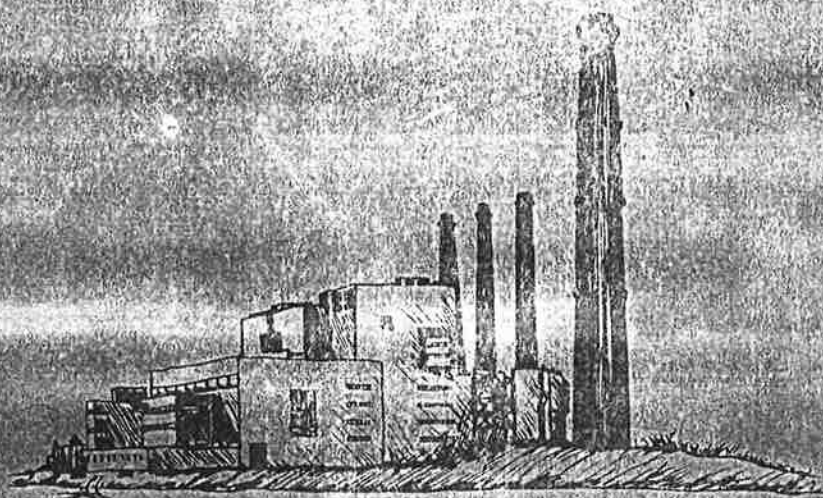


PROGRESS REPORT NO. 9
OCTOBER-DECEMBER, 1973



*INVESTIGATIONS OF THE EFFECTS OF
ELECTRICAL POWER GENERATION ON
MARINE RESOURCES IN SALEM HARBOR*

Arthur P. Chesmore, David J. Brown,
Barry A. Ketschke and Elaine M. Sawin

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Department of Natural Resources
The Commonwealth of Massachusetts



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1.0 INTRODUCTION

The following is the ninth quarterly progress report of research performed by the Division of Marine Fisheries operating under contract DMF-2-72 with the New England Power Company. Included are data collected from 1 October through 31 December, 1973.

Current and thermal surveys were performed. Catch/effort statistics for dominant finfish species sampled in 1965, and since July 1971 were compiled. Sport finfish data and lobster tag returns are summarized. Bioassays were initiated for lethal levels of residual chlorine on selected finfish.

Biological impact of a new 860 MW generating unit in Salem Harbor is under initial review.

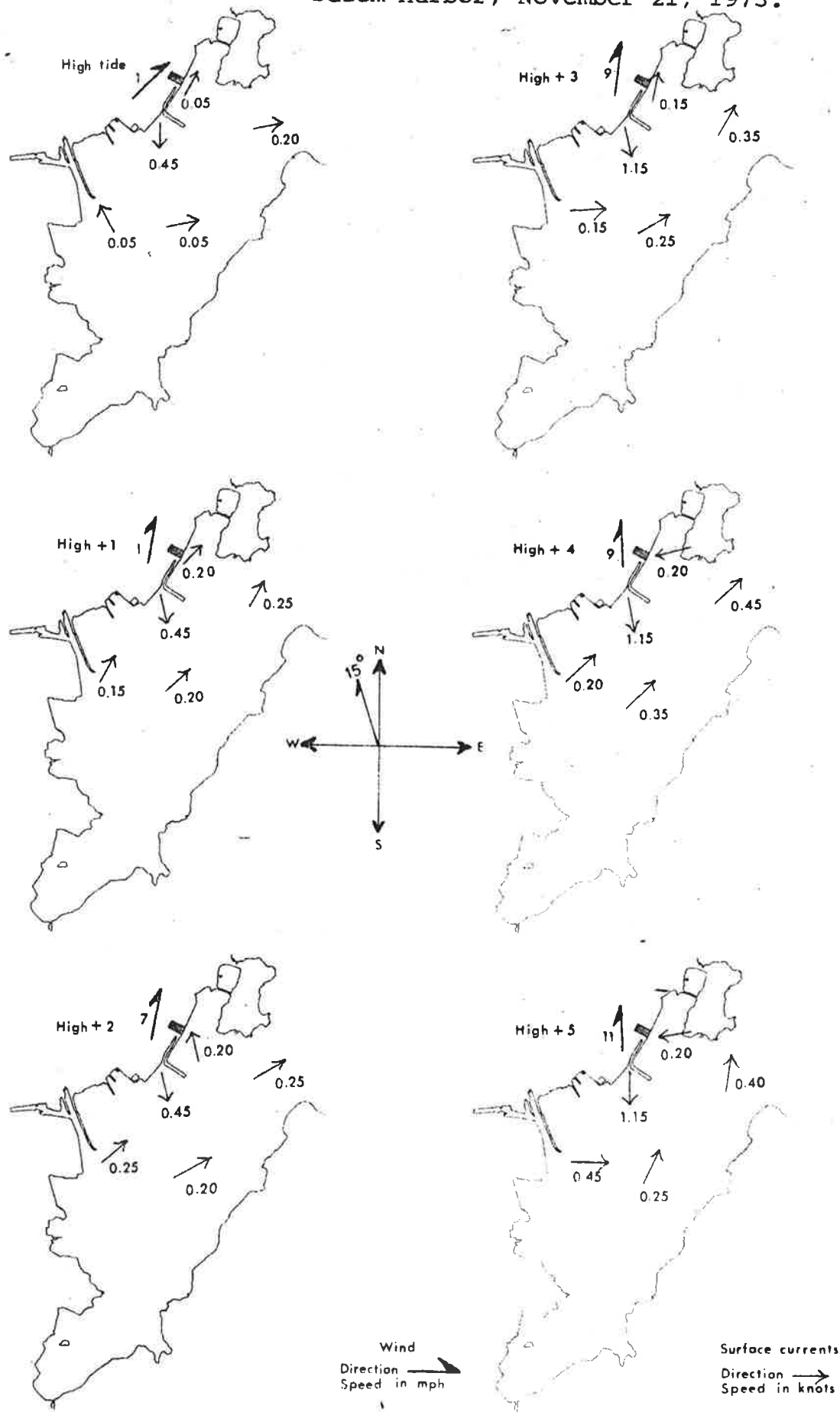
2.0 PHYSICAL INVESTIGATIONS

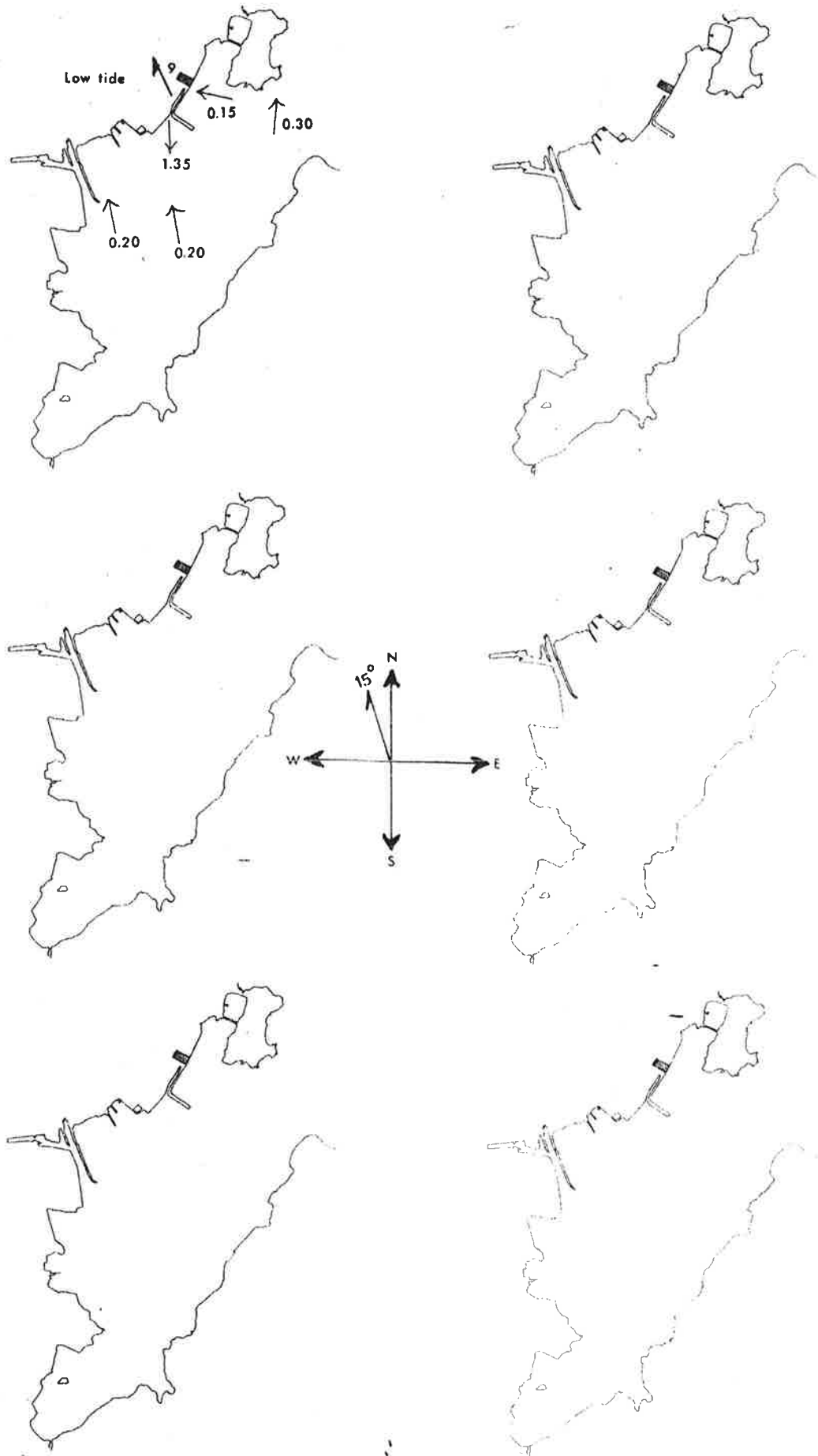
2.1 Hydrology

Surface currents were surveyed on November 21 during an ebb tide using an Endeco 110 remote reading current meter. Station locations, wind and current directions and velocities are presented in Figure 2.1. Current direction was generally northeasterly, and current velocity increased with falling tide and increasing wind velocity. Wind direction shifted from southwesterly to south-southeasterly during the survey. Current direction at the point of discharge was southerly and velocity increased as the tide ebbed. Circulating water volume through the plant was constant during the survey.

Identification of plume characteristics by surface current patterns were discontinued in favor of two and three dimensional thermal surveys.

Figure 2.1. Surface current patterns for Salem Harbor, November 21, 1973.





2.2 Temperature

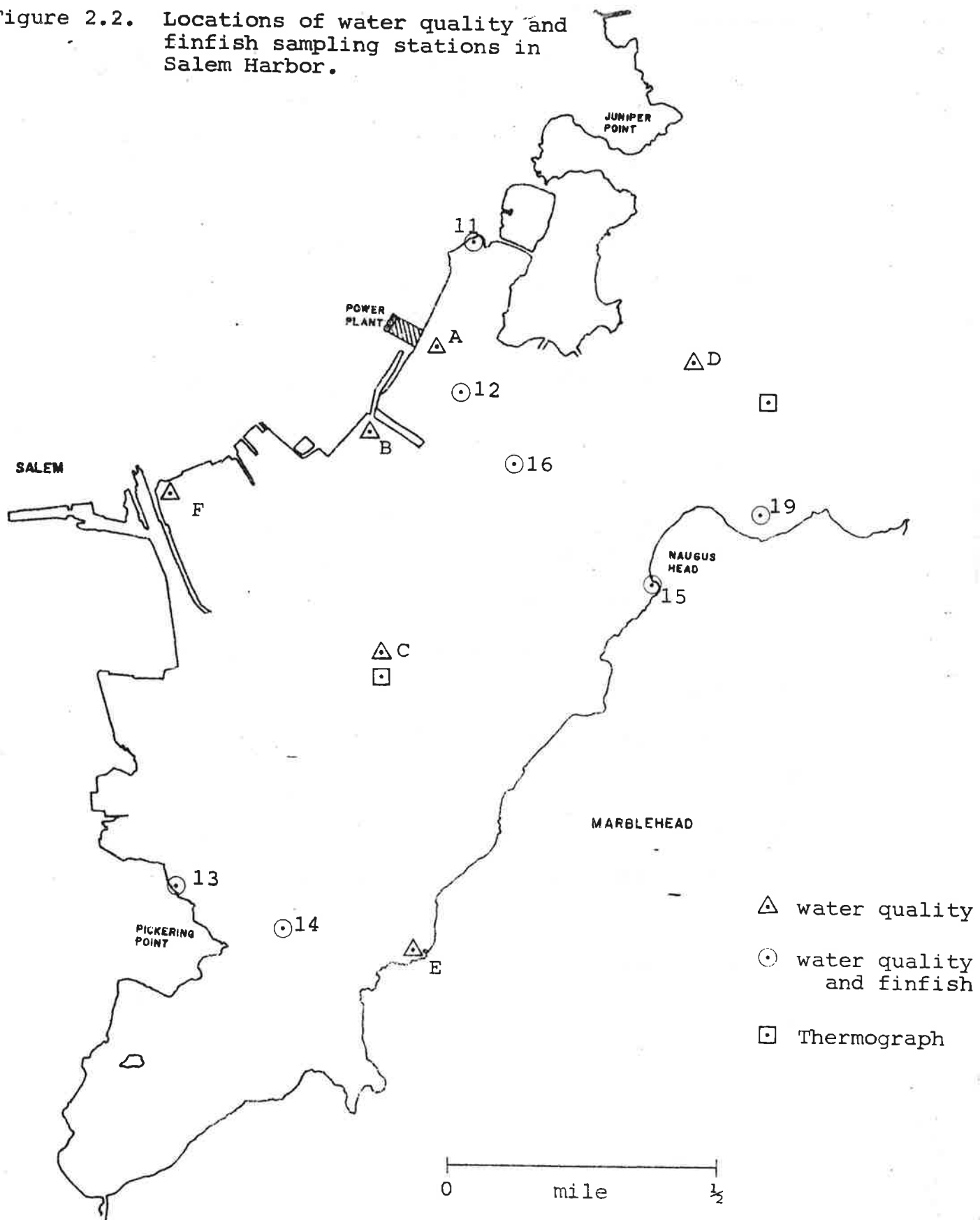
Average surface water temperature for the quarter in Salem Harbor decreased from 18.5 to 9.1°C and was similar for the same period in 1972.

Mean daily water temperatures obtained from continuous recording thermographs through November 13 continue to show minimal variation among Stations A, C, and D (Figures 2.2 and 2.3). Temperatures at Stations A, C, and D ranged from 4.4 to 17.0°C; corresponding ranges at Station B were 6.5 to 23.4°C.

Thermal surveys on October 15 and December 13 along three transects at four tidal stages indicated return of Salem Harbor to isothermic conditions (Figures 2.4 - 2.6). Circulating water volume at the Power Plant averaged 206,500 and 219,320 gpm on the respective sampling days.

Effects of the heated effluent, horizontally and vertically, were similar on both surveys. Surface dispersion of the plume extended to 2400 feet from the mouth of the discharge canal. These findings are similar to those reported in Quarterly Reports No. 5 and No. 8. Except for the December 13 mid-ebb survey when thermal effects existed to a depth of 14 feet, heated water at the discharge was confined to a depth <10 feet, approximating studies done in the Fall of 1972.

