"	B	.12	26	10,000
		1508	S	.09	26	26,000
		"	B	.12	26	24,000
			S	.34	25.3	52,000
			B		25.8	28,000
			S	.38	25.5	2,400
			B	.15	25.5	84,000
Blind Pass	Sept. 28	925	S	.05		1,870,000
	(before	"	B	.08		1,850,000
	dusting)	941	S	.04		2,490,000
		"	B	.08		1,370,000
	Sept. 29	1755	S	.33	28.8	10,000
	(with	"	B	.60		0
	dusting)	1842	S	.86		0
		"	B			370,000

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Blind Pass	Sept. 29	1845	S	.29		60,000
(cont'd)	(with	"	B			340,000
	dusting)	1848	S	.09		190,000
		"	B	.22		940,000
		1850	S	3.63		0
		"	B	.55		0
		1852	S	.34		0
		"	B	.56		0
		*1856	S	.08		23,000
		"	B	.22		540,000
		*1859	S			60,000
		"	B			390,000
	(before	1225	S		28.7	3,100,000
	dusting)	"	B		28.8	3,100,000
		1230	S		28.7	30,000,000
		"	B			4,940,000
	Sept. 30	1005	S	1.78		0
	(with		S	4.94		0
	dusting)		S			0
		1200	S	2.58		0
		930	S	3.49		0
		"	B	.35		0
		937	S	1.45		0
		"	B	1.82		0
		939	S			0
		"	B	1.76		0
		941	S	.34		0
		"	B	.81		0
		943	S	.19		0
		"	B	.37		0
		1100	S	4.14		0
		1124	S	2.42		0
		1157	S	1.57		0
		"	B			0
		1201	S	4.09		0
		"	B	2.93		0
		1204	S	1.88		0
		"	B	2.29		0

* = Outside dusting area

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Blind Pass	Oct. 1	1532	S			242,000
(cont'd)		"	B	.11		10,600
		1536	S	Broken		0
		"	B	1.13		145,000
	Oct. 2	1028	S	.05	27	2,300
		"	B	.02	26.5	0
		1132	S	.09	26.9	150,000
		"	B	.02	26.8	0
		1120	S	.04	27.5	0
		"	B		27.4	0
	Oct. 4	1220	S	.28		28,000
		"	B			6,000
		1235	S			15,000
		"	B	.07		1,000
		1245	S	.15		4,300
		"	B			0
		1255	S			13,000
		"	B	.20		0
		1305	S	.05		7,000
		"	B			0
	Oct. 6	1136	S	.10	27.7	0
		"	B	.03	27.7	0
		1145	S	.09	27.4	100
		"	B	.07	27.9	0
	Oct. 7	1040	S	.27	27.1	0
		"	B	.21	27.3	0
		1047	S		27.3	0
		"	B	.16	27.7	0
	Oct. 8	1028	S	.08	27	200
		"	B	.10	27	0
		1007	S	.05	26.7	0
		"	B	.00	27.5	0
		1015	S	.21	26.5	0
		"	B	.04	27	0
	Oct. 10	1552	S	.05	26.3	800
		"	B	.09	26.4	1,000
		1540	S	.14	26.1	18,000
		"	B	Broken	26.3	1,900
			S	.13	25.8	480,000

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Blind Pass	Oct. 10		B	.07	25.8	580,000
(cont'd)			S	.15	25.3	280,000
			B	.22	25.7	146,000
Indian Rocks	Oct. 1	1201	S	.07		1,390,000
		"	B	.13		1,180,000
		1207	S	.04		1,170,000
		"	B	.09		1.360,000
		1215	S	.08		406,000
		"	B	.04		239,000
		1228	S			1,670,000
		"	B	.15		1,200,000
		1235	S	.08		2,090,000
		"	B	.05		249,000
		1325	S	.07		1.380,000
	Oct. 2	1246	S	.02	26.5	0
		"	B	.07	27.6	105,000
		1215	S	.08	27.4	250,000
		"	B		26.8	129,000
		1237	S	.06	28	500,000
		"	B	.09	27.5	0
		1225	S	.03	27.5	275,000
		"	B	.40	27.2	400
	Oct. 3	0959	B	.41	26.8	4,900
		1535	S	.73	27.7	0
		"	B	1.50	27.7	0
	Oct. 4	1132	S	.25	27.3	0
		"	B	.23	27.1	0
		1136	S	.36	27.4	0
		"	B	.26	27.2	0
	Oct. 5	1050	S	.32	28	0
		"	B	.40	27.3	0
		1105	S	.19	28	0
		"	B	.12	27.3	0
		1421	S	.22	27.5	300
		"	B	.11	27.5	0
		1434	S	.25	27.3	100
		"	B	.29	27.2	0
		1444	S	.16	27.3	0
		"	B	.17	27.2	0

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper(ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Indian Rocks	Oct. 5	1456	S	.26	27.2	0
(cont'd)		"	B	.03	27.2	0
		1507	S	.13	27.6	0
	Oct. 6	1238	S	.08	26.7	200
		"	B	.21	26.6	100
		1255	S	.07	27	100
		"	B	.09	27	0
		1310	S	.06	26.7	9,600
		"	B	.12	26.6	7,000
	Oct. 7	1134	S	.08	26.5	3,900
		"	B		26.3	30,000
		1150	S	.05	26.5	35,000
		"	B		26.5	300
		1200	S	.14	26.5	680,000
		"	B	.21	26.5	5,000
	Oct. 8	1103	S	.09	26.3	122,000
		"	B	.14	26	140,000
		1052	S	.16	26	126,000
		"	B	.32	26.1	52,000
		1102	S	.21	26	100,000
		"	B	.16	26	72,000
		1119	S	.05	26.1	540,000
		"	B	.51	26.1	136,000
	Oct. 10	1446	S	.12	26	100,000
		"	B	.37	26.1	72,000
		1421	S	.11	25.6	94,000
		"	B	.11	25.7	112,000
			S	.09	25.2	84,000
			B	.10	25.3	42,000
			S	.21	25.3	140,000
			B	.15	25.3	84,000
Clearwater	Oct. 2	1300	S	.15	27.2	17,000,000
Beach		"	B	.12	27.2	370,000
		1320	S	.03	27.5	620,000
		"	B		27.4	380,000
		1407	S	.13	27.9	119,000
		"	B	.09	27.8	400
		1410	S	.23	27	5,700
		"	B	.03	27.2	500

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Clearwater	Oct. 2	1520	S		27.1	1,220,000
Beach		"	B	.01	27.1	11,000
(cont'd)		1640	S	.10	25.2	1,550,000
	Oct. 3	1220	S	.36	28	2,630,000
	(Before	1410	S	.43	27.7	480,000
	start)	1443	S	2.26	27.7	0
		1444	B	.79	27.7	0
		1447	S	1.93	27.4	0
		1448	B	.28	27.3	0
		1451	S	1.11	27.4	0
		1456	B	.66	27.4	0
	Oct. 4	1150	S	.44	27.3	0
		"	B	.51	27.7	0
		1212	S	.24	27.5	34,000
		"	B	.15	27.5	0
		1219	S	.20	27.5	0
		"	B	.31	27.3	0
	Oct. 5	1121	S	.32	28	0
		"	B	.21	27.5	0
		1350	S	.34	27.3	148,000
		"	B	.10	27.7	73,000
		1405	S	.20	27.4	8,700
		"	B	.10	27.4	0
		1413	S	.28	27.5	200
		"	B	.18	27.5	0
		1229	S		27.6	0
		"	B	.12	28	0
	Oct. 6	1321	S	.07	26.7	430,000
		"	B	.16	26.8	310,000
	Oct. 7	1215	S	.21	27	240,000
		"	B	.13	26.5	43,000
	Oct. 8	1140	S	.12	26.2	302,000
		"	B	.31	26	1,800
		1133	S	.13	26	340,000
		"	B	.16	26	28,000
	Oct. 10	1400	S	.17	25.8	560,000
		"	B	.17	25.7	2,600
			S	.10	25.2	130,000
			B	.04	25.4	92,000

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
Clearwater	Oct. 4	1227	S	.25	27.3	10,500
Beach to	(no	1231	S	.08	27.5	960,000
Anclote	spray)	1352	S	.13	27	3,250,000
		1542	S	.12	28	3,310,000
		1615	S	.14		790,000
	Oct. 5	1135	S	.07	27.8	260,000
	(unsprayed	"	B	.09	27.1	3,000
	area)	1153	S	.16	27.5	1,570,000
		"	B	.12	27.5	2,190,000
		1215	S	.54	27.5	0
		"	B	.15	27	239,000
		1320	S	.28	27.8	0
		"	B	.16	27	168,000
		1350	S	.28	27.7	530,000
		"	B	.03	27.1	0
		1405	S	.21	27.6	85,000
		"	B		27.1	59,000
		1520	S	2.53	28	0
		"	B	.41	27.4	0
	Oct. 6	1336	S	.16	26.7	130,000
		"	B	.12	26.7	103,000
		1523	S	.18	26.7	640,000
		"	B	.20	26.7	17,000
		1545	S	.13	26.3	1,330,000
		"	B	.11	26.5	760,000
		1612	S	.15	25.7	100
		"	B	Broken	26	100
North of	Oct. 7	1245	S	.22	25.4	330,000
Clearwater		"	B	.09	25.3	300,000
Beach		1304	S	.12	26	90,000
		"	B	Broken	25.9	4,900
		1322	S	.18		47,000
		"	B	.18		23,000
	Oct. 8	1153	S	.09	25	360,000
		"	B	.05	25.5	300,000
		1209	S	.06	25.8	780,000
		"	B	.26	25.3	13,400
		1223	S	.10	25.6	0
		"	B	.02	25.4	0

Table 5. (cont'd)--Individual sample values of Gymnodinium breve, copper (ug at/l), and temperature, by depth and date

Locality	Date	Time	Depth	Copper	Temperature	Gymnodinium breve
North of	Oct. 8	1251	S		25.5	0
Clearwater		"	B	.16	25.2	0
Beach(cont'd)		1313	S	.13	25.7	30,000
		"	B		25.5	0
		1335	S	.07	26.6	400,000
		"	B	.12	26.2	0
		1407	S		26.8	800
		"	B	.17	27	0
		1437	S	.12	27	90,000
		"	B	.08	27.1	0
		1506	S	.07	27.3	890,000
		"	B	.07	27.5	0
		*1154	S	.29	26	380,000
		* "	B	.16	26	300,000
		*1231	S	.06	25.5	480,000
		* "	B	.17	25.5	140,000
		*1240	S	.11	25.2	48,000
		* "	B	.08	25.1	46,000
		*1319	S	.23	25.3	120,000
		* "	B	.08	25.4	144,000
	Oct. 10	1340	S	.04	25.6	420,000
		"	B	.12	25.7	140,000
		1320	S	.16	25.6	16,000
		"	B	.07	25.7	22,000
			S	.04	25	10,000
			B	.07	25.4	6,000
			S	.03	25.1	104,000
			B	Broken	25.1	88,000
			S	.09	26.6	36,000
			B	.01	26.6	13,000
			S	.10	25.2	130,000
			B	.04	25.4	92,000