Figure 2.2. Locations of water quality and finfish sampling stations in Salem Harbor.

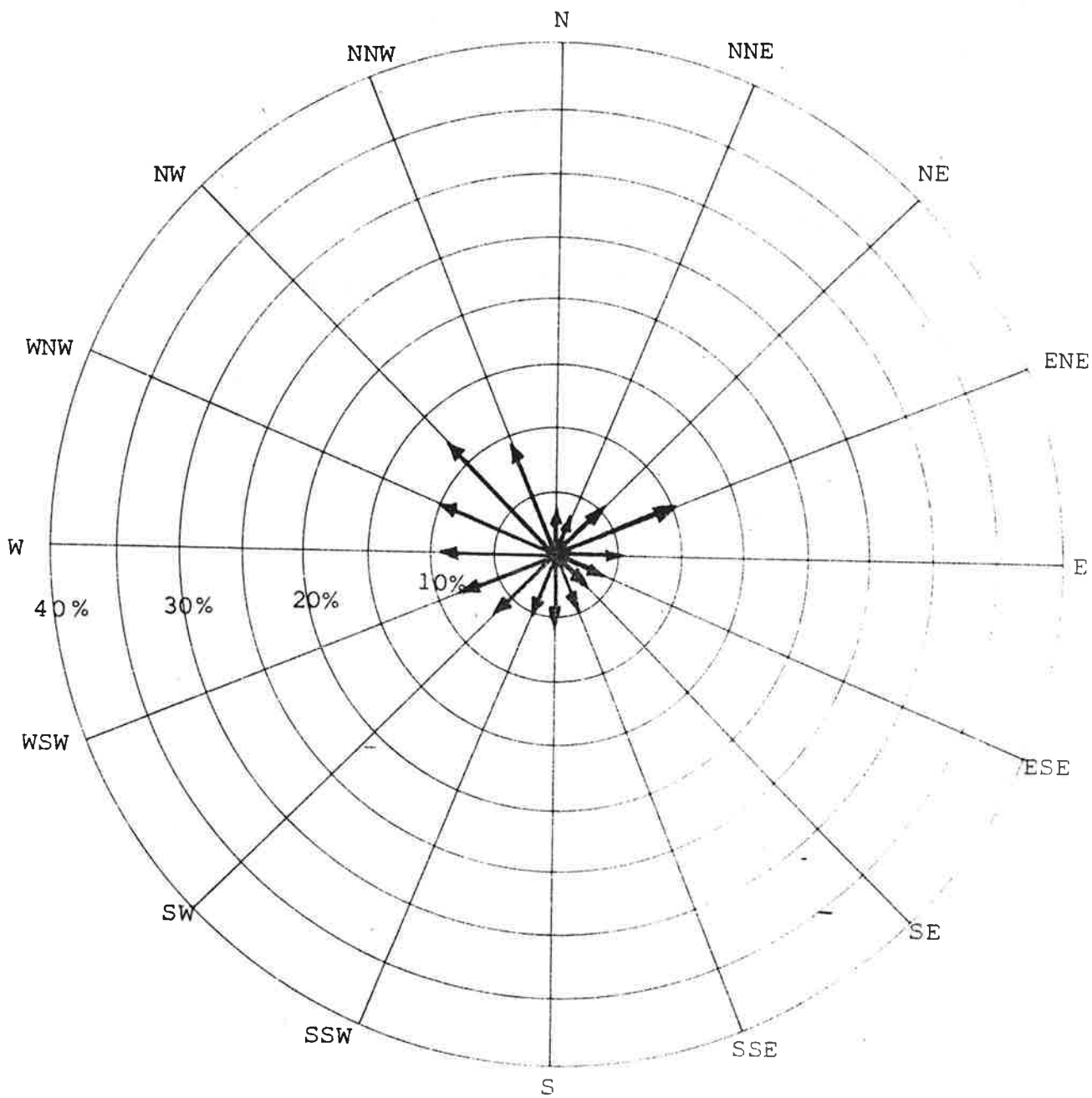


2.3 Wind

Variations in wind direction at the Power Plant for the quarter are presented in Figures 2.7 - 2.9. Hourly and average wind velocities are supplied by the New England Power Company. Due to computer error, data presented in Quarterly Report No. 8 (Figures 2.19 - 2.27) should be corrected by rotating directional arrows 15° to the east (clockwise).

Field recording of wind direction and velocity has been terminated due to unreliability of methods and equipment.

Figure 2.7. Wind occurrence in Salem Harbor, October, 1973.



→ Wind Origin

Figure 2.4. Locations of temperature profile transects, Salem Harbor, October 15 and December 13, 1973.

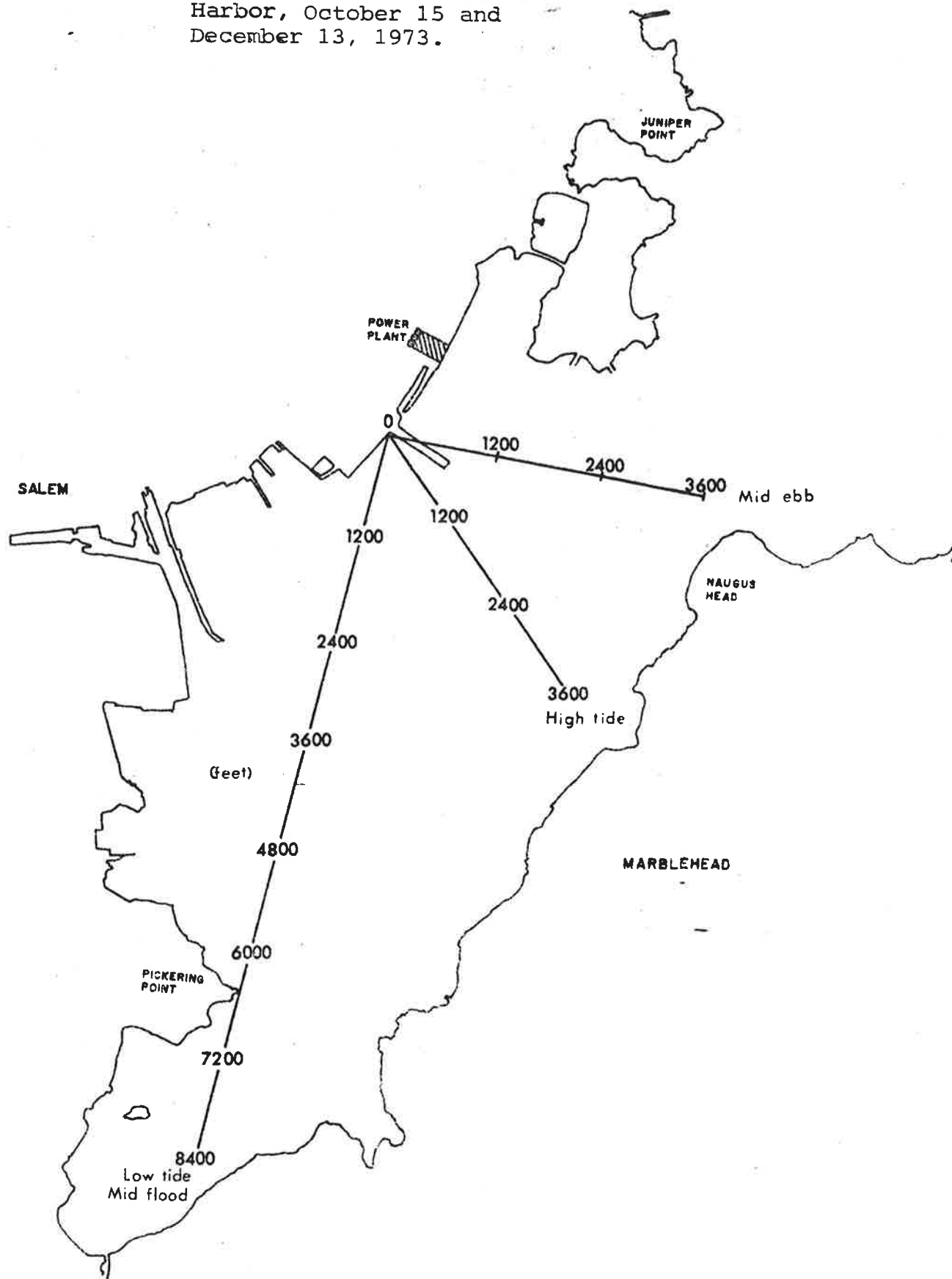


Figure 2.3. Mean surface water temperatures recorded at Stations A - D in Salem Harbor, October - December, 1973.

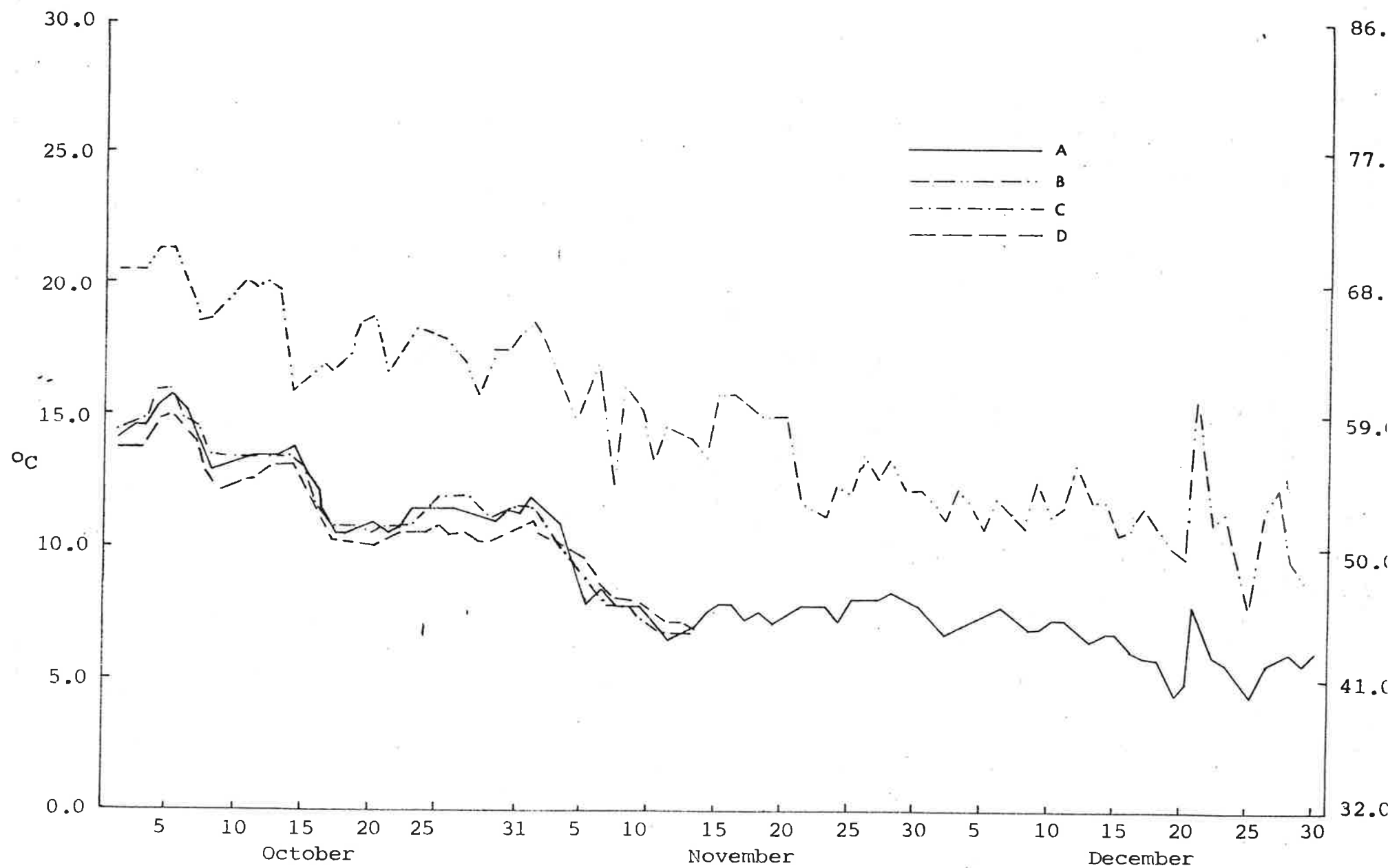


Figure 2.5. Vertical isotherms ($^{\circ}\text{C}$) in Salem Harbor, October 15, 1973.

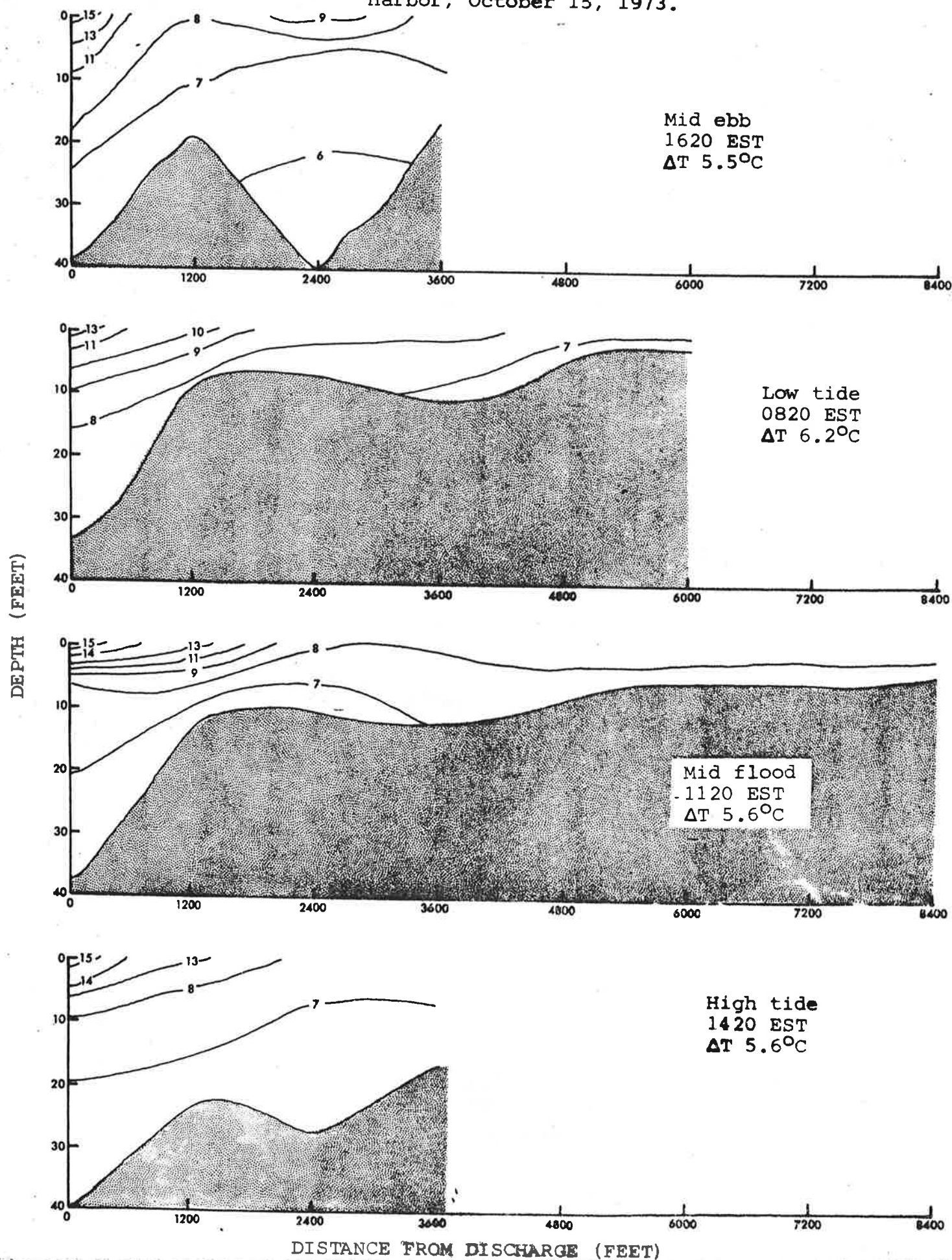


Figure 2.6. Vertical isotherms ($^{\circ}\text{C}$) in Salem Harbor, December 13, 1973.

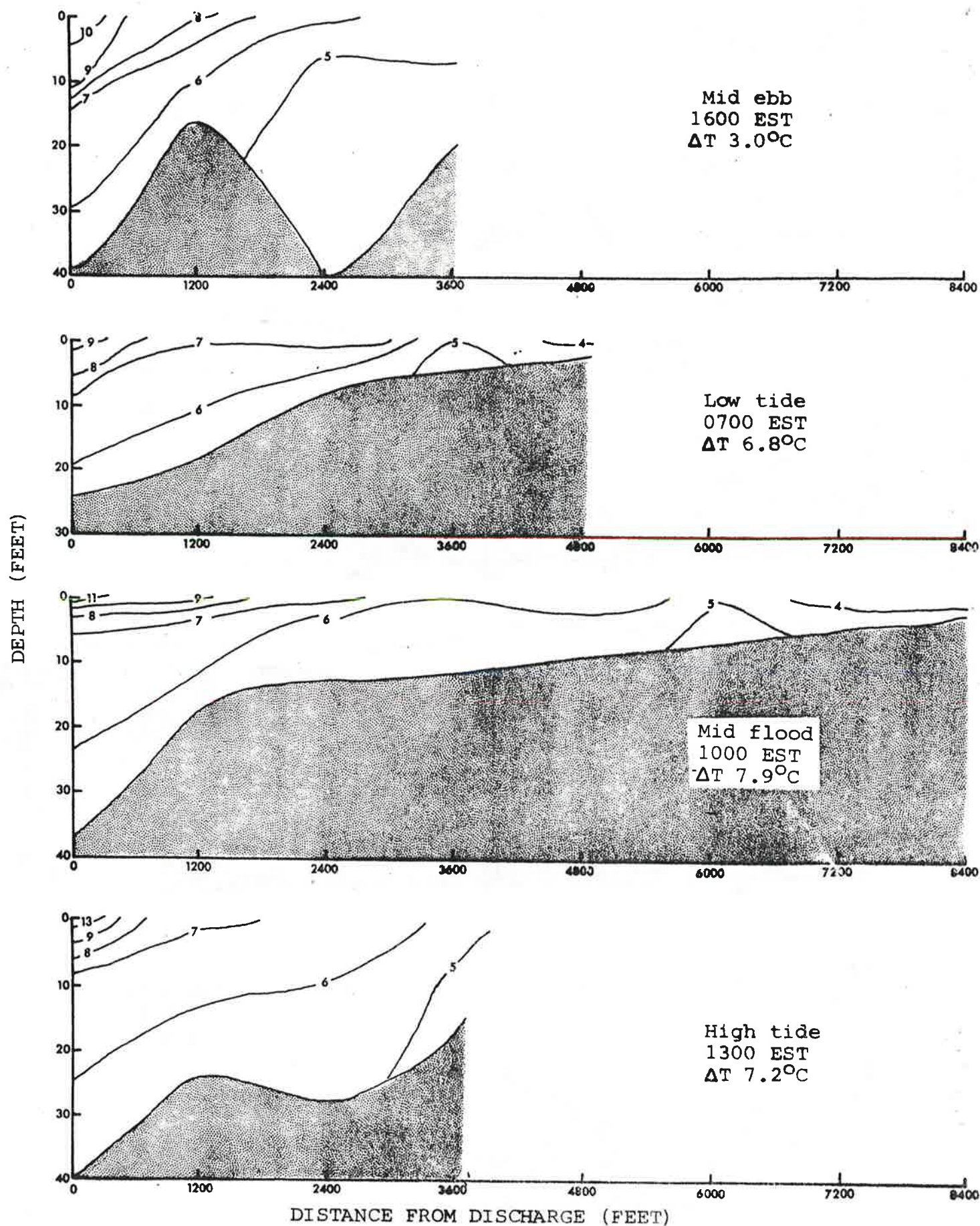


Figure 2.8. Wind occurrence in Salem Harbor, November, 1973.

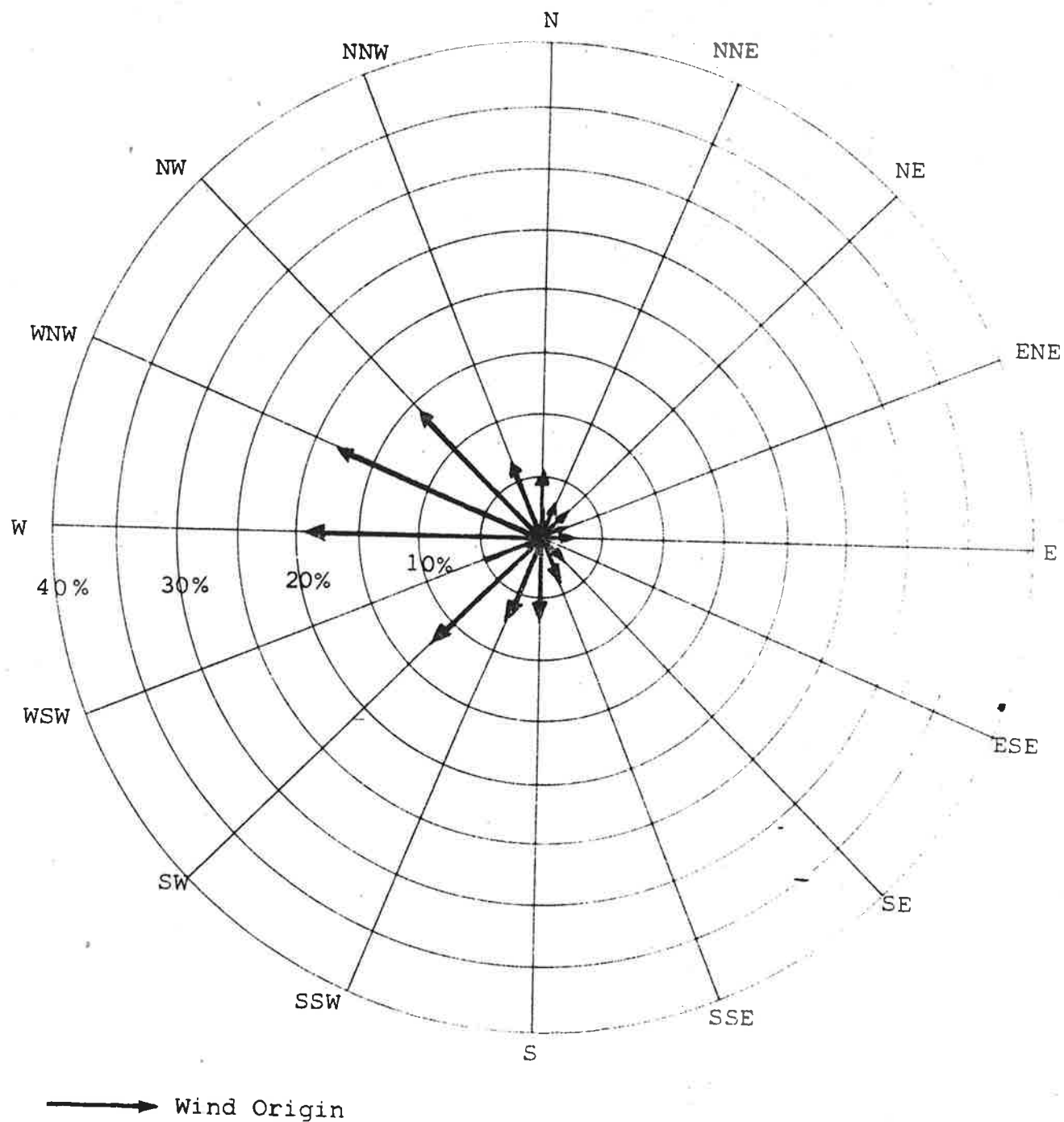


Figure 2.9. Wind occurrence in Salem Harbor, December, 1973.

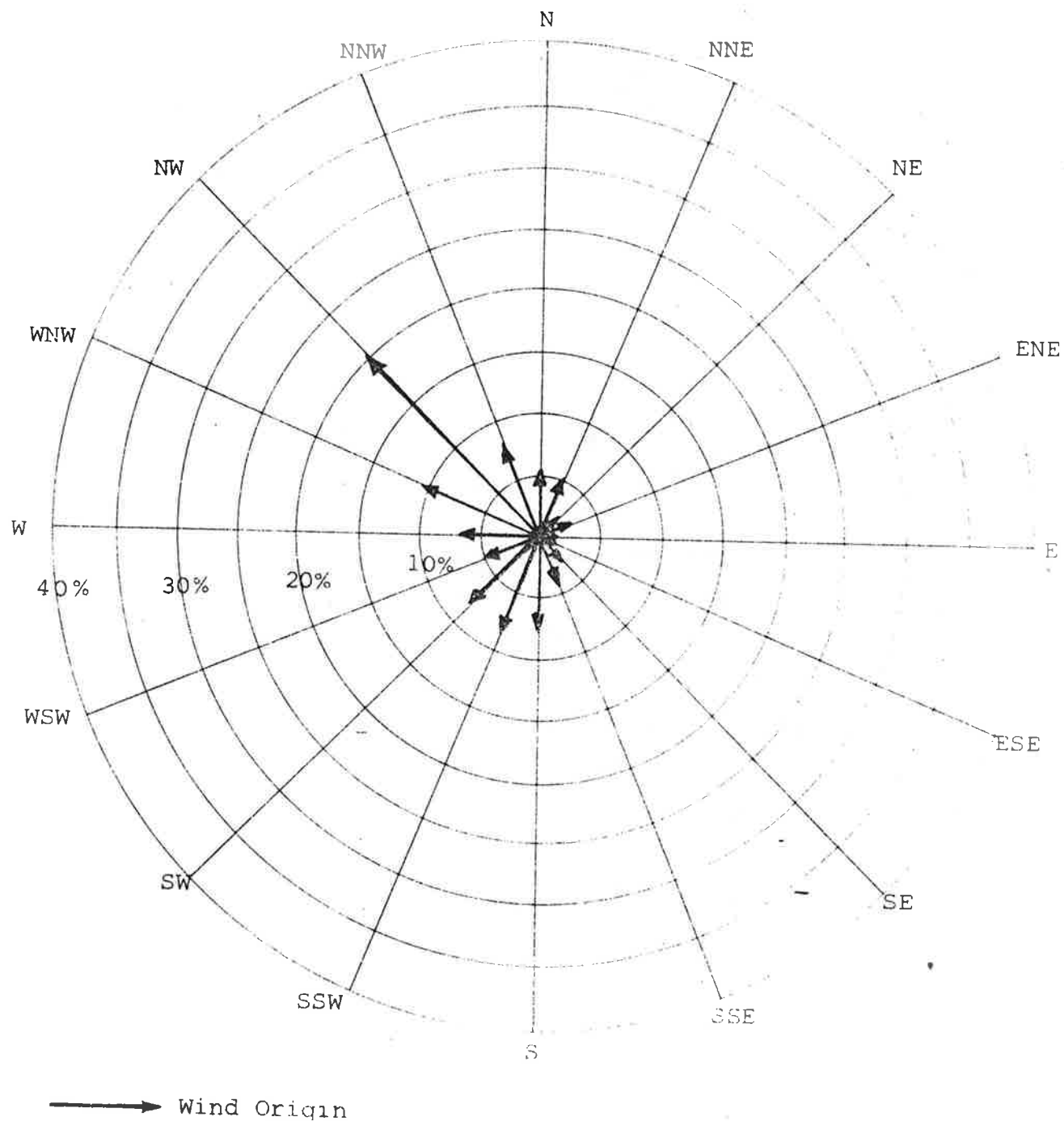


Table 3.1. Water quality data for Salem Harbor, October - December, 1973.

			TIDAL	WIND		CLOUD			TEMP °C	SALINITY		CO ₂	O ₂	BOD	NO ₂ -N	NO ₃ -N	PO ₄ -P
DATE	SAMPLE NUMBER	TIME (EST)	STAGE (HOURS)	DIR/VEL (MPH)	COVER (%)	DEPTH (FEET)	AIR	WATER	(0/00)	pH	(ppm)	(ppm)	(ppm)	µg-atom/L			
Station A																	
10/4	001213	0820	high +4	0	100	S	17.0	15.0	30.0	8.5	10.0	8.7	4.1	0.4	34.4	5.9	
10/11	001243	1040	high + ½	0	30	S	15.0	12.0	31.4	8.5	10.0	8.7	2.2	0.2	32.3	2.9	
10/15	001249	1110	low +4½	0	10	S	20.0	13.0	31.4	8.5	10.0	8.9	2.2	0.1	34.0	4.7	
10/23	001265	1040	high +2	SE/5	30	S	14.0	10.5	31.0	8.5	5.0	9.5	3.4	0.8	39.4	10.3	
11/2	001289	1409	low +4	0	30	S	16.0	10.5	30.1	8.5	10.0	8.3		0.1	31.6	12.5	
11/6	001299	0800	high + ½	0	10	S	0.5	8.0	31.5	8.5	10.0	8.4		0.9	32.7	15.5	
11/12	001311	1135	low +5½	SW/5	90	S	4.5	7.0	31.2	8.5	10.0	10.0		2.0	31.3	14.8	
11/20	001328	0825	high +1	0	80	S	3.0	7.0	31.8	8.5	10.0	9.8	2.1	0.8	28.3	14.8	
11/26	001331	1115	low +5½	0	0	S	5.5	7.5	31.5	8.5	5.0	10.4	2.9	0.9	26.3	9.4	
12/3	001341	1513	low +4	SW/10	80	S	5.5	6.0	31.4	8.5	5.0	9.8	2.7	0.8	34.3	15.5	
12/12	001357	0930	low +3	0	0	S	2.0	6.0	31.6	8.5	10.0	8.9	1.6	1.5	38.6	20.4	
12/18	001364	0845	high +2½	W/5	10	S	-2.0	4.5	30.7	8.5	10.0	9.7	1.2	1.8	37.3	21.9	
12/27	001379	1220	high	NE/5	100	S	5.0	5.5	31.1	8.5	5.0	10.2	3.3	0.7	42.2	17.4	
Station B																	
10/4	001216	1030	low	NW/5	100	S	19.0	22.0	30.1	8.5	10.0	8.0	2.4	0.1	35.3	11.3	
10/11	001248	1130	high +1½	0	60	S	13.0	19.0	31.2	8.5	10.0	8.9	2.4	0.4	30.0	9.5	
10/15	001241	1040	low +4	SW/15	10	S	14.0	19.0	31.5	8.5	10.0	8.4	2.2	0.3	29.4	4.4	
10/23	001270	1110	high +2½	SE/5	30	S	15.5	18.5	31.1	8.5	10.0	8.5	2.1	0.6	37.8	11.0	
11/2	001290	1510	low +5	0	40	S	13.0	17.5	30.7	8.5	10.0	8.2		0.0	30.7	11.9	
11/6	001296	1025	high +3	W/5	90	S	2.0	16.0	31.5	8.5	10.0	8.4		0.6	35.0	24.5	
11/12	001312	1216	high	0	90	S	5.0	14.5	31.3	8.5	10.0	9.6		1.2	34.2	14.8	
11/20	001325	1100	high +3½	0	10	S	4.0	15.0	31.4	8.5	5.0	9.0	1.3	0.4	33.8	12.7	
11/26	001332	1105	low +5½	0	0	S	5.0	14.0	31.5	8.5	5.0	9.7	3.1	1.6	30.2	10.1	
12/3	001342	1505	low +4	SW/10	70	S	5.5	13.0	31.4	8.5	5.0	9.4	1.7	0.4	45.7	16.1	
12/12	001355	1100	low +4½	NW/15	0	S	2.5	13.0	31.4	8.5	10.0	8.9	1.7	0.9	38.8	24.6	
12/18	001365	0910	high +3	W/15	10	S	-7.5	12.0	30.8	8.5	10.0	11.7	3.9	2.2	47.2	19.4	
12/27	001380	1245	high	0	100	S	8.0	15.0	31.1	8.5	5.0	9.8	2.8	0.5	42.2	15.9	