* = Unsprayed areas

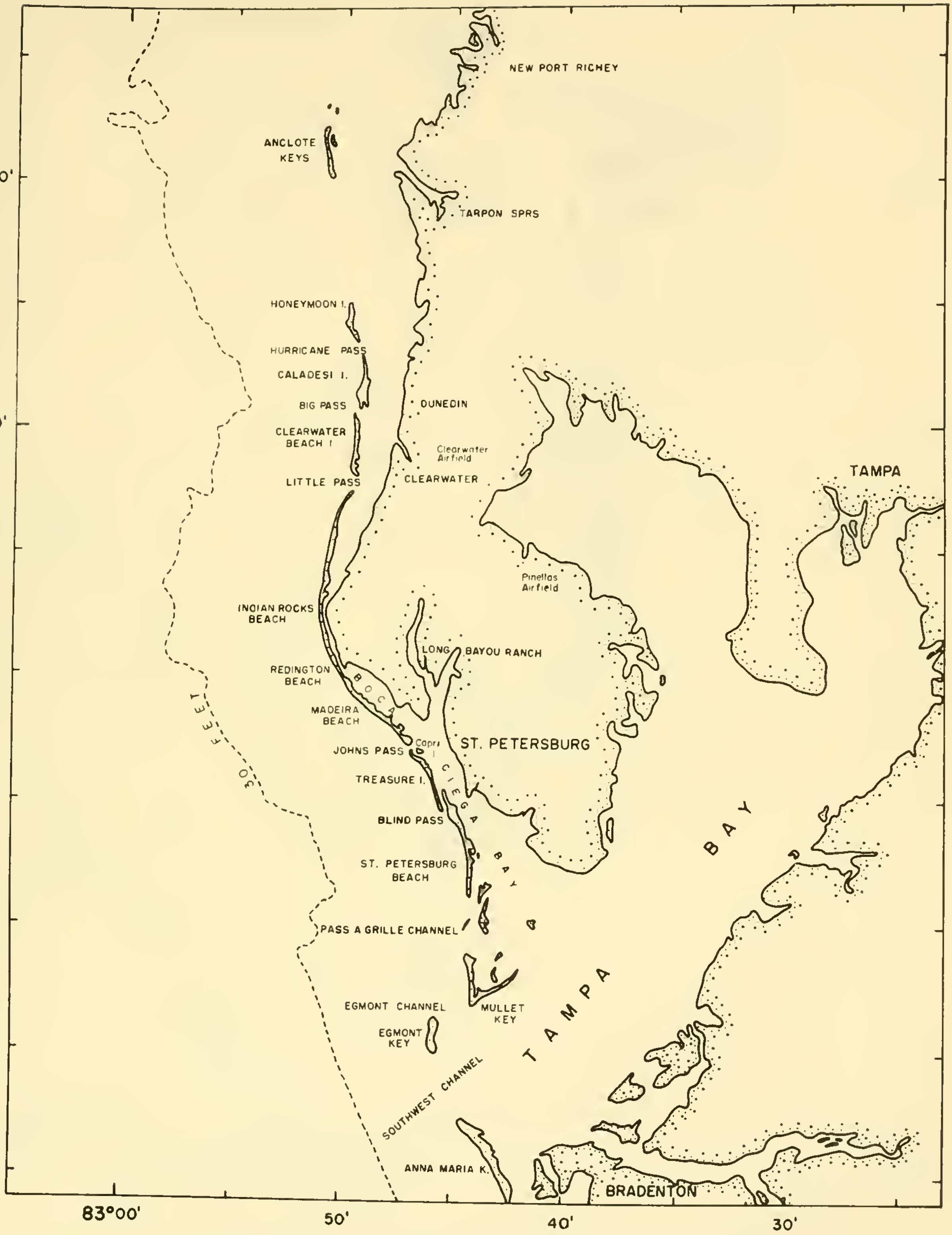

Figure 1.--Portion of Florida west coast in which experimental control of red tide was attempted during September and October 1957.

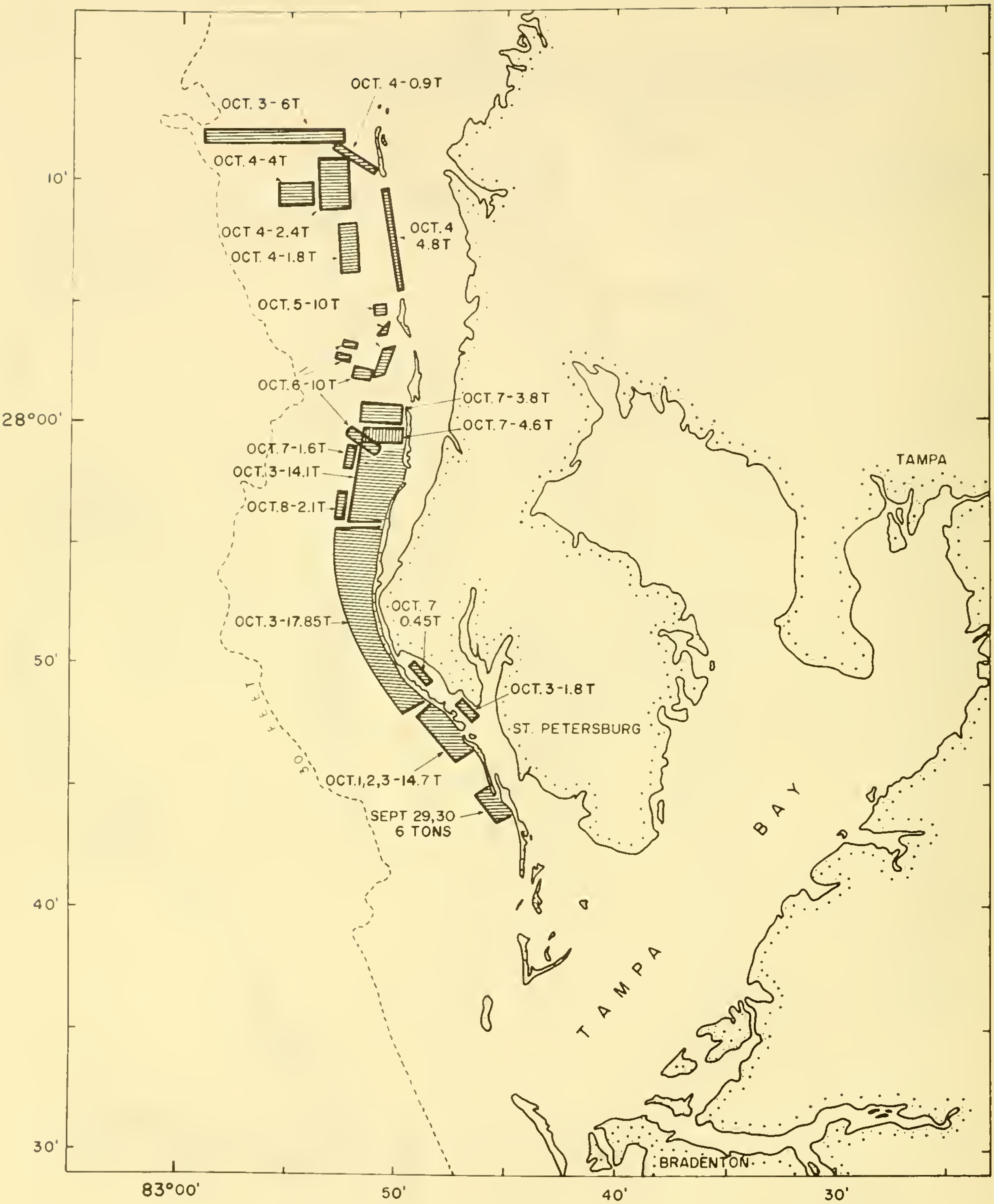

Figure 2.--Areas dusted with copper sulfate showing the dates and the tonnage used (see table 1).