3.0 CHEMICAL INVESTIGATIONS

3.1 Water Quality

Surface water quality exhibited the following ranges: temperature, 1.5 - 22.0°C; salinity, 26.2 - 34.0 ‰; pH, 8.0 - 8.5; carbon dioxide, 5.0 - 10.0 ppm; dissolved oxygen, 5.3 - 13.3 ppm; biochemical oxygen demand, 1.1 - 6.0 ppm; nitrite-N, 0.0 - 2.2 µg-atoms/l; nitrate-N, 17.4 - 85.5 µg-atoms/l; and phosphate-P, 1.6 - 54.8 µg-atoms/l (Table 3.1).

Field tests for carbon dioxide have been terminated. Review of data collected since 1971 reflects minimal variance in CO₂ recordings (5.0 - 15.0 ppm). Carbon dioxide is never a limiting factor in phytoplankton production since CO₂ used during photosynthesis is replaced by the hydrolysis of the bicarbonates (Sverdrup, et al., 1942).

Table 3.1. Continued

DATE	SAMPLE NUMBER	TIME (EST)	TIDAL		WIND		CLOUD		DEPTH (FEET)	TEMP °C		SALINITY (0/00)	CO ₂ pH (ppm)	O ₂ (ppm)	BOD (ppm)	NO ₂ -N µg-atom/L	NO ₃ -N µg-atom/L	PO ₄ -P µg-atom/L
			STAGE (HOURS)		DIR/VEL (MPH)	COVER (%)	AIR	WATER										
Station C																		
10/4	001215	0935	high	+5	SW/10	100	S	21.0	17.0	30.0	8.5	10.0	8.8	2.9	0.2	17.4	7.6	
10/11	001245	1105	high	+1	0	20	S	10.5	12.0	31.1	8.5	10.0	8.9	2.7	0.2	17.6	11.3	
10/15	001240	1000	low	+3	SW/25	0	S	15.0	12.0	31.5	8.5	10.0	8.5	3.2	0.5	27.9	4.7	
10/23	001267	1050	high	+2	SE/5	30	S	14.0	10.0	31.0	8.5	10.0	9.3	2.2	0.6	38.0	9.4	
11/2	001291	1430	low	+4½	SW/15	30	S	13.0	10.5	30.7	8.5	10.0	8.3		0.1	31.0	9.7	
11/6	001297	0925	high	+2	W/20	40	S	2.0	8.0	31.5	8.5	10.0	8.6		0.7	31.0	21.3	
11/12	001313	1153	high		0	90	S	4.5	8.0	31.2	8.5	10.0	9.9		1.2	28.0	15.2	
11/20	001326	1010	high	+3	NW/5	20	S	2.5	7.0	31.4	8.5	5.0	9.9	2.1	1.1	32.7	11.9	
11/26	001333	1035	low	+5	0	0	S	3.5	9.0	31.5	8.5	5.0	10.2	3.5	0.9	37.2	10.1	
12/3	001343	1444	low	+3½	SW/10	90	S	5.0	6.5	31.4	8.5	5.0	9.6	2.2	0.8	43.6	14.8	
12/12	001358	1010	low	+4	NW/15	10	S	-1.0	6.5	31.7	8.0	10.0	9.0	1.6	1.1	42.1	22.1	
12/18	001366	0930	high	+3½	W/15	10	S	-6.5	4.0	31.1	8.5	10.0	12.7	4.8	0.9	38.2	19.4	
12/27	001383	1345	high	+1	NE/10	100	S	5.0	5.0	30.7	8.5	10.0	10.2	3.6	0.5	39.2	18.2	
Station D																		
10/4	001214	0900	high	+4½	W/5	100	S	19.0	15.0	30.0	8.5	10.0	9.2	2.8	0.3	30.4	5.9	
10/11	001244	1050	high	+1	0	20	S	10.0	11.0	31.2	8.5	10.0	8.8	2.0	0.2	30.0	1.6	
10/15	001250	1135	low	+5	SW/20	10	S	18.0	12.0	31.0	8.5	5.0	8.9	2.0	0.1	28.8	3.7	
10/23	001266	1045	high	+2	SE/5	30	S	14.5	10.5	31.2	8.5	10.0	9.5	2.7	0.9	39.7	11.0	
11/2	001292	1425	low	+4½	SW/15	40	S	14.0	10.0	30.5	8.5	10.0			0.1	29.6	12.2	
11/6	001298	0850	high	+1½	W/25	20	S	1.0	8.0	31.5	8.5	10.0	8.6		0.7	31.3	20.6	
11/12	001314	1145	low	+5½	0	90	S	6.5	6.5	31.5	8.5	10.0	9.6		1.5	31.5	14.2	
11/20	001327	0915	high	+2	NW/5	40	S	4.0	6.5	31.4	8.5	5.0	9.8	2.2	0.5	29.4	13.6	
11/26	001334	1025	low	+4½	0	0	S	3.5	7.0	31.5	8.5	10.0	9.8	3.4	1.3	35.6	10.8	
12/3	001344	1433	low	+4½	SW/5	90	S	4.5	6.0	31.6	8.5	5.0	9.7	2.3	0.5	39.6	12.9	
12/12	001356	0834	high	+2½	NW/20	10	S	-1.0	6.5	31.5	8.5	10.0	9.0	1.4	1.4	47.9	17.0	
12/18	001367	0945	high	+3½	W/15	10	S	-7.5	4.0	31.1	8.5	10.0	5.3		1.0	37.8	19.4	
12/27	001384	1355	high	+1	NE/10	100	S	5.0	5.0	31.1	8.5	5.0	10.0	3.4	0.4	31.9	18.9	

Table 3.1. Continued

DATE	SAMPLE NUMBER	TIME (EST)	TIDAL		WIND		CLOUD		DEPTH (FEET)	TEMP °C		SALINITY (0/00)	CO ₂ pH (ppm)	O ₂ (ppm)	BOD (ppm)	NO ₂ -N µg-atom/L	NO ₃ -N µg-atom/L	PO ₄ -P µg-atom/L
			STAGE (HOURS)		DIR/VEL (MPH)	COVER (%)	AIR	WATER										
Station E																		
10/4	001227	1216	low	+2	W/5	0	S	19.0	17.5	28.0	8.5	10.0	7.7	3.9	0.4	34.1	30.2	
10/11	001246	1115	high	+1	0	40	S	13.0	12.0	31.1	8.5	10.0	8.5	2.4	0.3	39.7	7.4	
10/15	001260	1345	high	+1	W/5	0	S	17.5	13.5	30.5	8.5	5.0	8.8	4.8	0.6	62.5	21.8	
10/23	001268	1055	high	+2	SE/5	30	S	14.0	10.0	30.8	8.5	10.0	9.0	2.3	0.8	44.5	11.3	
11/2	001293	1445	low	+5	SW/15	40	S	13.0	10.5	30.4	8.5	10.0	8.4		0.1	28.0	15.0	
11/7	001299	0920	high	+1½	W/15	0	S	3.0	6.0	28.1	8.5	5.0	9.6		1.2	66.4	54.8	
11/12	001315	1201	high		0	90	S	5.5	6.5	31.2	8.5	10.0	10.0		1.2	30.5	16.1	
11/20	001329	1325	low		0	0	S	3.5	6.5	30.7	8.5	10.0	9.8	3.5	0.4	38.7	29.7	
11/26	001335	1045	low	+5	0	0	S	3.5	7.0	30.8	8.5	5.0	9.6	3.3	1.1	26.4	16.1	
12/3	001345	1450	low	+4	SW/10	80	S	5.5	5.5	31.4	8.5	5.0	10.5	2.9	1.5	32.7	9.7	
12/12	001360	1240	high	+½	NW/20	0	S	3.5	6.0	26.2	8.5	10.0	10.6	4.4	2.0	85.5	95.9	
12/18	001368	0927	high	+3½	W/20	10	S	-3.0	7.0	29.0	8.5	10.0	10.5	2.5	1.2	53.6	27.7	
12/27	001382	1335	high	+1	NE/10	100	S	5.5	5.5	31.7	8.5	10.0	10.3	3.4	0.4	41.0	16.6	
Station F																		
10/4	001228	1230	low	+2	0	30	S	18.5	16.0	30.1	8.5	5.0	8.9	3.7	0.2	32.1	10.5	
10/11	001247	1120	high	+1½	0	40	S	13.0	13.0	31.0	8.5	10.0	8.4	1.6	0.4	55.8	1.6	
10/15	001261	1400	high	+1	W/10	0	S	19.0	13.5	31.5	8.5	10.0	8.9	3.1	0.4	34.1	8.1	
10/23	001269	1105	high	+2½	SE/5	30	S	15.5	10.5	31.0	8.5	10.0	8.8	1.7	0.9	47.2	9.0	
11/2	001294	1450	low	+5	SW/10	20	S	15.0	10.5	30.4	8.5	10.0	6.2		0.0	28.5	15.0	
11/7	001300	1000	high	+2	W/10	0	S	4.5	8.0	31.8	8.5	10.0	8.3		1.2	37.8	20.6	
11/12	001316	1210	high		0	90	S	5.0	7.5	31.2	8.5	10.0	9.9		1.7	32.8	14.2	
11/20	001330	1345	low		0	0	S	4.5	7.5	31.4	8.5	10.0	10.7	2.5	0.6	35.1	16.1	
11/26	001336	1055	low	+5	0	0	S	5.0	8.0	31.5	8.5	5.0	10.2	3.1	0.6	31.2	9.4	
12/3	001346	1457	low	+4	SW/5	80	S	4.5	5.5	31.4	8.5	5.0	10.4	2.4	0.7	34.0	11.6	
12/12	001359	1210	high		NW/10	0	S	4.0	6.5	31.5	8.5	10.0	9.4	4.9	1.3	36.0	22.9	
12/18	001369	0920	high	+3½	W/15	10	S	-6.5	4.5	30.8	8.5	10.0	13.3	5.5	1.1	41.8	21.3	
12/27	001381	1250	high		NE/5	100	S	5.5	6.5	30.5	8.5	5.0	9.8	3.0	0.6	34.8	15.1	

Table 3.1. Continued

DATE	SAMPLE NUMBER	TIME (EST)	TIDAL STAGE (HOURS)	WIND DIR/VEL (MPH)	CLOUD COVER (%)	DEPTH (FEET)	TEMP °C AIR WATER	SALINITY (0/00)	pH	CO ₂ (ppm)	O ₂ (ppm)	BOD (ppm)
<u>Station 5</u>												
10/9	001229	0815	high	0	10	S	8.0 12.0	32.5	8.5	5.0	9.1	
11/5	001288	1000	high +3½	SW/5	80	S	7.5 8.5	34.0	8.5	5.0	8.3	
12/6	001338	1015	high +3	W/5	60	S	11.5 7.5	31.0	8.5	5.0	9.1	2.8
12/20	001373	1000	high +2½	N/5	100	S	-2.0 5.5	31.0	8.5	5.0	10.1	1.8
<u>Station 11</u>												
10/9	001233	0900	high	0	10	S	19.5 12.5	34.0	8.5	5.0	8.3	3.1
10/10	001234	0845	low +5	NE/5	60	S	12.0 13.5	31.5	8.5	5.0	8.6	2.7
10/23	001262	0800	low +5½	0	0	S	11.0 10.0	31.5	8.5	10.0	8.1	4.6
10/24	001271	0830	low +5	0	0	S	9.5 10.0	31.5	8.5	10.0	7.7	1.7
11/7	001304	0840	high + ½	SW/5	0	S	5.5 7.0	33.0	8.5	5.0	8.5	
11/9	001306	0905	low +5½	SW/5	10	S	4.5 7.5	33.0	8.5	5.0	8.8	
11/19	001322	0755	high +1½	0	100	S	3.5 8.0	32.5	8.5	10.0	9.4	4.0
11/21	001321	0905	high +1	0	0	S	2.5 6.0	32.0	8.5	5.0	10.2	2.1
12/10	001349	0900	low +4½	0	100	S	8.5 7.5	31.0	8.5	10.0	7.7	2.1
12/11	001352	0930	low +4	0	100	S	4.5 6.0	31.5	8.5	5.0	8.5	1.1
12/18	001363	0910	high +3	SE/10	80	S	-9.0 4.5	30.5	8.5	10.0	12.3	3.8
12/19	001372	1015	high +3		0	S	-6.5 2.5	30.0	8.5	10.0	10.6	2.7
<u>Station 12</u>												
10/11	001237	0820	low +4½	0	20	S	7.5 12.0	32.0	8.5	10.0	8.4	4.3
10/24	001274	1145	high +2	NE/5	0	S	12.5 11.0	31.5	8.5	10.0	9.7	2.4
11/8	001309	0850	high	W/5	10	S	5.0 8.0	34.0	8.5	5.0	8.7	
11/19	001323	1600	low +4	0	0	S	3.5 7.0	31.0	8.5	10.0	10.0	2.3
12/10	001350	1205	high +2½		60	S	6.5 6.5	30.5	8.5	10.0	9.1	2.0
12/27	001378	1235	low +5½	NE/5	100	S	5.0 5.5	31.0	8.5	5.0	10.3	2.5