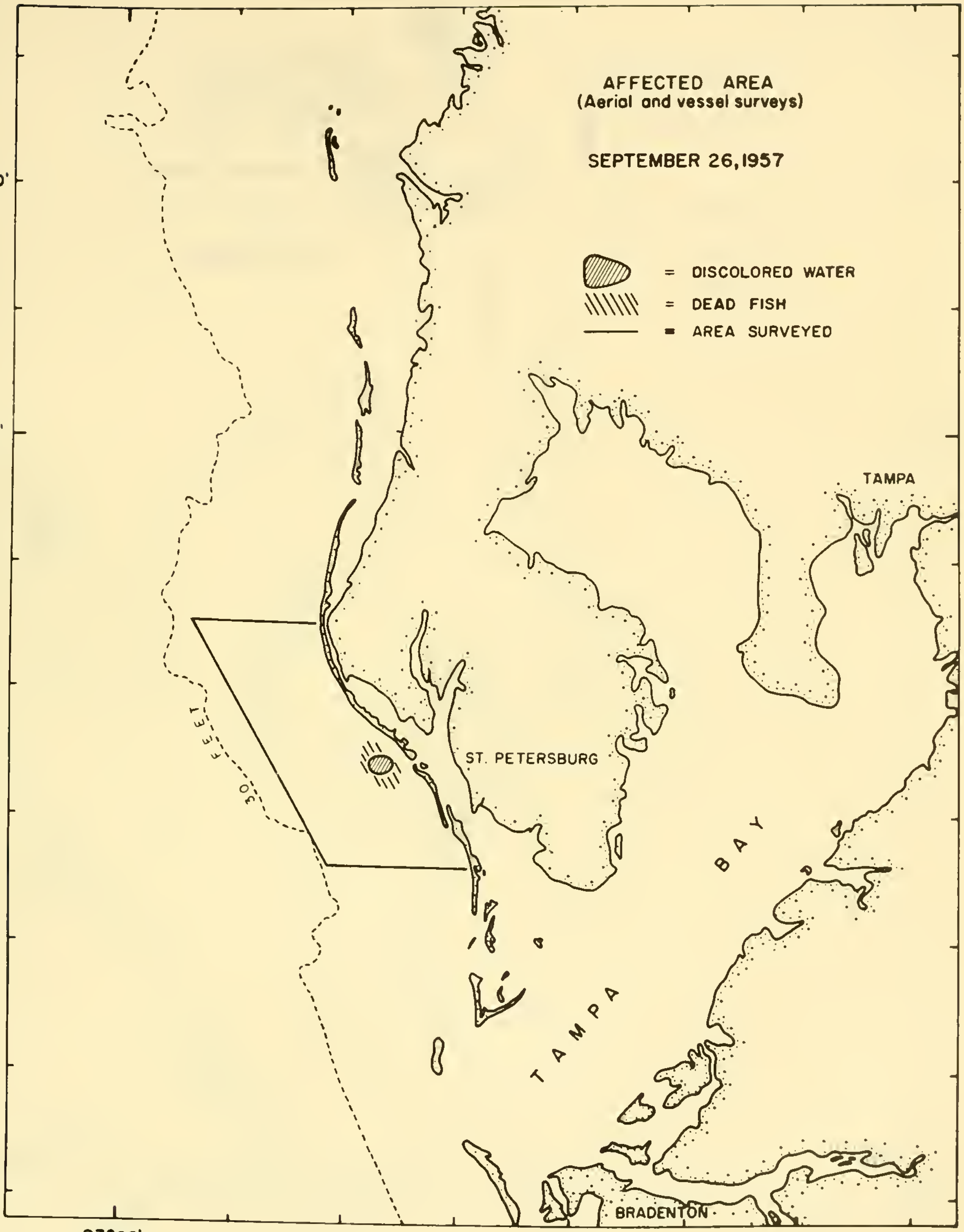

Figure 3.--Survey of red tide occurrence on September 26, 1957.

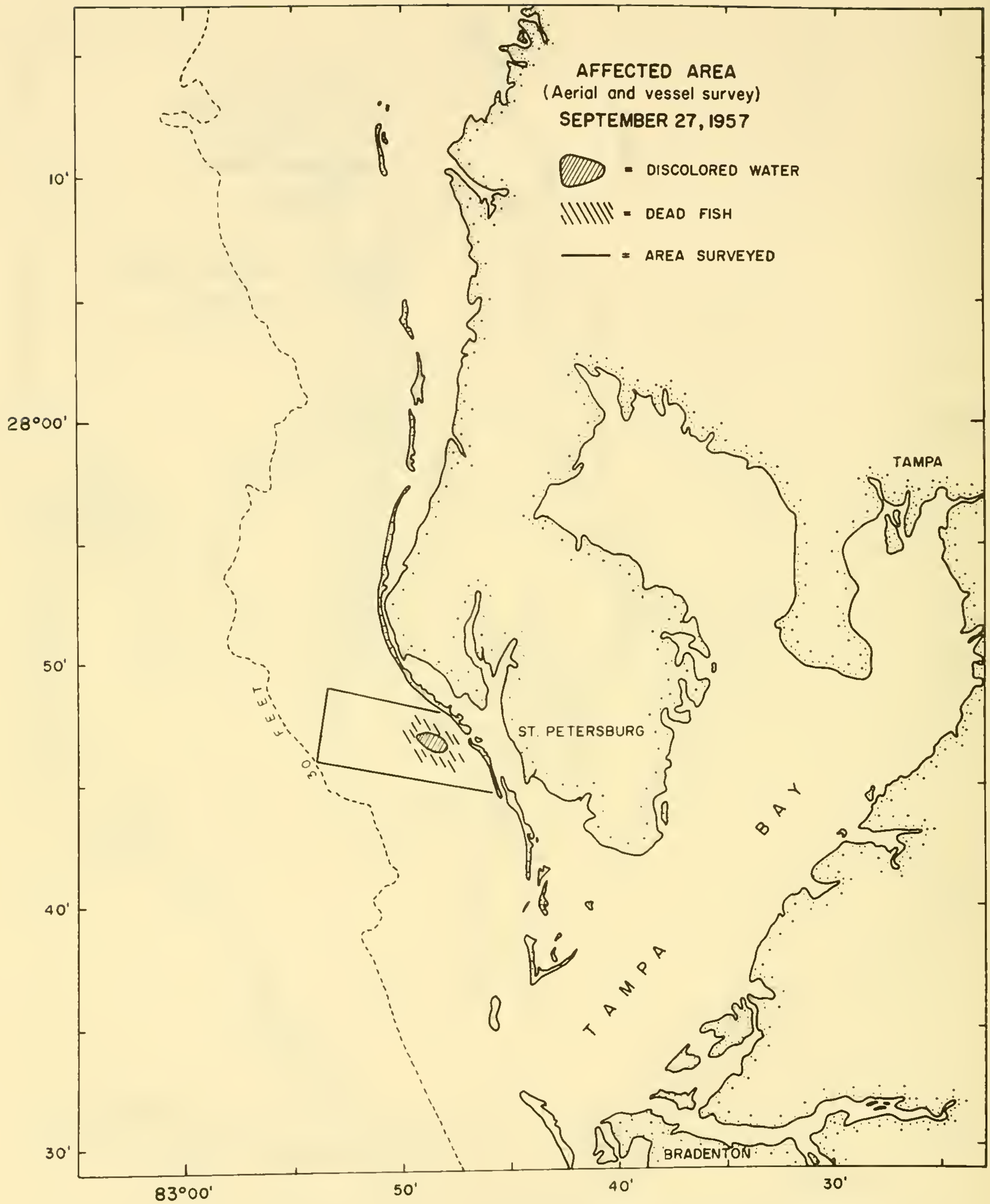

Figure 4.--Survey of red tide occurrence on September 27, 1957.

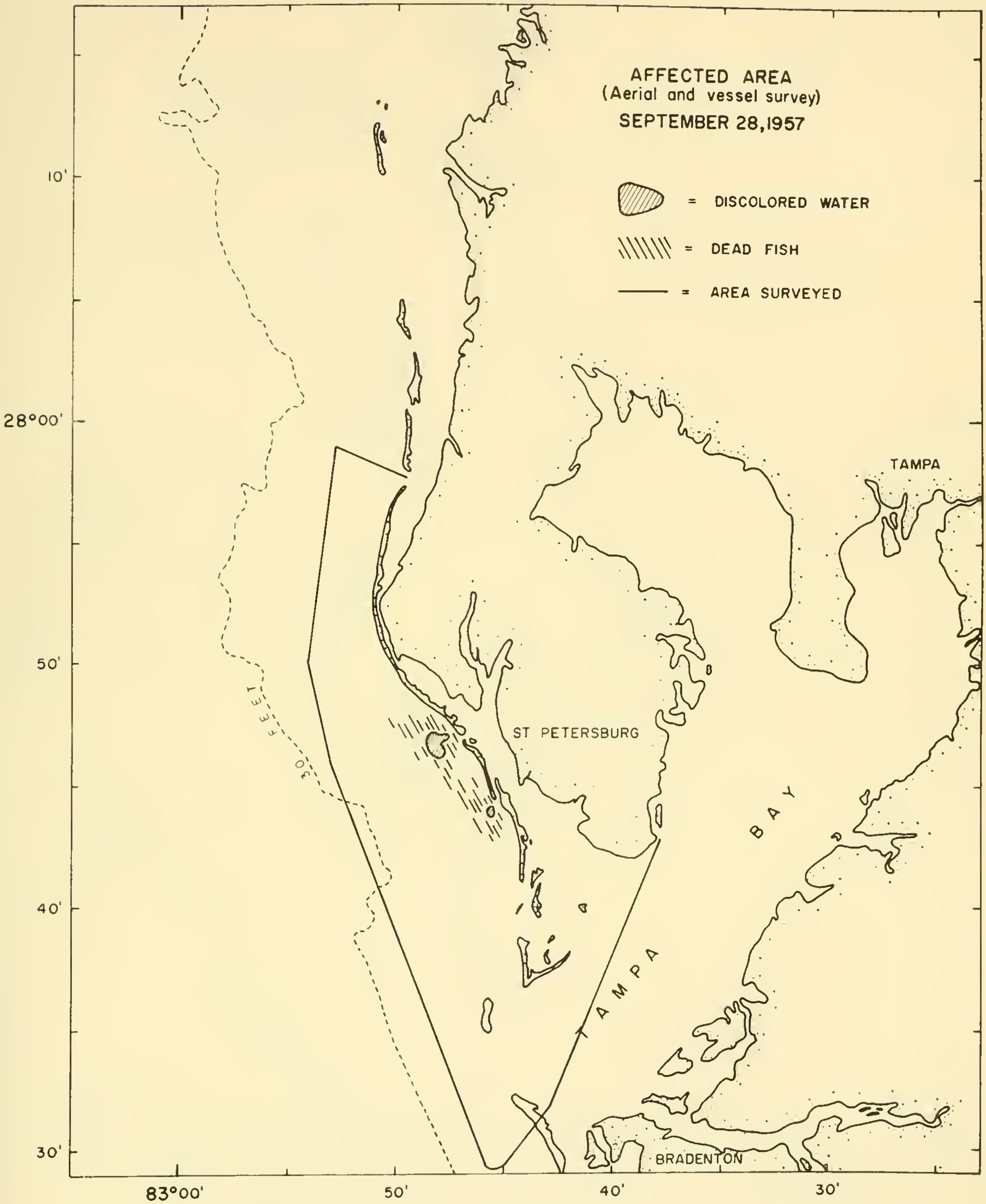

Figure 5.--Survey of red tide occurrence on September 28, 1957.

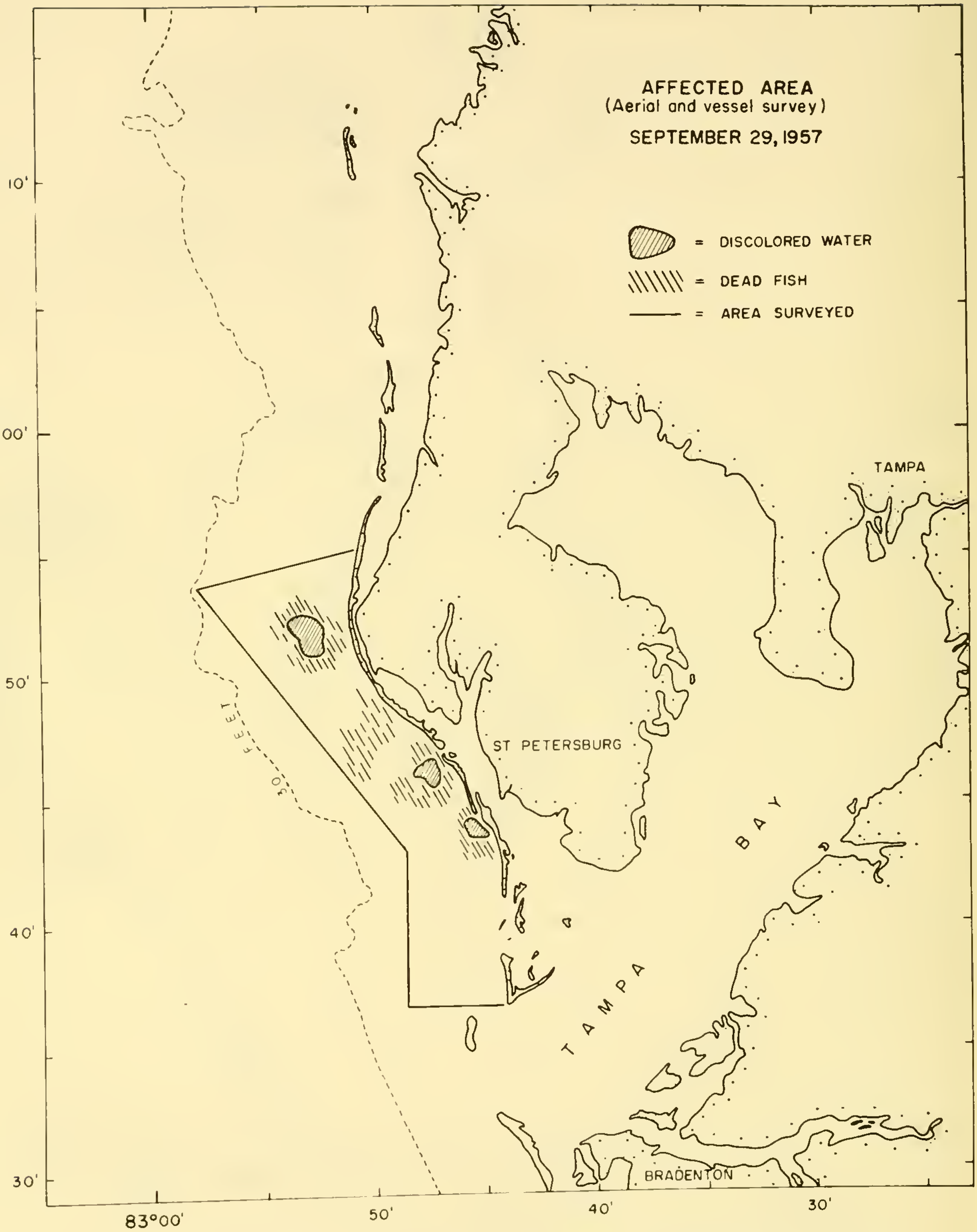

Figure 6.--Survey of red tide occurrence on September 29, 1957.

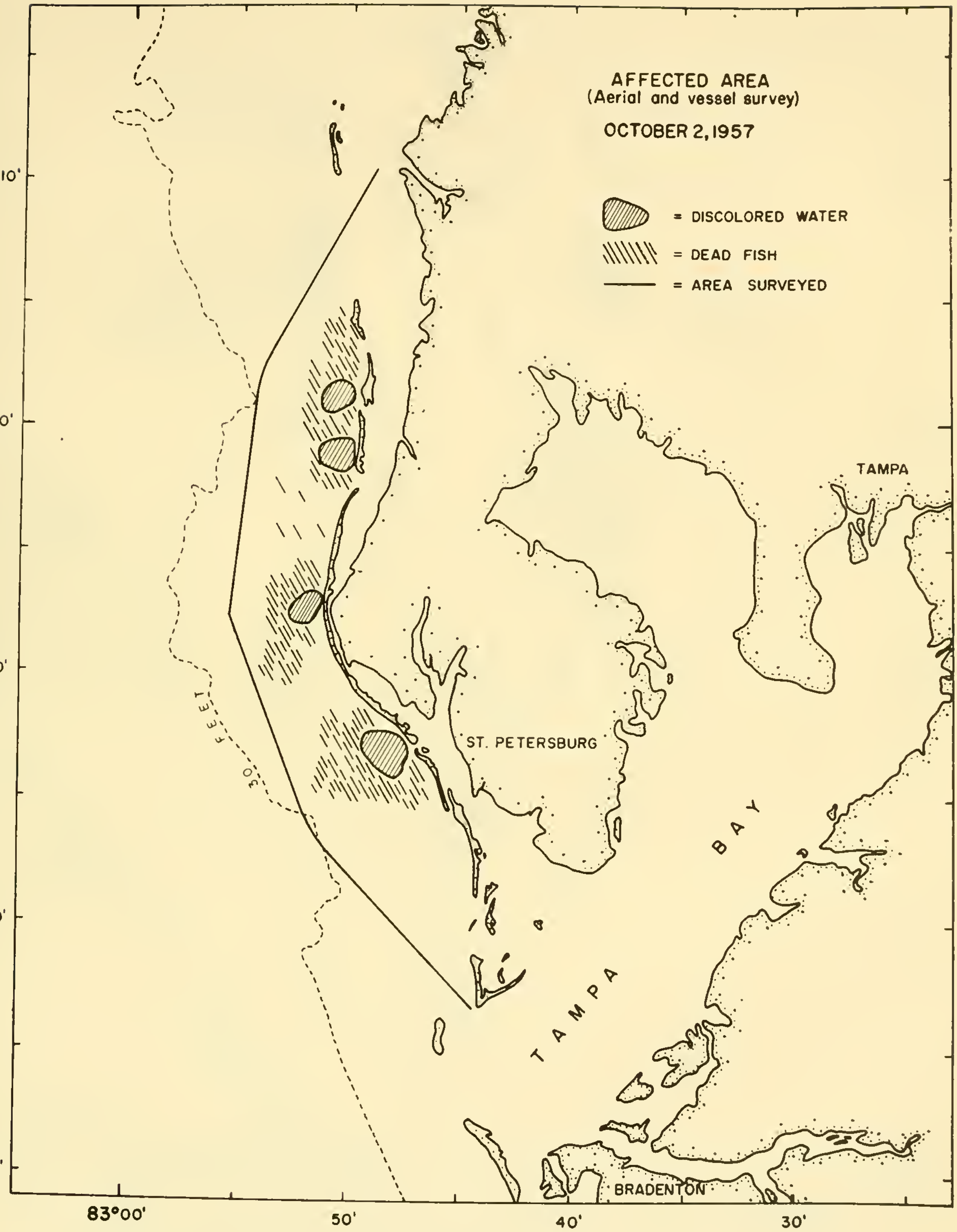

Figure 7.--Survey of red tide occurrence on October 2, 1957.

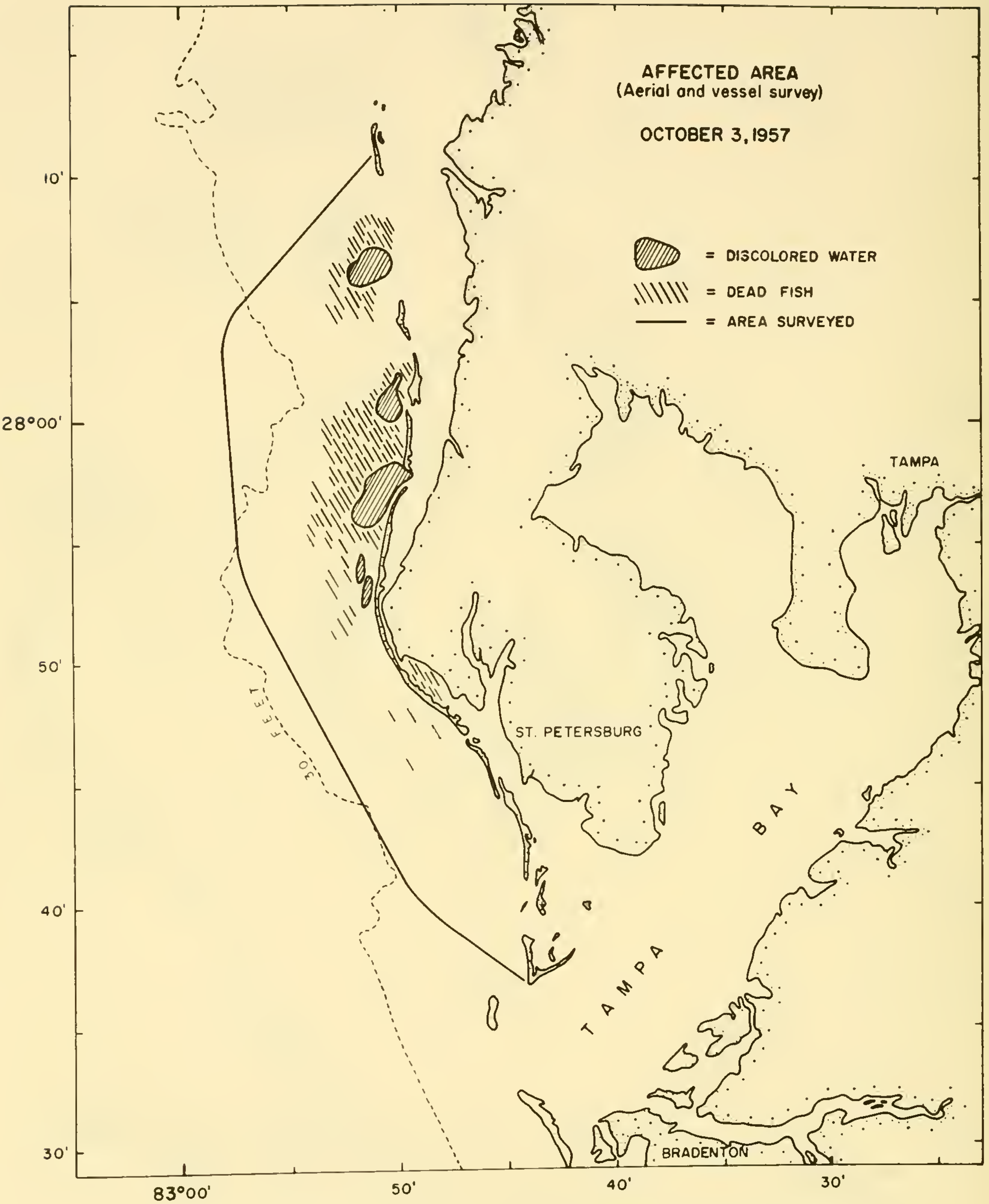

Figure 8.--Survey of red tide occurrence on October 3, 1957.