Table 3.1. Continued

DATE	SAMPLE NUMBER	TIME (EST)	TIDAL STAGE (HOURS)	WIND DIR/VEL (MPH)	CLOUD COVER (%)	DEPTH (FEET)	TEMP °C AIR WATER	SALINITY (0/00)	pH	CO ₂ (ppm)	O ₂ (ppm)	BOD (ppm)
Station 13												
10/9	001231	1055	high +2	0	10	S	15.0 13.5	30.5	8.5	10.0	8.7	2.4
10/10	001235	0940	high	NW/5	100	S	11.5 13.5	30.5	8.5	5.0	8.6	2.2
10/23	001263	0950	high +1	0	40	S	12.0 10.0	30.5	8.5	10.0	9.1	3.4
10/24	001273	0840	low +3½	0	0	S	12.0 10.0	31.5	8.5	10.0	9.0	2.6
11/7	001303	0940	high +1½	0	0	S	3.0 7.0	33.0	8.5	5.0	8.9	
11/9	001308	1030	high +1	SW/5	20	S	4.5 8.0	33.0	8.5	5.0	9.2	
11/19	001318	1000	high +3½	0	20	S	4.5 7.5	32.0	8.5	10.0	9.1	1.9
11/21	001320	1020	high +2	0	10	S	4.0 7.0	31.5	8.5	5.0	9.7	2.3
12/10	001348	1020	high	0	100	S	8.5 7.0	30.5	8.5	5.0	9.1	2.3
12/11	001353	1045	low +5	NW/5	100	S		31.0	8.5	5.0	9.6	2.4
12/18	001361	1015	high +4	W/10	80	S	-7.5 3.0	30.0	8.5	5.0	10.2	2.5
12/19	001371	0920	high +2½	NW/5	0	S	-11.5 1.5	30.0	8.5	10.0	10.7	1.2
Station 14												
10/11	001238	0855	low +5	N/5	60	S	9.5 13.5	30.5	8.5	10.0	8.7	2.8
10/24	001275	1020	high +1	0	0	S	15.0 12.5	32.0	8.5	10.0	9.8	2.6
11/8	001310	0925	high + ½	SW/10	20	S	5.0 8.0	33.0	8.5	5.0	8.5	
11/19	001324	1520	low +3½	0	0	S	5.0 7.5	32.0	8.5	10.0	10.4	3.1
12/10	001351	1130	high + ½	W/10	40	S	7.0 6.5	30.0	8.5	10.0	9.4	1.1
12/27	001377	1310	high + ½	NE/5	100	S	5.5 5.5	30.5	8.5	5.0	9.9	2.6
Station 15												
10/9	001232	1000	high +1	0	10	S	16.5 13.0	32.0	8.5	10.0	7.8	2.4
10/10	001236	0910	high	0	100	S	13.5 14.0	31.5	8.5	5.0	9.0	2.4
10/23	001264	0900	high	0	30	S	13.0 10.0	31.5	8.5	10.0	9.1	4.2
10/24	001272	0815	low +5	0	0	S	11.5 10.0	31.0	8.5	10.0	9.0	1.8
11/7	001305	0905	high +1	W/15	0	S	4.0 7.0	32.0	8.5	5.0	9.2	
11/19	001317	0900	high +2½	0	100	S	4.5 7.0	31.5	8.5	5.0	8.9	1.9
11/21	001319	0950	high +1½	0	20	S	4.0 7.0	31.5	8.5	5.0	10.1	2.0
12/11	001354	1015	low +4½	0	100	S		30.5	8.5	5.0	9.3	4.0
12/18	001362	0940	high +3½	W/30	90	S	-9.0 3.0	30.0	8.5	5.0	11.1	3.1
12/19	001370	0900	high +2		0	S	-10.5 0.0	31.5	8.0		10.7	1.6

3.2 Heavy Metals

Copper concentrations ranged from 2.6 - 6.6 ppm in soft shell clams, Mya arenaria; 16.6 - 93.3 ppm in northern lobsters; 0.001 - 0.006 ppm in water; and 7.4 - 19.8 ppm in sediment (Table 3.2). Scheduling difficulties prevented collection of samples during October.

Table 3.1. Continued

DATE	SAMPLE NUMBER	TIME (EST)	TIDAL STAGE (HOURS)	WIND DIR/VEL (MPH)	CLOUD COVER (%)	DEPTH (FEET)	TEMP °C		SALINITY (0/00)	pH	CO ₂ (ppm)	O ₂ (ppm)	BOD (ppm)
							Station 16						
10/9	001230	1030	high +2	0	10	S	13.5	14.0	32.5	8.5	5.0	8.9	2.6
11/5	001287	1145	high +5	W/10	90	S	4.5	10.5	34.0	8.5	5.0	8.3	
12/6	001337	1315	low	W/10	50	S	11.5	9.0	30.0	8.5	5.0	8.9	2.3
12/20	001374	1245	low	0	100	S	2.0	4.5	30.0	8.5	5.0	10.3	6.0

Table 3.2. Copper concentrations (ppm) in soft shell clams, Mya arenaria, lobsters, Homarus americanus, water, and mud from Salem Harbor, November 1973 - January 1974.

Date	Station	Soft shell clam	Lobster	Water	Mud
11/2	A	3.9	25.8	0.003	
	B	3.9	28.6	0.002	
	C	4.4	29.5	0.004	
	11	5.2		0.003	18.5
	13	4.9		0.001	7.4
11/26	A	5.3	16.6		
	B	4.8	93.3		
	C	5.5			
11/27	A			0.005	
	B			0.004	
	C			0.005	
	11	4.4		0.004	16.6
	13	5.9		0.004	7.4
12/6	B	4.8			
12/10	B	3.3			
1/2	A	4.4	28.2	0.004	
	B	2.6	60.3	0.006	
	C		24.1	0.006	
1/4	11	6.6		0.003	19.8
	13	5.1		0.004	7.7

4.0 BIOLOGICAL INVESTIGATIONS

4.1 Primary Production

Chlorophyll a concentrations and ^{14}C assimilation rates fluctuated at Stations A through D. Except for Station C, chlorophyll a levels varied correspondingly with ^{14}C uptake (Figure 4.1). Chlorophyll a peaked on November 20 to levels previously obtained on October 4. ^{14}C also peaked on that date, but at lower levels than October 4.

Chlorophyll a concentrations were similar at Stations A, C and D during respective sampling periods. Except on December 12, chlorophyll a at Station B was low in comparison with other stations (Table 4.1).

Ranges for chlorophyll a and other accessory pigments for the quarter were:

Chlorophyll a	1.58 - 13.85 mg/m ³
b	0.05 - 4.67 mg/m ³
c	0.89 - 14.67 mg/m ³
Carotenoids	0.43 - 5.94 mg/m ³

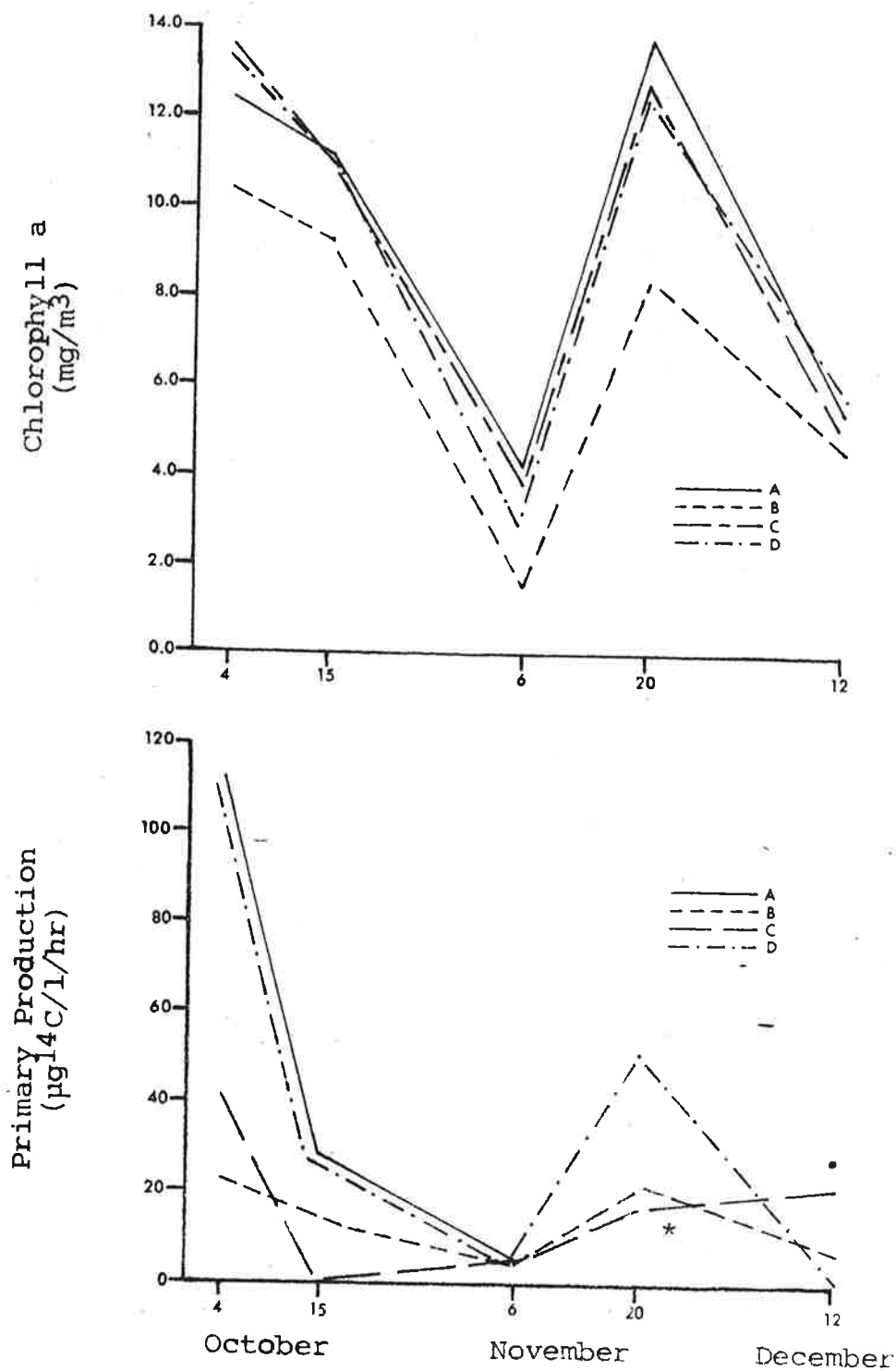
Minimal chlorophyll and carotenoid values were recorded at Station B (discharge) on November 6.

Primary production samples (^{14}C uptake) were incubated in situ at depths corresponding to relative light intensities of 100% (surface), 50%, 25%, 10% and 1%, when possible. The depths to which the various light intensities penetrated was determined with a submarine photometer (Table 4.2).

Units indicating rates of production differ from the last report and are now expressed as $\mu\text{g}^{14}\text{C}/\text{l}/\text{hr}$ not $\text{mg}^{14}\text{C}/\text{l}/\text{hr}$.

Average ^{14}C values for the quarter were highest when

Figure 4.1. Chlorophyll a (mg/m^3) and ^{14}C assimilation ($\mu\text{g}^{14}\text{C}/\text{l}/\text{hr}$) taken at the surface for Stations A - D in Salem Harbor, October - December, 1973.



*Sample lost

Table 4.1. Chlorophyll counts (mg/m³) in Salem Harbor, October - December, 1973.

Date	Station	Chlorophyll a	Chlorophyll b	Chlorophyll c	Carotenoids
10/4	A	12.38	1.72	14.67	5.94
	B	10.37	1.74	14.09	3.98
	C	13.66	0.25	2.93	3.65
	D	13.36	4.67	2.37	5.27
10/15	A	11.13	0.66	4.94	5.39
	B	9.19	0.96	5.04	2.20
	C	11.04	1.04	6.42	5.65
	D	11.00	1.43	6.67	5.81
11/6	A	4.24	0.37	2.44	1.52
	B	1.58	0.05	0.89	0.43
	C	3.88	0.92	3.09	1.27
	D	3.04	0.11	1.60	1.36
11/20	A	13.85	0.53	7.14	5.14
	B	8.15	1.27	6.68	2.23
	C	12.68	1.41	7.15	4.98
	D	12.52	1.19	6.58	4.78
12/12	A	5.35	0.67	4.61	1.36
	B	4.38	0.73	3.03	1.53
	C	5.12	0.48	2.68	1.61
	D	5.82	0.86	2.72	1.43

Table 4.2. Primary production (^{14}C) in Salem Harbor, October - December, 1973.

Date	Station	Depth (feet)	Temp °C	Light intensity (%)	$\mu\text{gC}/\text{l}/\text{hr}$
10/4	A	S	15.5	100	112
		4	15.5	50	79
		11.5	14.5	25	97
		13.5	14.0	16	35
	B	S	22.0	100	23
		5	16.5	50	10
		11	14.5	25	23
		15	14.5	10	43
	C	S	17.0	100	41
		5	16.5	50	33
		11	16.0	25	35
		16	15.0	10	13
		19	14.5	2	0
	D	S	15.5	100	106
		3	15.5	50	123
		7.5	14.5	25	91
		13	14.0	10	26
		27	13.5	1	6
10/15	A	S	13.5	100	28
		4	13.5	50	54
		8	13.0	25	15
		13	13.0	10	13
	B	S	19.0	100	14
		3	19.0	50	--
		7	14.5	25	33
		12	13.0	10	0
	C	S	13.0	100	0
		3.5	13.0	50	25
		8	13.0	25	17
		14	13.0	10	3
	D	S	13.0	100	26
		4	13.0	50	26
		9	12.5	25	24
		16	12.5	10	11

Table 4.2. Continued

Date	Station	Depth (feet)	Temp °C	Light intensity (%)	µgC/l/hr
11/6	A	S	8.0	100	5
		3*	8.0	50	4
		5	8.0	25	5
		15	7.5	18	5
	B	S	15.0	100	4
		9	8.5	50	10
		20	8.0	25	4
		29	8.0	10	4
		39	8.0	4	0
	C	S	8.0	100	5
		5	8.0	50	5
		10	8.0	25	8
		20*	8.0	10	0
	D	S	8.0	100	4
		5	8.0	50	2
		13	8.0	25	7
		24	8.0	10	4
		33*	8.0	4	0
11/20	A	S	6.5	100	--
		4	6.5	50	55
		11	6.5	25	14
		15.5	6.5	18	46
	B	S	14.5	100	22
		4	12.0	50	16
		12	7.5	25	6
		20	7.0	10	3
	C	S	7.0	100	17
		10	7.0	50	17
		16	6.5	25	7
		21	6.5	10	12
	D	S	6.0	100	50
		9	6.0	50	48
		15	6.0	25	4
		22	6.0	10	2

Table 4.2. Continued

Date	Station	Depth (feet)	Temp °C	Light intensity (%)	µgC/l/hr
12/12	A	S	6.0	100	28
		7.5	6.0	50	5
		13	6.0	25	2
	B	S	12.0	100	7
		9.5	6.5	50	0
		13	6.5	25	18
		19	6.5	10	0
		34	6.5	1	0
	C	S	6.0	100	22
		7	6.0	50	19
		11	6.0	25	0
		15	6.0	10	0
		24	6.0	2	8
	D	S	6.5	100	2
		6	6.5	50	0
		10	6.5	25	0
		17	6.5	10	0
		29	6.5	2	0

*Dark bottle lost; count of nearest depth dark bottle used.

relative light intensities were 50 and 100% (24 and 27 $\mu\text{g}^{14}\text{C}/\text{l}/\text{hr}$, respectively). In general, primary productivity was minimal when relative light intensity was less than 25%. Ranges and means for ^{14}C assimilation for all stations are presented in Table 4.3.

Stations A and D had similar productivity values at equal light intensities (Figure 4.2). Values for Station C were less than A and D. Production at Station B did not correspond to the other stations. As light intensity at Stations A, C and D decreased below 50%, production also decreased. Conversely, at Station B primary production was reduced in the warm water wedge of the plant discharge.

Data collected to date indicates that primary productivity in Salem Harbor is highly variable. The high variability could be due to the interaction of many factors such as temperature, availability of nutrients, total light intensity, cloud cover, time of day, tidal stage, wave action, fresh water runoff and predation.

ATP sampling was expanded to include control Stations 11 and 12 (Figure 4.3). ATP values ranged from 0 - 740 mpgATP/l (Table 4.4). ATP levels at the control stations showed minimal variation from Stations 1 and 4 through 10 (Figure 4.4). Water from Station 2 (Unit 4 condenser) was available only on December 12 due to shutdown of Unit 4. ATP levels decreased from Station 1 (intake) to Station 3 (mid canal) on all sampling days.

Since previous sampling indicated 100% phytoplankton mortality at Station 2, an attempt was made on December 19 through 21 to isolate the cause (thermal or mechanical). ATP samples were

Table 4.3. Mean primary production levels ($\mu\text{g}^{14}\text{C}/\text{l}/\text{hr}$) in Salem Harbor, October - December, 1973

Relative light intensity (%)	Station									
	A		B		C		D		A-D	
	Range*	Mean*	Range	Mean	Range	Mean	Range	Mean	Range	Mean
100	5-112	43	4-23	14	0-41	17	2-106	38	0-112	27
50	4-79	39	0-16	9	5-33	20	0-123	40	0-123	28
25	2-97	27	4-33	17	0-35	13	0-91	25	0-97	20
10	-	13	0-43	10	0-13	6	0-26	9	0-43	8
<3	-	-	-	0	-	4	0-6	2	0-8	2

* $\mu\text{g}^{14}\text{C}/\text{l}/\text{hr}$

Figure 4.2. Mean primary production levels ($\mu\text{g}^{14}\text{C}/\text{l}/\text{hr}$) at relative light intensities (%) in Salem Harbor, October - December, 1973.

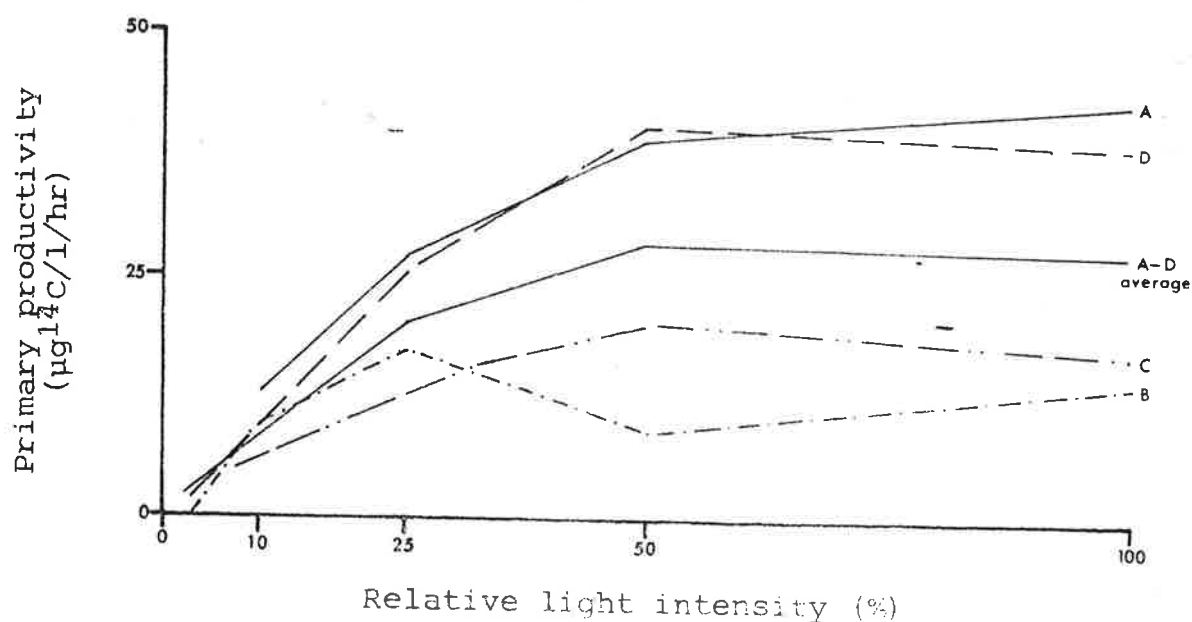


Figure 4.3. Location of ATP (Adenosine triphosphate) sampling stations in Salem Harbor.

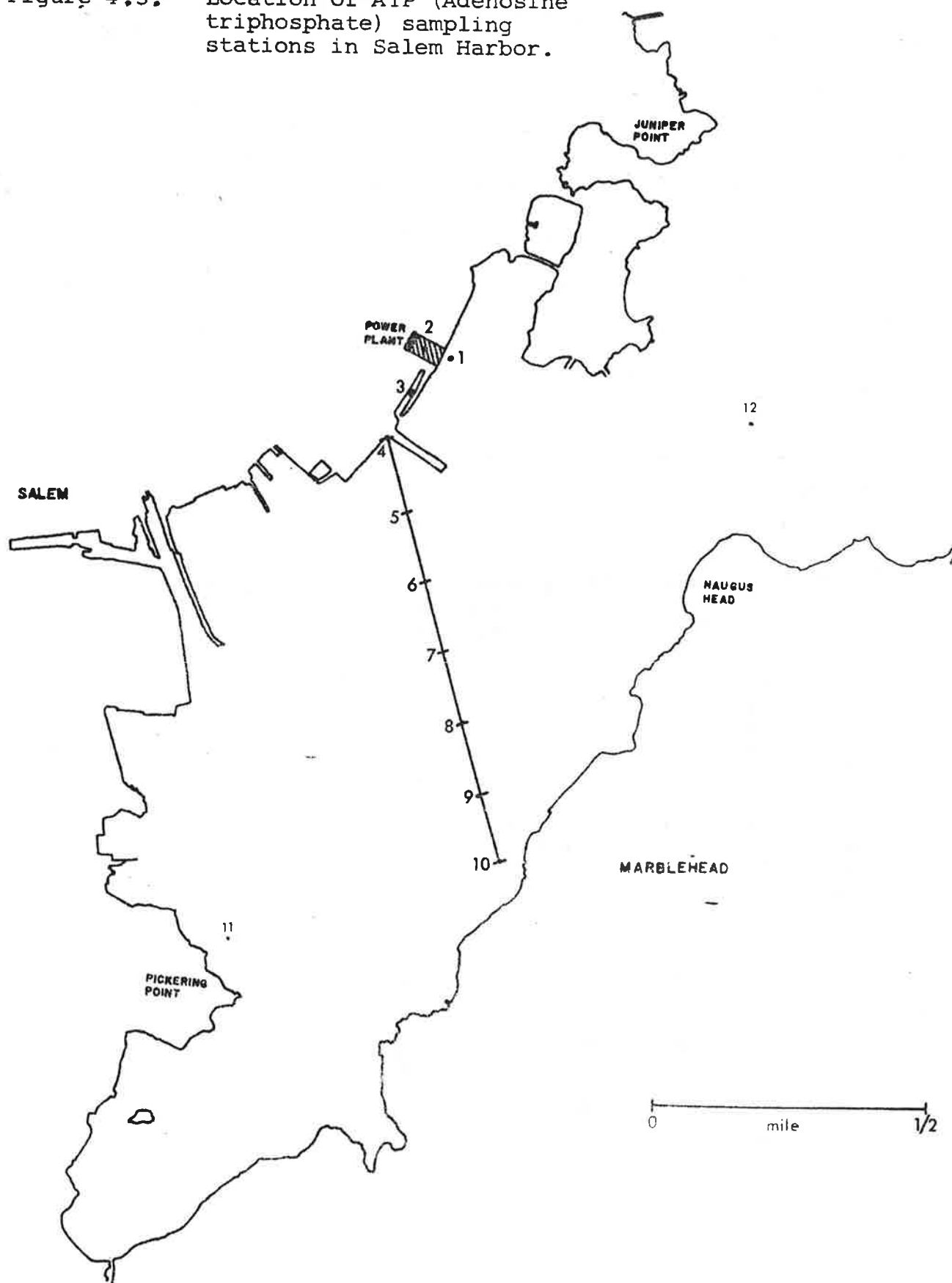
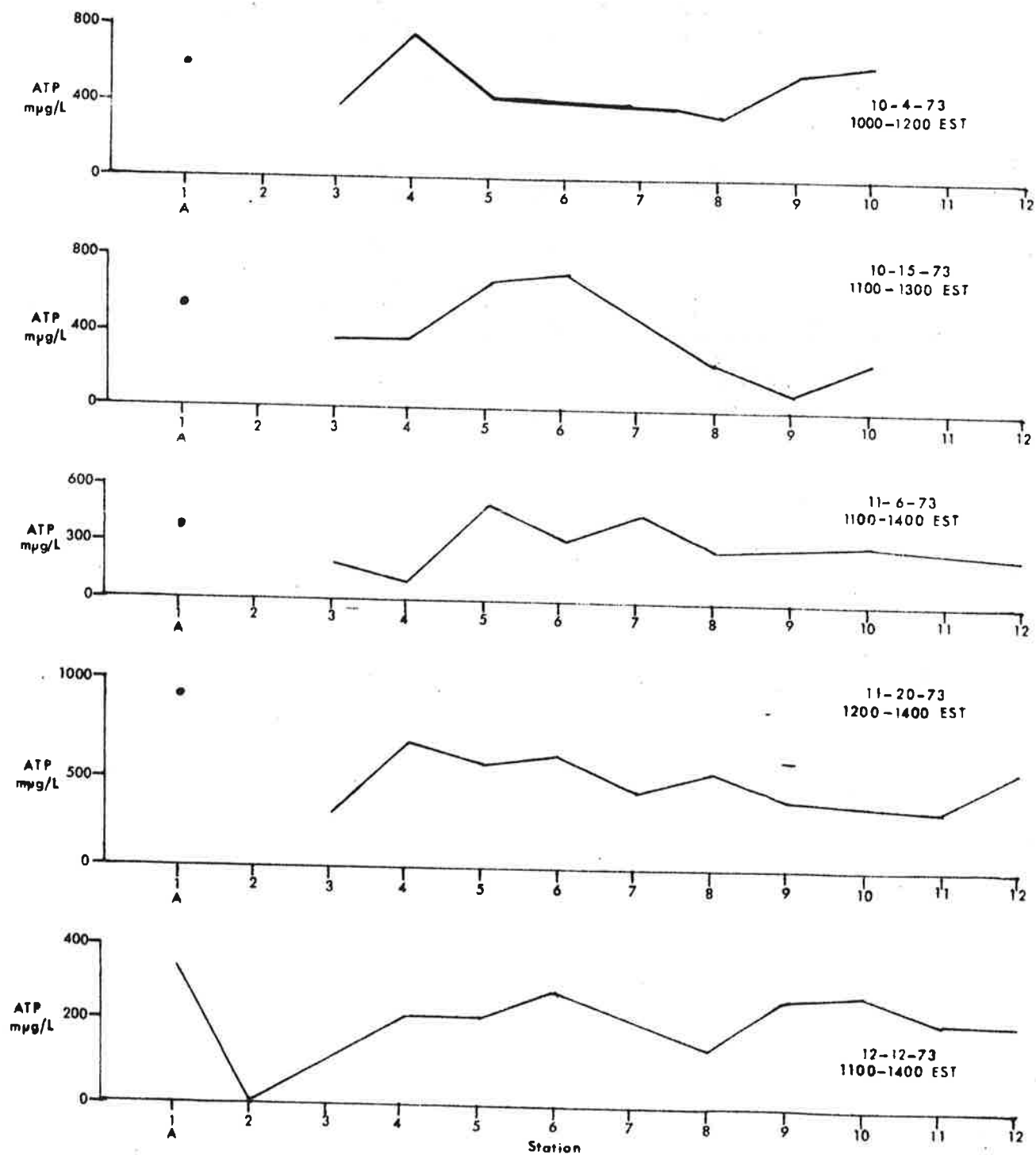


Table 4.4. Adenosine triphosphate (mpgATP/l) levels in Salem Harbor, October - December, 1973.

Station	Oct 4	Oct 15	Nov 6	Nov 20	Dec 12
1	610	550	400	880	360
2	*	*	*	*	0
3	340	360	200	280	120
4	740	380	110	640	220
5	410	650	500	530	210
6	400	720	330	600	290
7	390	470	440	400	230
8	330	250	270	490	150
9	570	100	250	380	270
10	600	300	310	380	280
11			250	310	210
12			240	540	210

*Unit 4 shut down

Figure 4.4. Adenosine triphosphate (ATP) in phytoplankton, Salem Harbor, October - December, 1973.



taken from Stations 1 and 2 as generation was stepped up from 0 MW to 300 MW. ΔT 's were: 3.0°C, 5.5°C, 10.0°C and 14.5°C. Chlorine was not in use. ATP levels for all samples taken from the condenser were 0, suggesting that phytoplankton mortality is mechanically induced.

4.2 Finfish

A total of 7,931 finfish were sampled by all methods, excluding sluiceway investigations (Tables 4.5 and 4.6). Winter flounder, Pseudopleuronectes americanus, was most abundant, comprising 48% of the catch inside the harbor and 75% of the catch outside the harbor.

Atlantic silverside, Menidia menidia, were dominant at the shore stations (Tables 4.7 and 4.8). Silverside and fourspine stickleback, Apeltes quadracus, were most abundant at the 30-ft trawl stations (Table 4.9). Winter flounder were dominant at the 49-ft trawl station (Table 4.10). Atlantic cod, Gadus morhua, were taken only with the 49-ft trawl and the gill nets (Table 4.11). Sampling with the 30-ft midwater trawl was terminated in mid-October due to gear inefficiency.

Finfish abundance declined from October through December at the shore stations. At the off-shore stations finfish abundance increased from October to November, but decreased sharply in December.

Figure 4.5 displays length frequency histograms for the four most abundant finfish species sampled: winter flounder, Atlantic silverside, fourspine stickleback, and Atlantic cod.

Species diversification for the quarter was least for the 50-ft seine, and about equal for other methods employed (Table 4.12).

Table 4.13 compares species occurrence in Beverly - Salem Harbor for 1965 (Jerome et al., 1967), and 1971 - 1973. Figures 4.6 through 4.9 compare species diversification for each type of gear and all gear combined for 1965, and 1971 - 1973.

Table 4.5. Rank of finfish collected in Salem Harbor, October - December, 1973.

Species	Method of Capture						Totals
	50-ft Seine	120-ft Seine	30-ft Trawl	Mid-** water Trawl	49-ft Trawl	Gill Net	
1. winter flounder		413	18		2,948	13	3,392
2. Atlantic silverside	142	1,587	432	1			2,162
3. fourspine stickleback	7	48	285	1			341
4. Atlantic cod					169	111	280
5. mummichog	161	37					198
6. threespine stickleback		4	126				130
7. pollock						112	112
8. striped killifish	12	69					81
9. skate*							66
10. Atlantic tomcod					66		66
11. rainbow smelt	1	3	37			4	45
12. blueback herring		6	13			20	39
13. ocean pout		34	1				35
14. yellowtail flounder					22		22
goosefish					15		15
15. Atlantic menhaden					12	3	15
ninespine stickleback						14	14
16. windowpane	2	7	5				14
17. grubby			1		11		12
18. northern pipefish		2	9				11
19. Atlantic herring			8				8
20. <u>Urophycis</u> sp.						5	5
white hake	3						3
21. cunner					1	2	3
Atlantic mackerel			2				2
butterfish						2	2
22. American sand lance					1	1	2
longhorn sculpin			1				1
Totals	328	2,210	938	2	3,245	288	7,011

*Not separated by species.