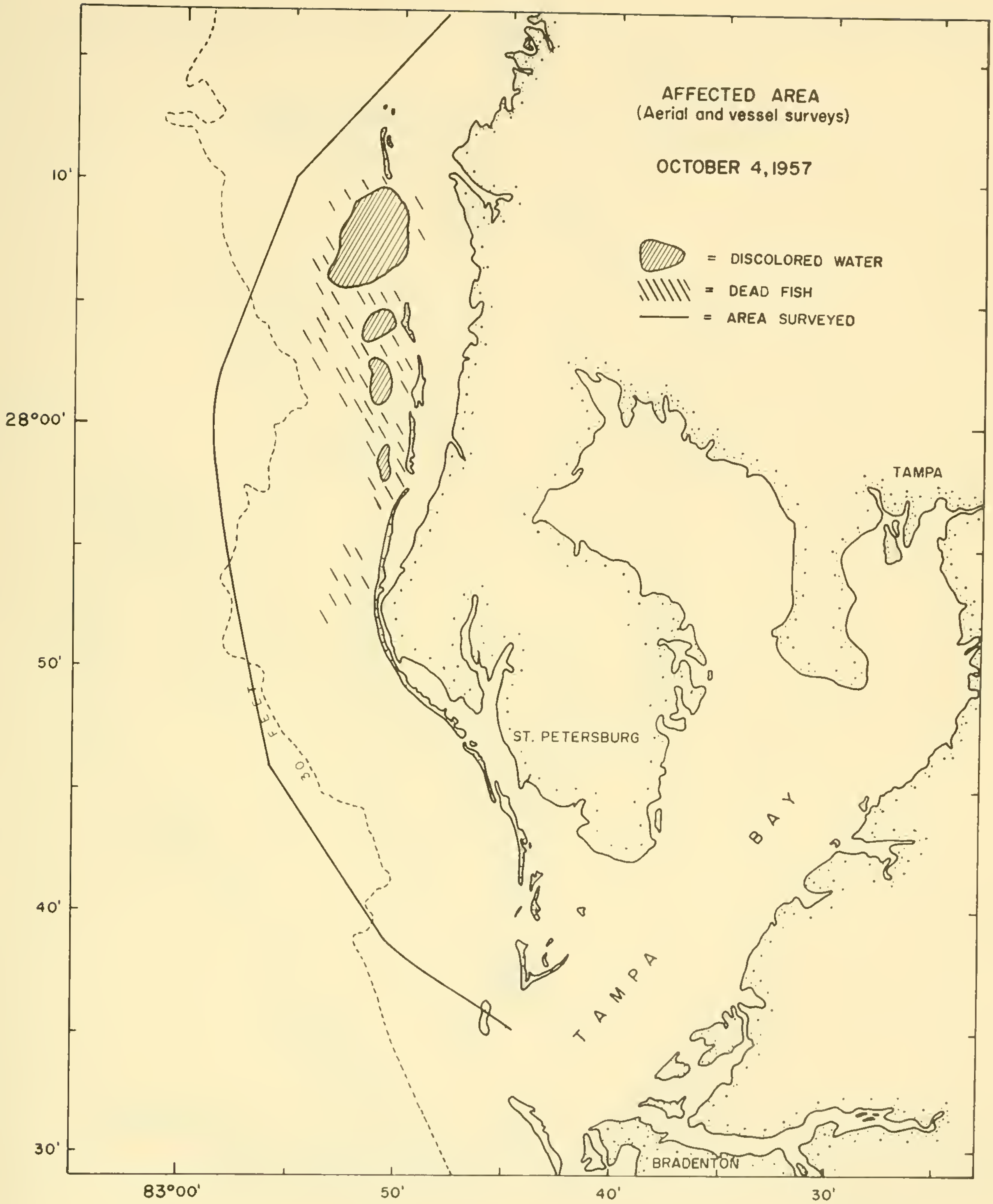

Figure 9.--Survey of red tide occurrence on October 4, 1957.

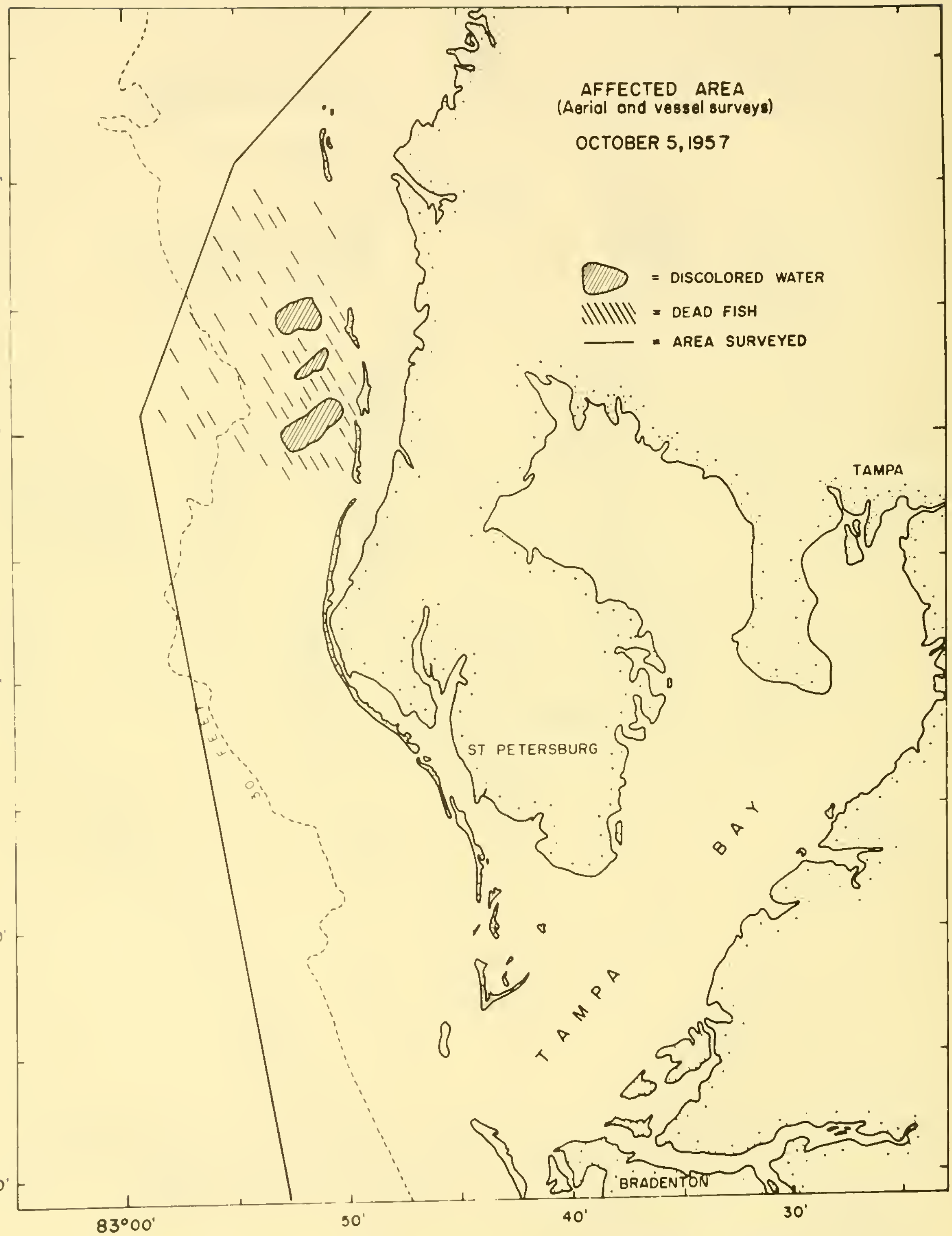

Figure 10.--Survey of red tide occurrence on October 5, 1957.

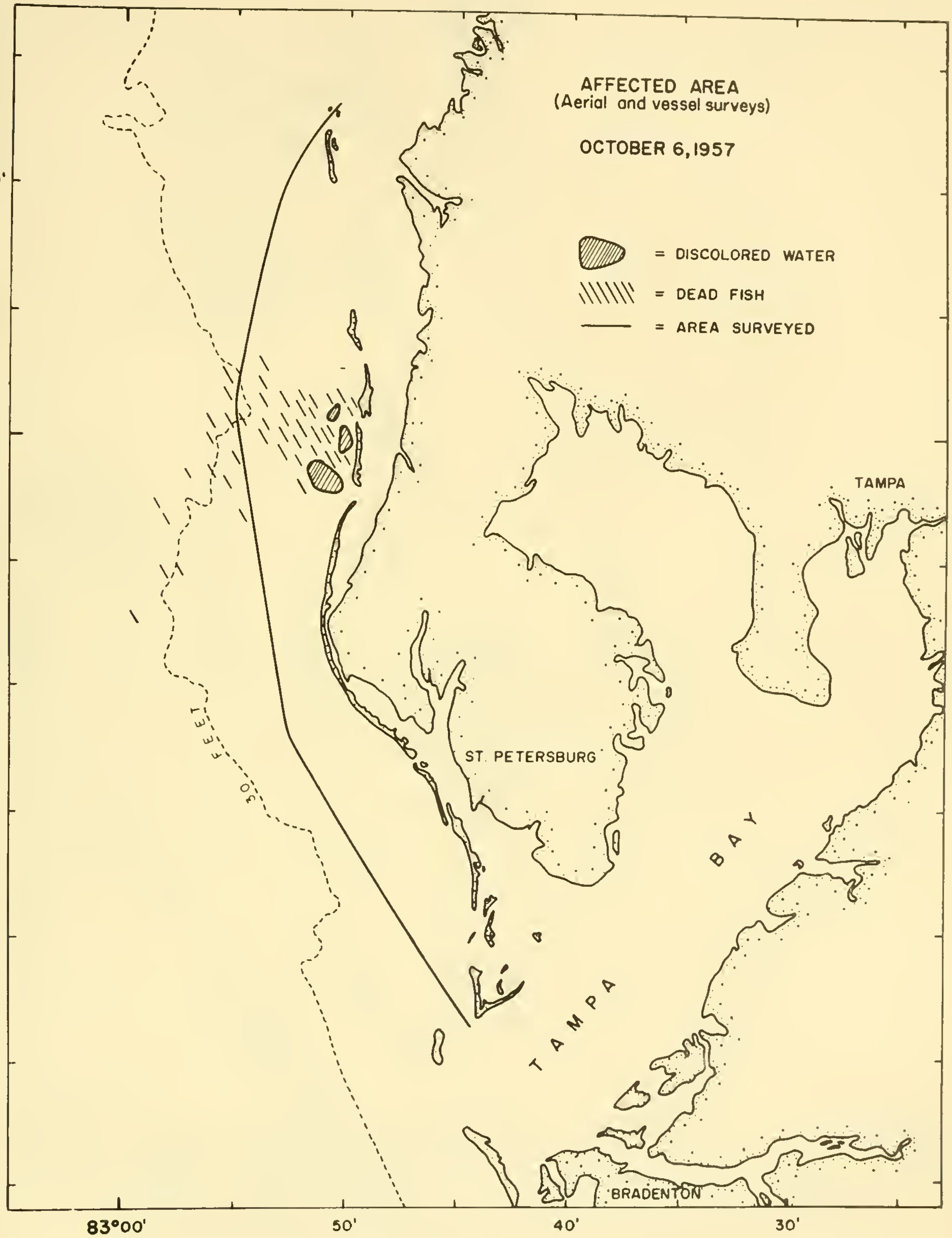

Figure 11.--Survey of red tide occurrence on October 6, 1957.

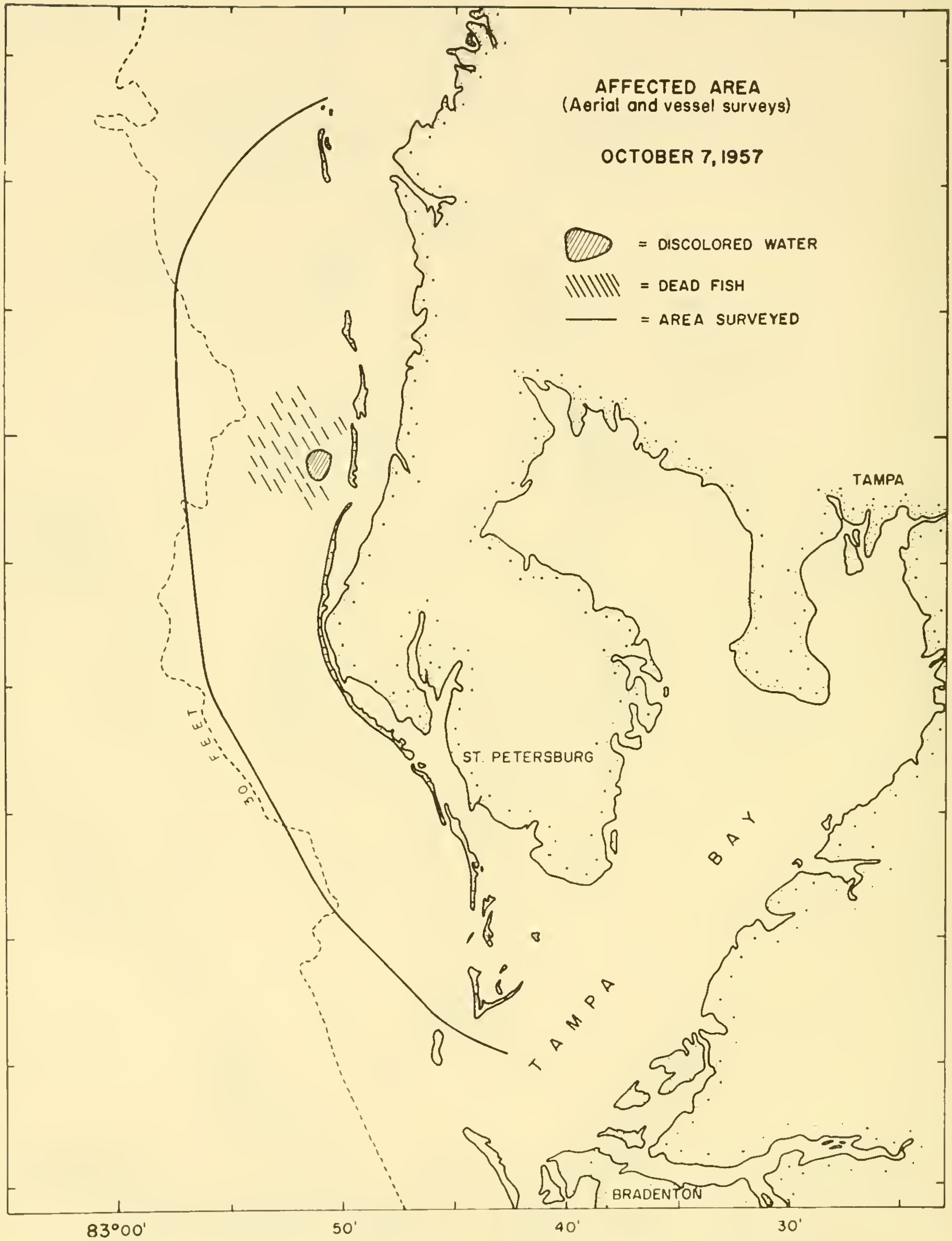

Figure 12.--Survey of red tide occurrence on October 7, 1957.

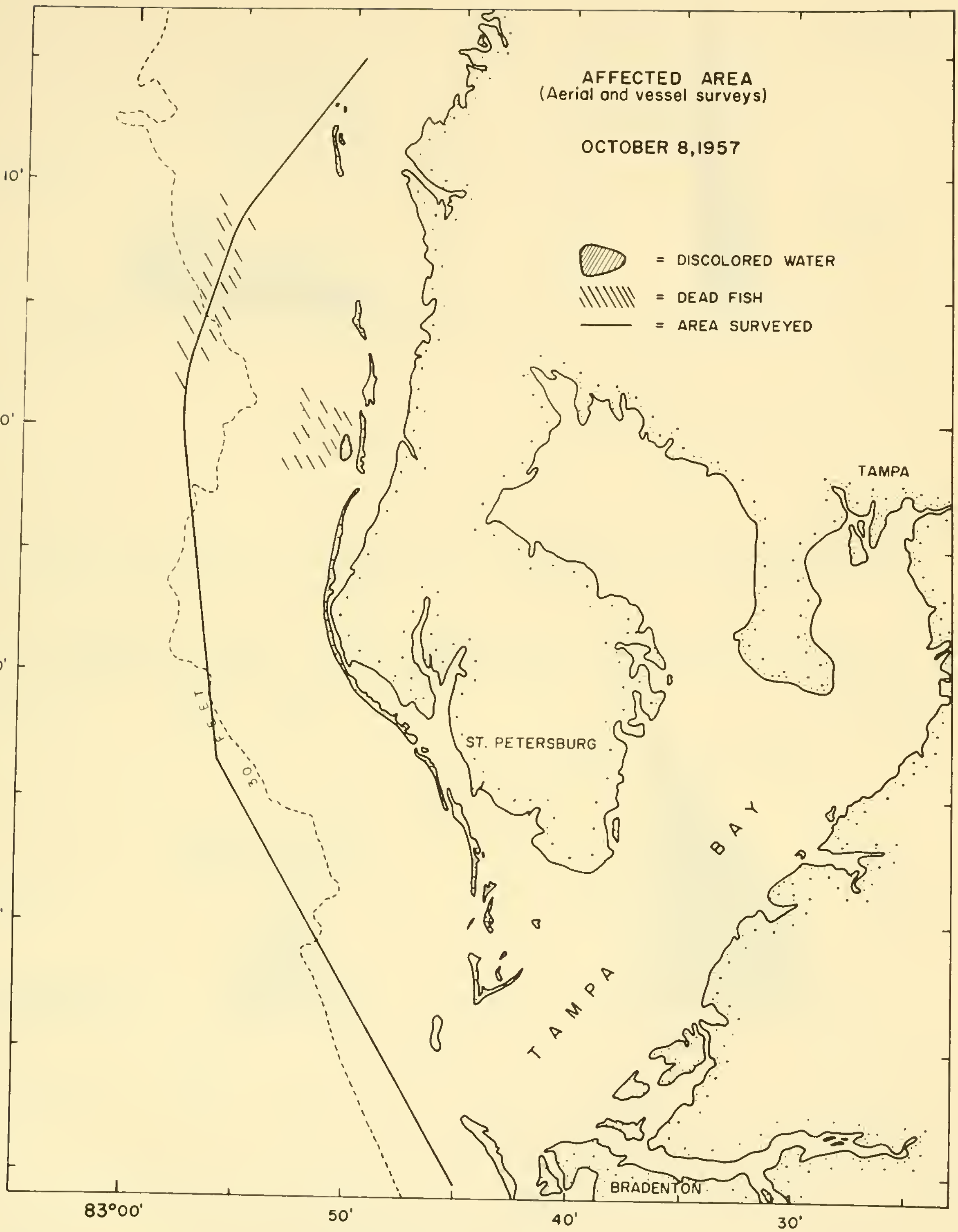

Figure 13.--Survey of red tide occurrence on October 8, 1957.

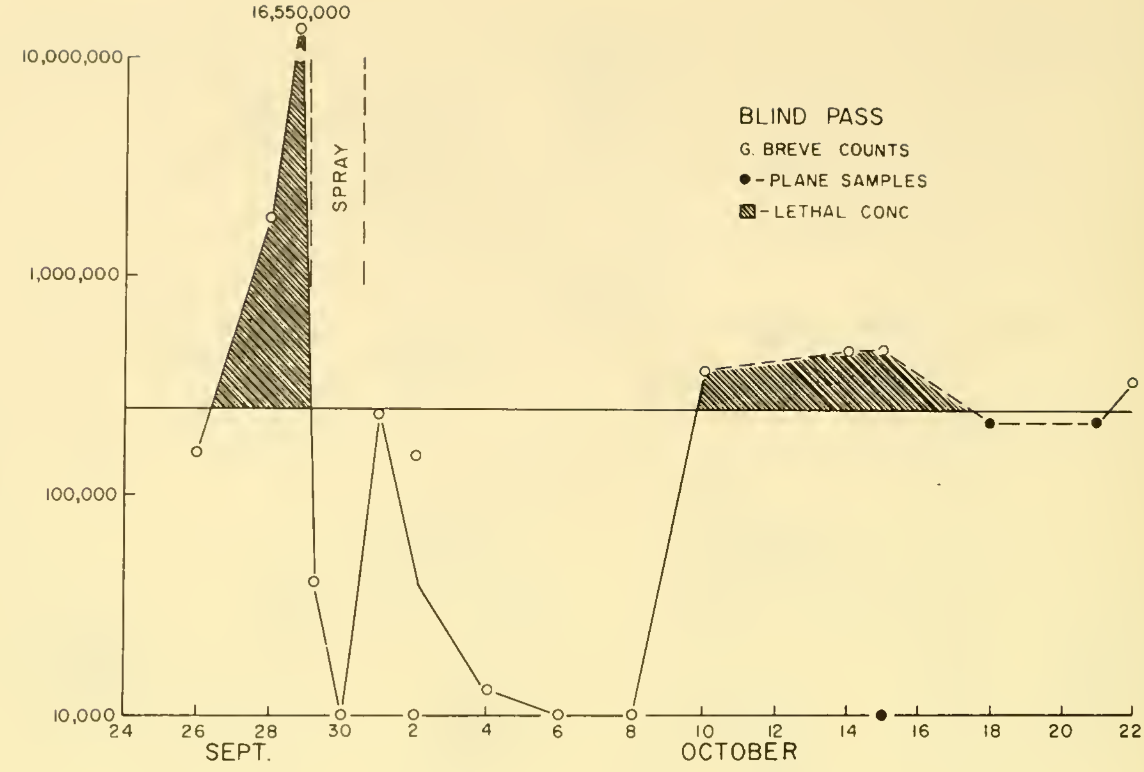

Figure 14.--Numbers of red tide organisms per liter off Blind Pass.