**Sampling terminated in October, 1973.

Table 4.6. Rank of finfish collected outside Salem Harbor with the 49-ft trawl, October - December, 1973.

Species	Totals
1. winter flounder	685
2. Atlantic cod	80
3. windowpane	59
4. yellowtail flounder	52
5. skate*	33
6. rainbow smelt	4
7. sea raven	3
8. blueback herring	2
9. goosefish	1
longhorn sculpin	1
Total	920

*Not separated by species.

Table 4.7. Dominant finfish species collected in Salem Harbor with the 50-ft seine, October - December, 1973.

mummichog (<i>Fundulus heteroclitus</i>)					Atlantic silverside (<i>Menidia menidia</i>)		
Date	Set No.	Total Collected	Size Range (mm)	Mean (mm)	Total Collected	Size Range (mm)	Mean (mm)
Station 11							
10/10	1	112	20-49	35			
	2	8	25-44	34			
12/18	1				1	-	67
Station 13							
10/10	1	8	35-59	46			
	2	5	40-54	47			
10/24	1	13	35-54	44	21	55-94	73
11/7	1	1	-	42			
	2				1		
12/11	2				45	40-114	87 80
Station 15							
10/10	1	6	30-54	45			
	2	1	-	42	6	70-104	84
10/24	1	6	40-54	48	51	65-109	89
	2	1	-	42			
11/7	1						
	2				2	90-99	95
11/21	1				6	85-114	100
12/11	2				1	-	75
					8	90-114	103

Table 4.8. Dominant finfish species collected in Salem Harbor with the 120-ft seine, October - December, 1973.

Atlantic silverside (<i>Menidia menidia</i>)					winter flounder (<i>Pseudopleuronectes americanus</i>)		
Date	Set No.	Total Collected	Size Range (mm)	Mean (mm)	Total Collected	Size Range (mm)	Mean (mm)
<u>Station 11</u>							
10/9	1	2	70-84	74	48	30-84	58
	2	17	65-119	86	2	35-49	42
10/23	1				13	50-84	60
	2				22	45-79	59
11/9	1	1	-	72	2	65-79	72
	2	568	85-129	108			
11/19	1	623	60-119	85	5	50-94	70
	2	2	85-124	104			
12/10	1	50	75-129	107	5	65-104	86
<u>Station 13</u>							
10/9	1	27	60-99	83	88	40-214	59
	2	2	90-109	100	53	40-84	56
10/23	1	158	65-124	85	23	50-79	60
	2	5	75-114	99	27	50-184	70
11/9	1	1	-	102			
	2	2	80-89	84			
11/19	1	2	65-69	67	1	-	62
12/10	1	2	65-84	74			
	2	2					
<u>Station 15</u>							
10/9	1				52	45-104	64
	2	1	-	107	19	50-94	65
10/23	1				14	55-104	83
	2	63	75-149	104	14	55-114	79
11/19	1	60	65-119	96	7	70-94	85
	2	1	-	97	9	70-119	89

Table 4.9. Dominant finfish species collected in Salem Harbor with the 30-ft trawl, October - December, 1973.

Atlantic silverside (<u>Menidia menidia</u>)					fourspine stickleback (<u>Apeltes quadracus</u>)		
Date	Set No.	Total Collected	Size Range (mm)	Mean (mm)	Total Collected	Size Range (mm)	Mean (mm)
<u>Station 12</u>							
10/11	1	5	75-99	89	8	30-44	39
	2				16	25-59	40
10/24	1	5	85-114	94	2	35-44	40
	2	2	110-114	112	10	30-59	42
11/8	1	50	75-124	101			
12/10	1	3	105-114	110			
12/27	1	14	70-119	86			
<u>Station 14</u>							
10/11	1				58	30-59	41
	2	10	75-109	92	1	-	42
10/24	1	195	70-129	104	35	25-54	39
	2	107	80-119	101			
11/8	1	25	85-114	103	1	-	47
	2				13	30-59	46
11/19	1				40	30-54	40
	2				24	25-59	41
12/10	2	16	85-124	107			
12/27	1				58	25-64	42
	2				19	30-59	42

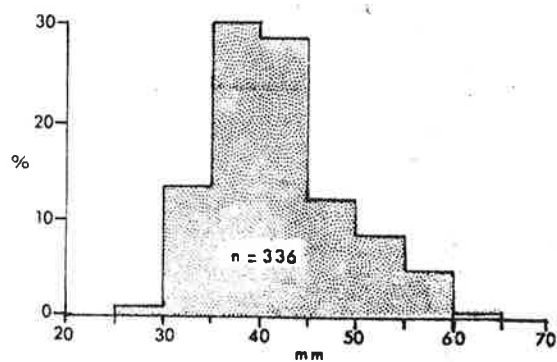
Table 4.10. Dominant finfish species collected in Salem Harbor with the 49-ft trawl, October - December, 1973.

winter flounder (<u>Pseudopleuronectes americanus</u>)					Atlantic cod (<u>Gadus morhua</u>)		
Date	Set No.	Total Collected	Size Range (mm)	Mean (mm)	Total Collected	Size Range (mm)	Mean (mm)
Station 16							
10/9	1	782	200-434	303	1	-	460
	2	576	255-419	314	1	-	725
11/5	1	997	225-439	302	4	520-735	641
12/6	1	268	130-449	278	16	485-720	581
	2	318	180-424	283	3	530-594	569
12/20	1	7	205-324	267	144	355-690	493

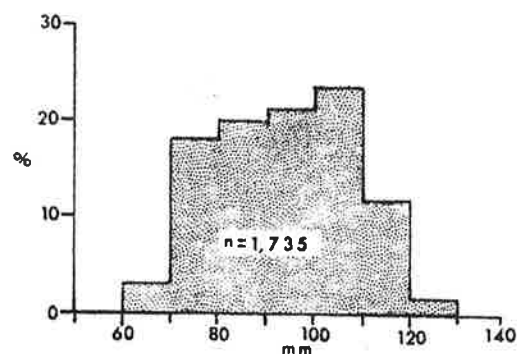
Table 4.11. Dominant finfish species collected in Salem Harbor with gill nets, October - December, 1973.

Atlantic cod (<u>Gadus morhua</u>)				pollock (<u>Pollachius virens</u>)		
Date	Total Collected	Size Range (mm)	Mean (mm)	Total Collected -	Size Range (mm)	Mean (mm)
Station 20						
10/25	3	390-550	481	36	270-344	300
11/27	62	305-589	390	14	275-339	313
12/19	1	-	342	3	310-324	317
Station 21						
10/25				11	200-349	301
11/27	39	315-534	394	29	280-349	314
12/19	6	355-574	432	19	195-254	219

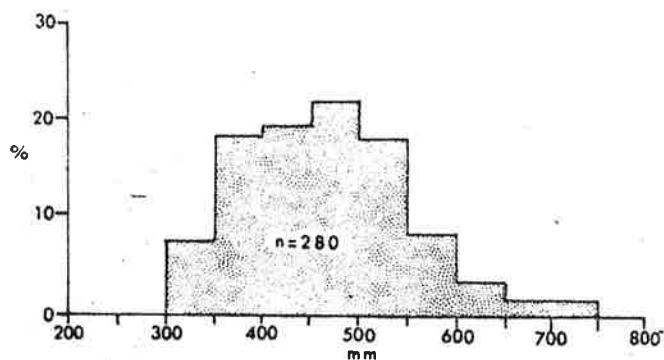
Figure 4.5. Length frequency histograms for dominant finfish species collected in Salem Harbor, October - December, 1973.



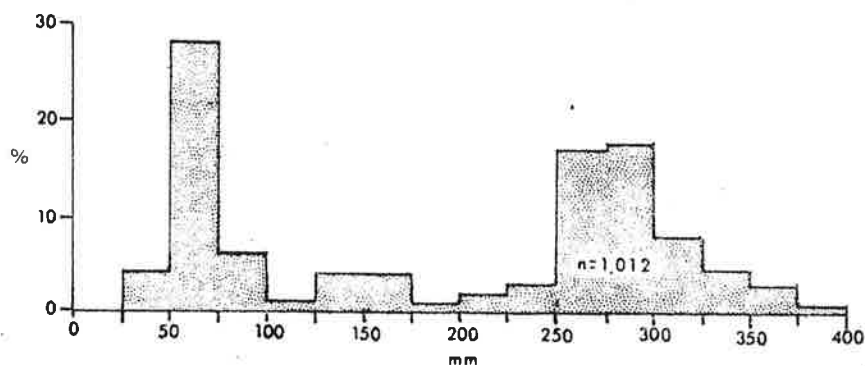
fourspine stickleback



Atlantic silverside



Atlantic cod



winter flounder

Table 4.12. Diversification index of finfish species by method of capture, Salem Harbor, October - December, 1973.

Date	50-ft Seine	120-ft Seine	30-ft Trawl	Midwater Trawl	49-ft Trawl	Gill Net
10/9		6			5	
10/10	4					
10/11			6	2		
10/23		6				
10/24	2		9			
10/25						11
11/5					7	
11/7	3					
11/8			7			
11/9		5				
11/19			6			
11/21	1					
11/27						6
12/6					8	
12/10		8	4			
12/11	2					
12/18	3					
12/19						5
12/20					4	
12/27			6			

Table 4.13. Finfish species occurrence in Beverly - Salem Harbor, 1965 and July 1971 - 1973.

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
alewife	-----			-----	-----	-----	-----			-----	-----	-----
American eel	-----		-----	-----	-----	-----	-----	-----	-----			
American plaice				-----	-----							
American sand lance							-----			-----		
Atlantic cod	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Atlantic herring			-----	-----	-----	-----	-----	-----	-----			
Atlantic mackerel					-----	-----	-----	-----	-----	-----	-----	-----
Atlantic menhaden					-----	-----	-----	-----	-----	-----	-----	-----
Atlantic moonfish									-----			
Atlantic silverside	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Atlantic tomcod	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Table 4.13. Continued

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
bay anchovy										—		
blueback herring				—				—	—	—	—	—
bluefish							—	—	—	—		
butterfish										—		
conger eel				—								
crevalle jack								—				
cunner								—	—	—	—	—
flyng gurnard										—		
fourbeard rockling										—		
fourspine stickleback												—

Table 4.13. Continued

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
goosefish							_____			-----	-----	-----
grubby	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
haddock												
longhorn sculpin	_____			-----	-----	-----	-----			-----	-----	-----
lumpfish				-----	-----			-----	-----	-----	-----	
mackerel scad									-----			
mummichog			-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
ninespine stickleback	_____			-----	-----	-----	-----	-----	-----	-----	-----	-----
northern pipefish				-----	-----	-----	-----	-----	-----	-----	-----	-----
northern searobin									-----			

Table 4.13. Continued

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
ocean pout	_____		_____	-----					_____		-----	-----
pollock					-----						-----	
rainbow smelt	-----		-----				-----			-----		-----
red hake					-----		_____			-----	-----	
rock gunnel								_____		_____		-----
rough scad								_____				
sea raven	-----								-----	-----	-----	
seasnail			_____					-----				
shorthorn sculpin					_____		-----				-----	
silver hake						_____						

Table 4.13. Continued

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
skate*				-----				-----	-----			
			-----					-----	-----			
spiny dogfish						-----						
striped bass					-----					-----		
striped killifish	-----							-----	-----			
	-----							-----	-----			
striped mullet								-----				
striped seasnail										-----		
threespine stickleback	-----			-----				-----	-----			
	-----			-----				-----	-----			
white hake					-----		-----					
					-----		-----					
white mullet										-----		
					-----					-----		
windowpane	-----							-----	-----			
	-----							-----	-----			

Table 4.13. Continued

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
winter flounder	-----		-----			-----	-----	-----	-----	-----	-----	-----
yellowtail flounder	-----		-----			-----		-----	-----	-----	-----	-----

*Not separated by species

----- 1965
 ----- 1971
 ----- 1972
 ----- 1973

Figure 4.6. Diversity of finfish species collected in Salem Harbor by gear, 1965.

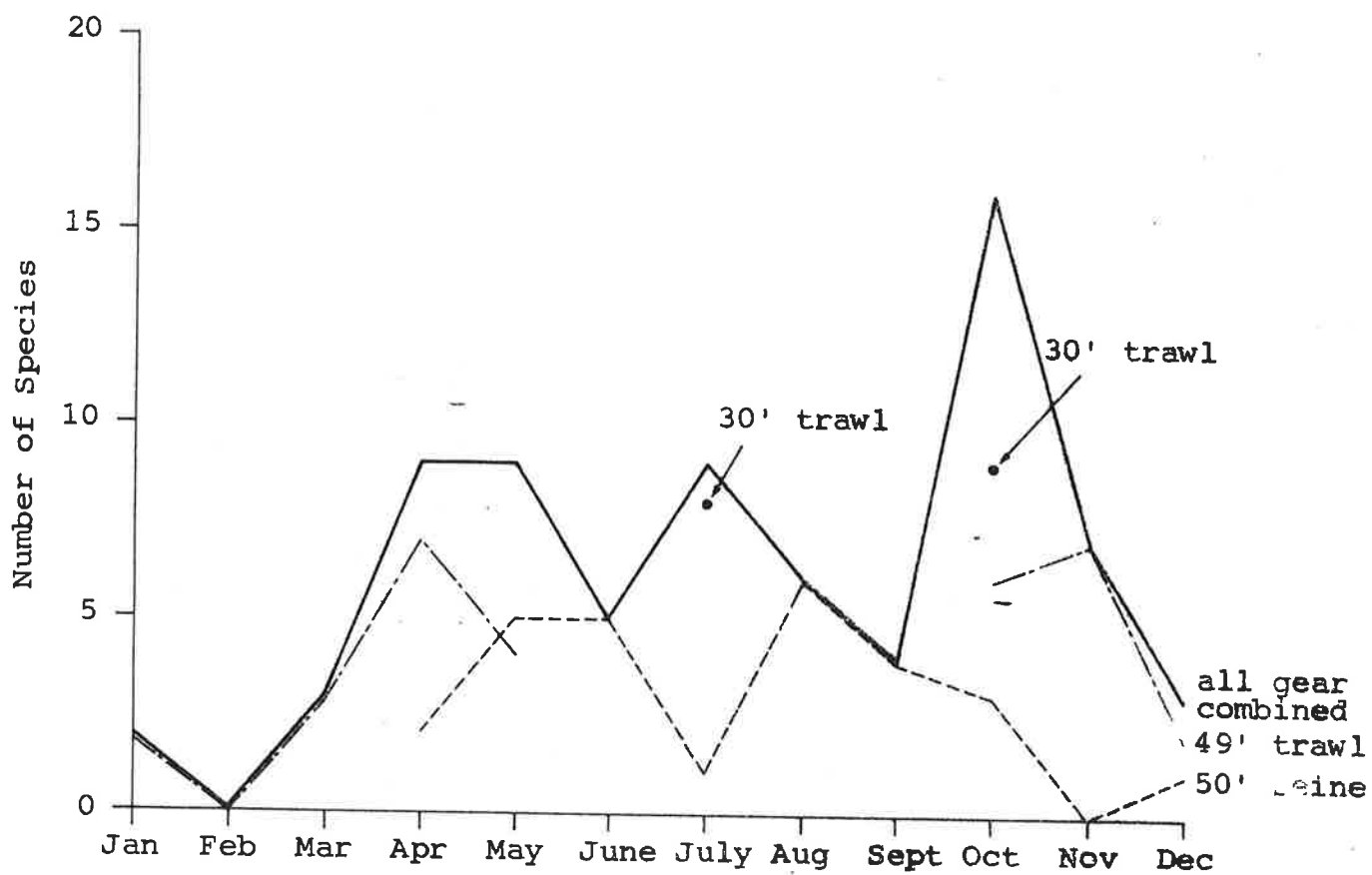


Figure 4.7. Diversity of finfish species collected in Salem Harbor by gear, 1971.