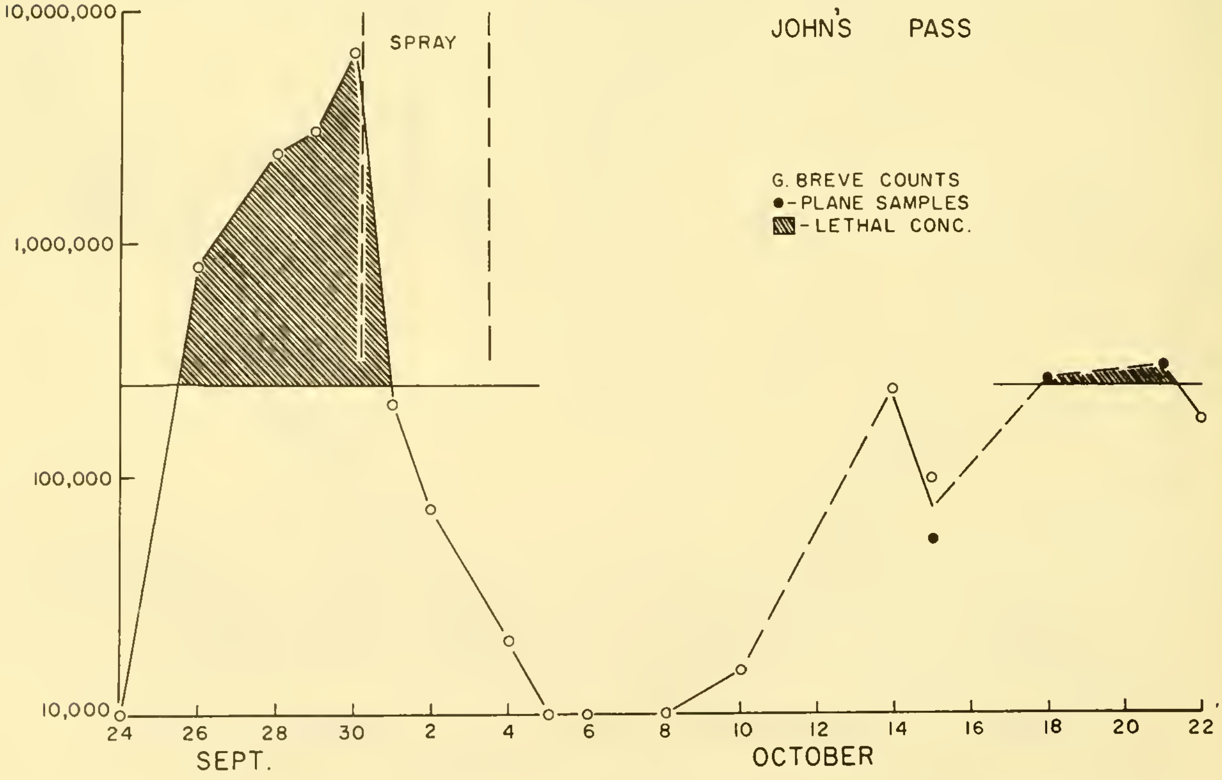

Figure 15.--Numbers of red tide organisms per liter off John's Pass.

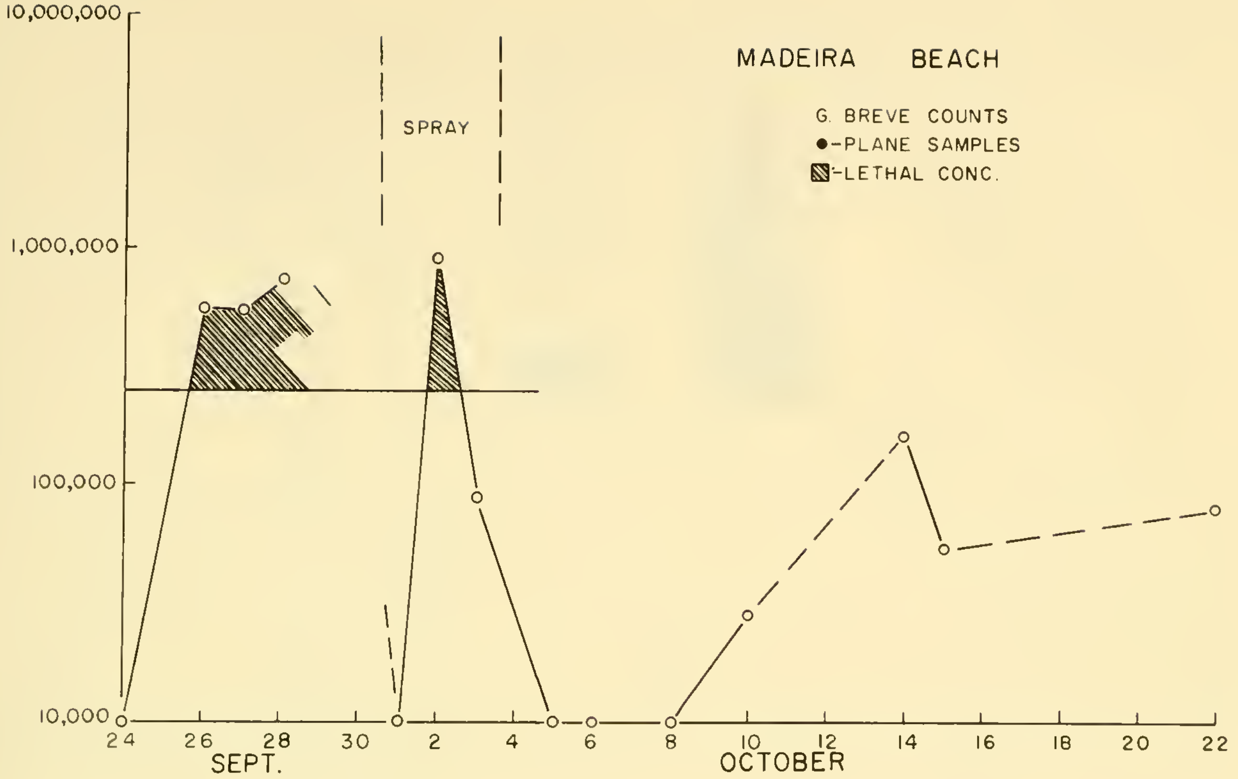

Figure 16.--Numbers of red tide organisms per liter off Madeira Beach.

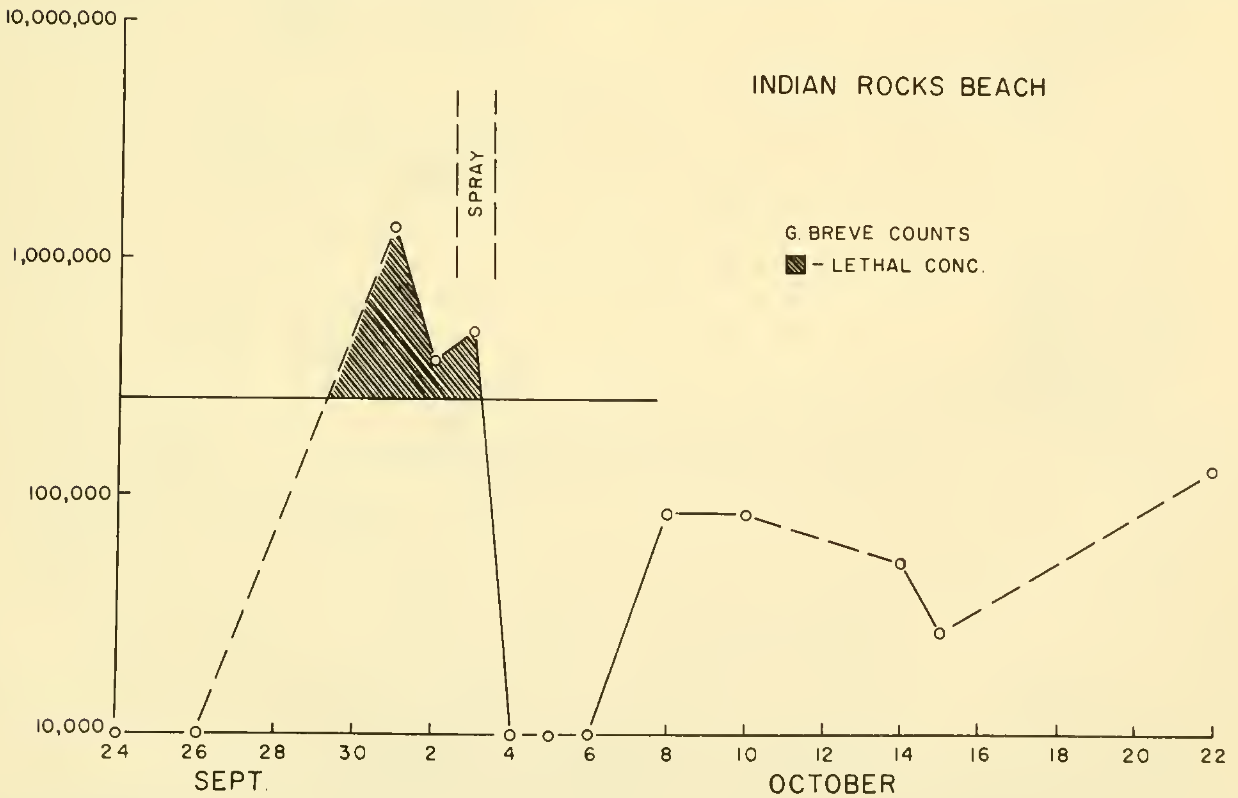

Figure 17.--Numbers of red tide organisms per liter off Indian Rocks Beach.

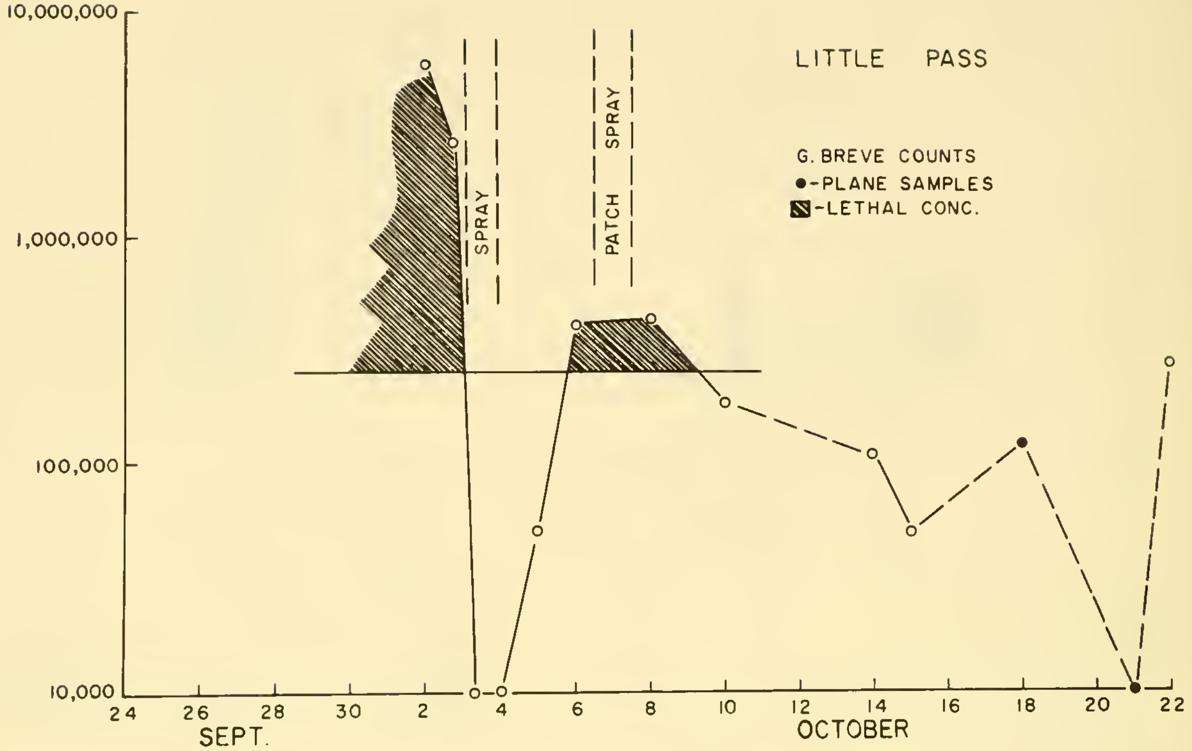

Figure 18.--Numbers of red tide organisms per liter off Little Pass.

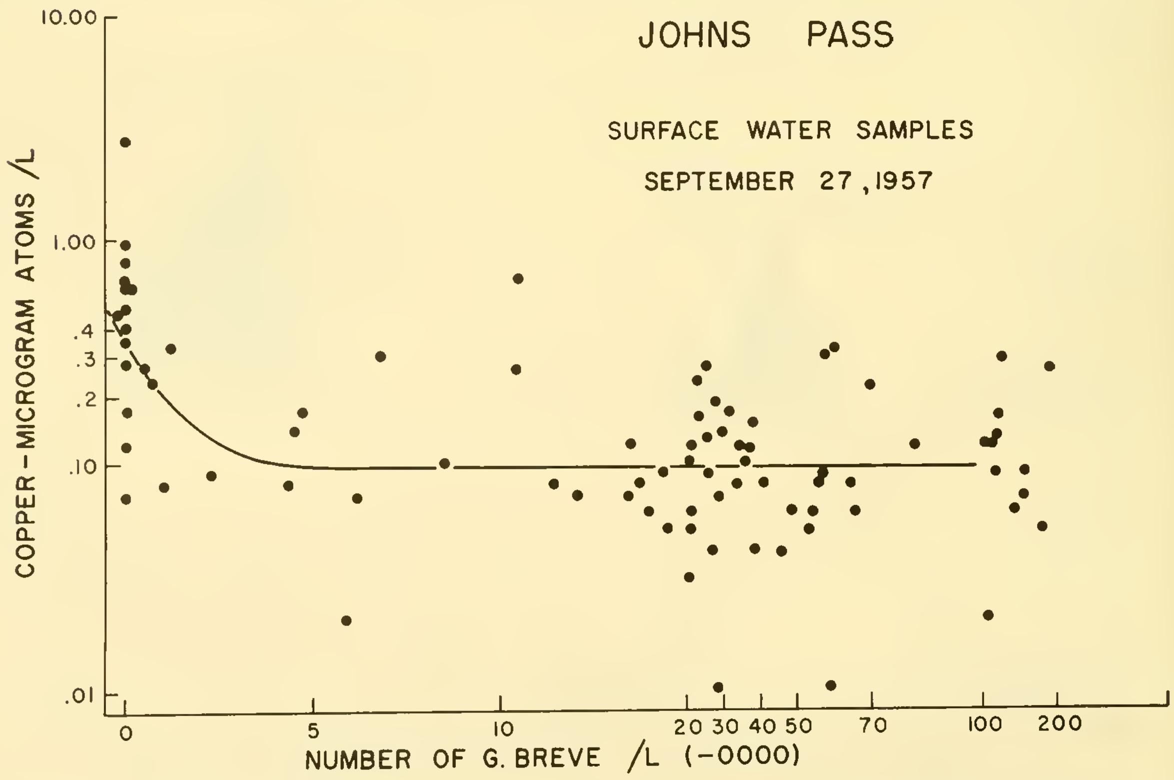

Figure 19.--Microgram atoms of copper per liter off John's Pass and number of red tid organisms per liter. Empirical curve shows that number of organisms was reduced at higher levels of copper.

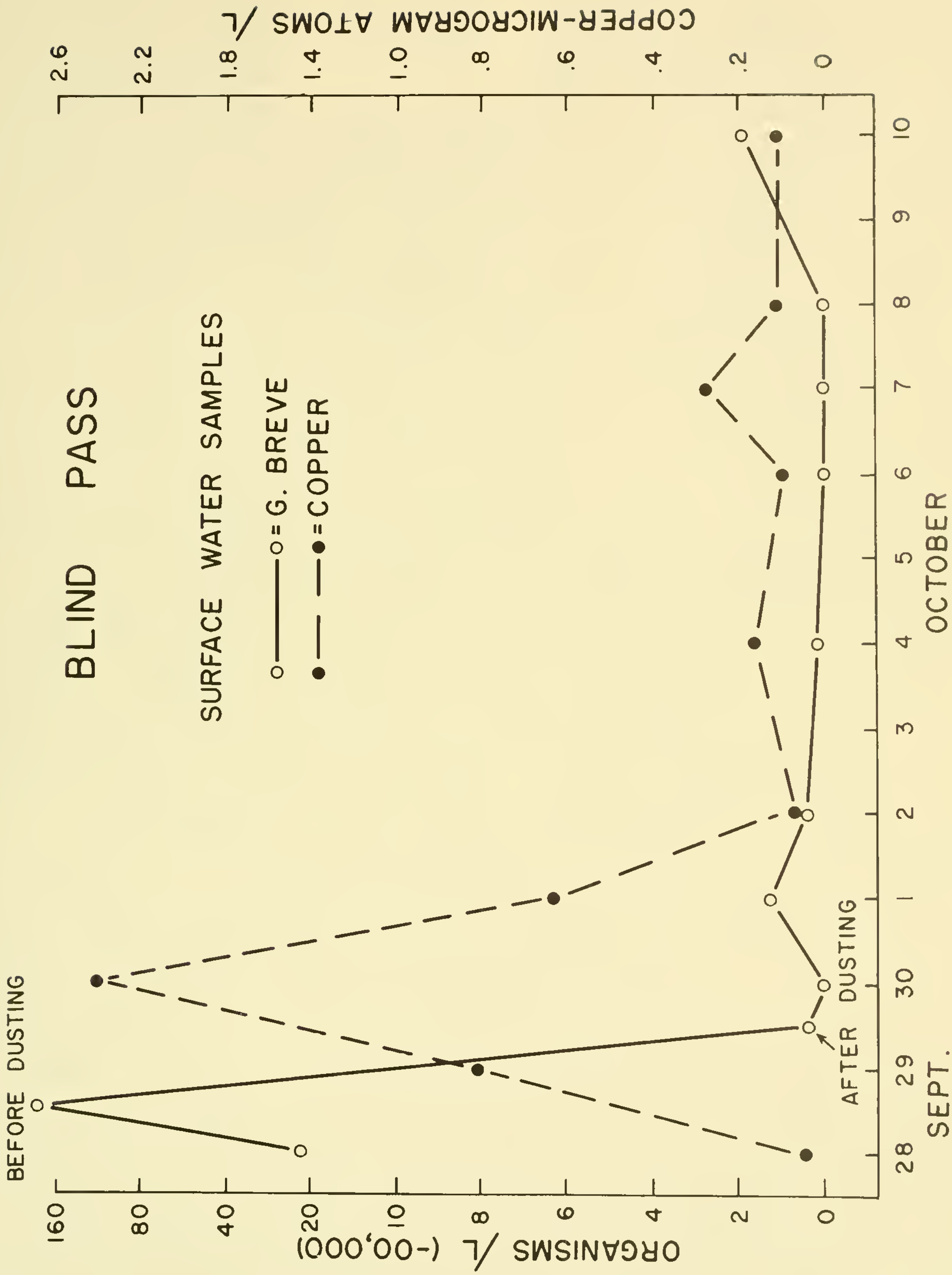

Figure 20.--Surface water samples from off Blind Pass showing the number of red tide organisms and copper concentrations per liter. The before and after dusting points for the G. breve curve on September 29 show the swift destruction of G. breve when the copper concentration rose.

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