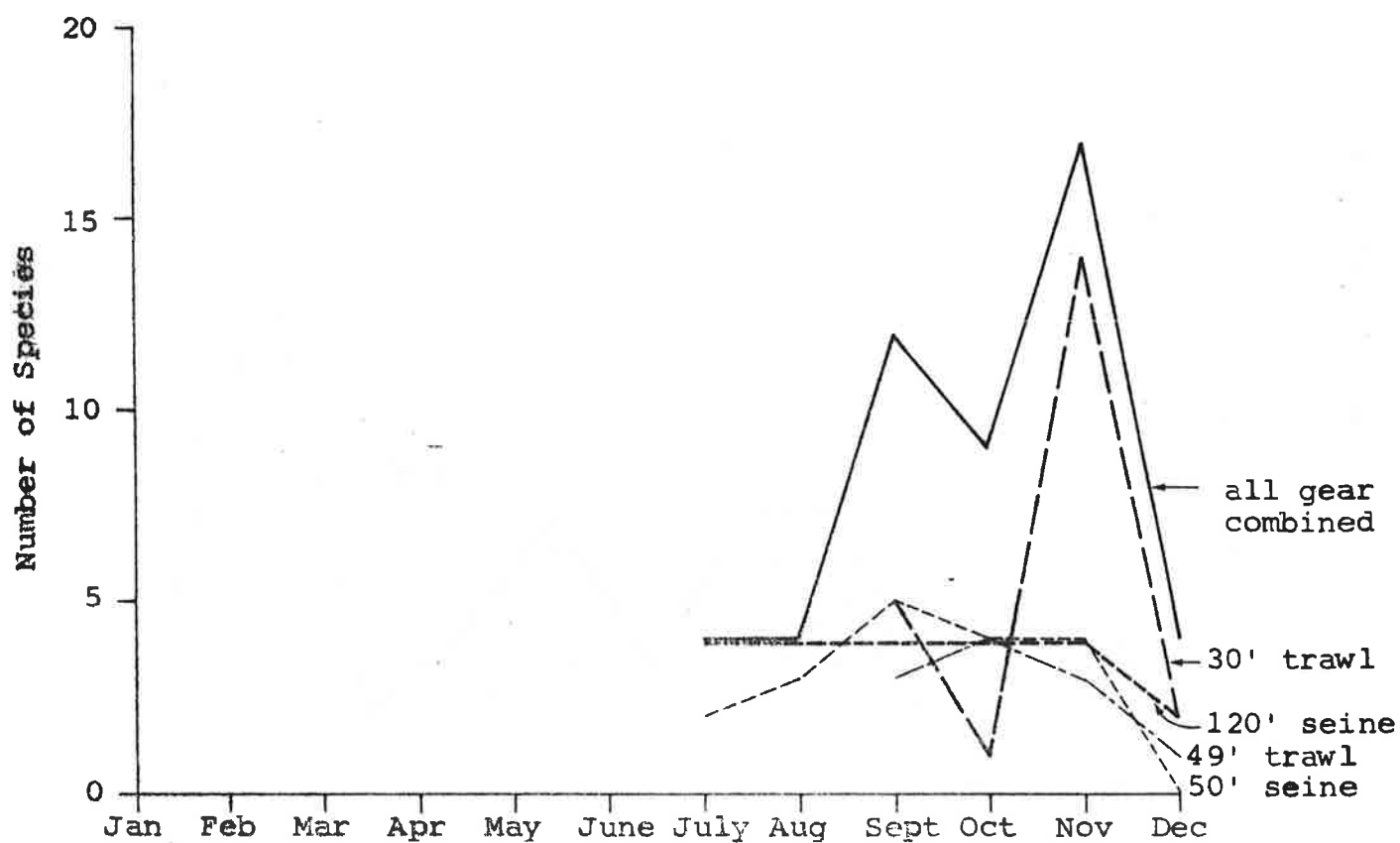


Figure 4.8. Diversity of finfish species collected in Salem Harbor by gear, 1972.

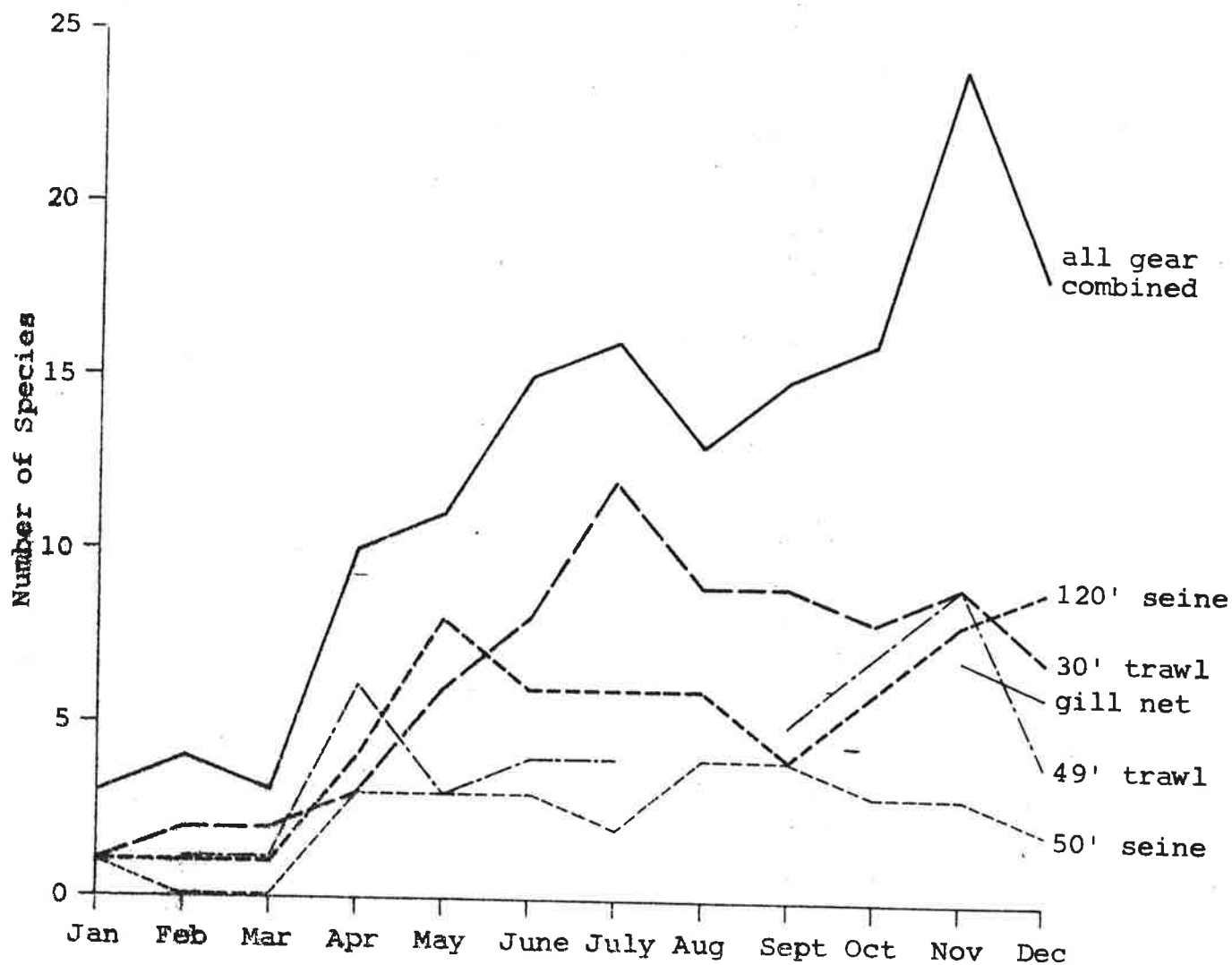
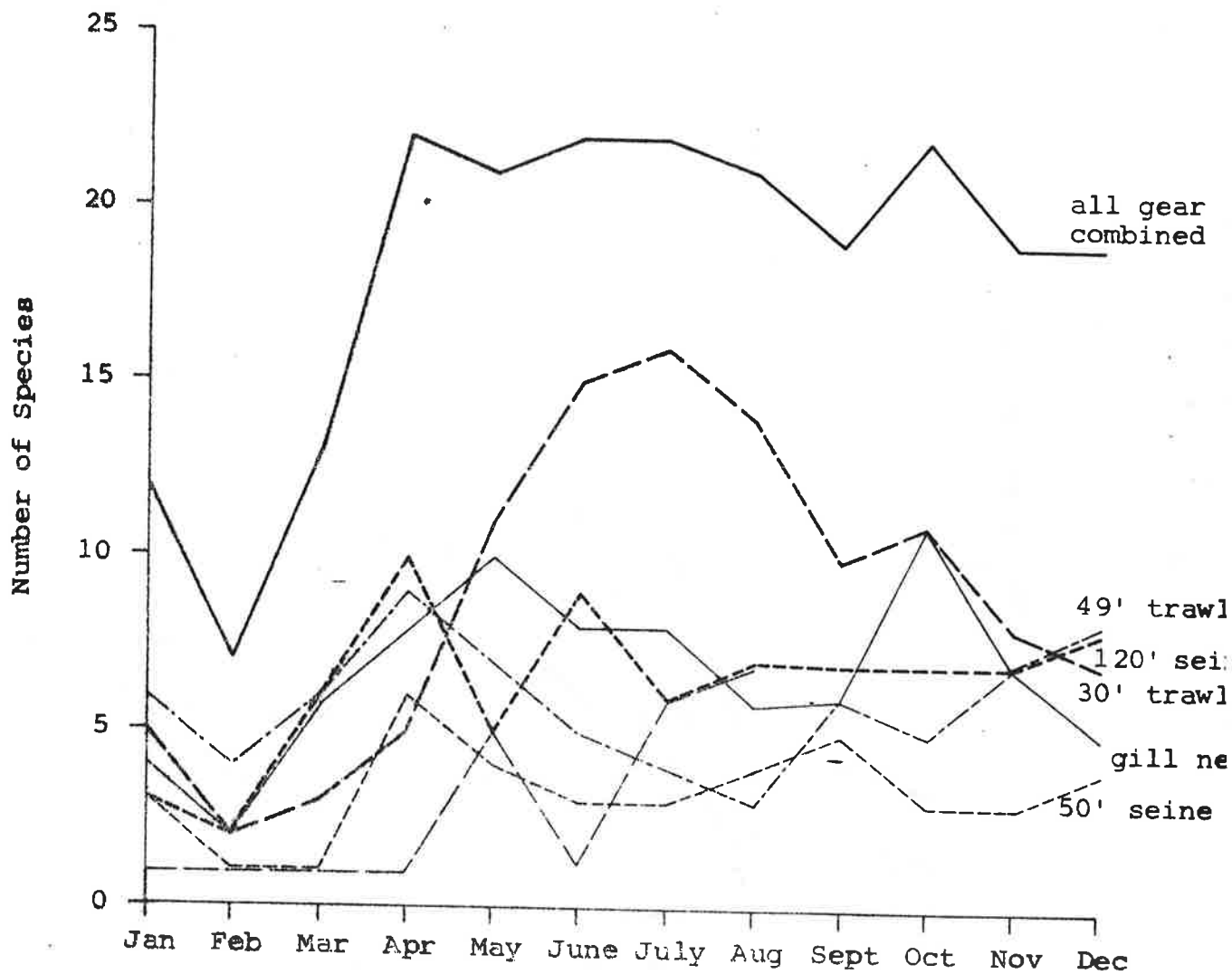


Figure 4.9. Diversity of finfish species collected in Salem Harbor by gear, 1973.



Catch per unit of effort (c/f), by gear type, are presented in Table 4.14 for Atlantic silverside, mummichog, and winter flounder. For presentation purposes c/f is defined as one set with a particular type of gear.

Silverside and mummichog c/f was greatest during the summer with the 50-ft seine and least during the winter. The variability, however, indicated by the standard deviation is large and probably results from their schooling habits. Few winter flounder are sampled with the 50-ft seine.

The c/f with the 120-ft seine was greatest for silverside during the fall. Variability in the size of the catch was large.

The c/f with the 30-ft trawl was generally low for all three species. This gear did not sample mummichogs.

Silverside and mummichog were not collected with the 49-ft trawl. The c/f for winter flounder was greatest during the summer and fall. The standard deviation was largest in the fall.

Table 4.14. Mean catch per unit of effort (c/f) for Atlantic silverside, Menidia menidia; mummichog, Fundulus heteroclitus; and winter flounder, Pseudopleuronectes americanus, collected in Salem Harbor, 1965 and July 1971 - 1973.

Atlantic silverside						mummichog			winter flounder		
Year	Quarter	No. Sets	No. Taken	c/f	S ⁺	No. Taken	c/f	S	No. Taken	c/f	S
<u>50-ft seine</u>											
1965	1										
	2	6	2	0.3	0.5	10	1.7	2.7			
	3	6	5	0.8	1.6	449	74.8	122.0	3	0.5	0.8
	4	6	62	10.0	25.3	234	39.0	95.5			
1971**	3	7	10,301	1,471.6	1,756.0	818	116.8	177.7			
	4	9	665	73.9	173.3	231	25.7	67.2			
1972	1	18	1	0.1	0.2						
	2	18	145	8.0	27.2	10	0.6	1.3			
	3	17	7,099	417.6	818.7	648	38.1	63.6	1	0.1	0.2
	4	18	657	30.9	70.6	27	1.5	4.0			
1973	1	36	25	0.7	3.2						
	2	34	54	1.6	6.7	17	0.5	2.5			
	3	34	8,324	244.7	748.6	3,281	96.5	198.3	21	0.6	2.1
	4	33	142	4.3	12.0	161	4.9	19.5			
<u>120-ft seine</u>											
1971**	3	6	789	131.5	142.9	241	40.2	90.1	33	5.5	4.8
	4	6	1,939	323.2	505.9	232	38.7	88.0	87	14.5	23.8
1972	1	8	10	1.3	3.5						
	2	12	708	59.0	138.9	41	3.4	5.1	48	4.0	4.6
	3	12	769	64.1	94.2	1,049	87.4	181.7	256	21.3	18.9
	4	13	3,253	250.2	340.0	20	1.5	3.0	37	2.8	3.1
1973	1	34	153	4.5	13.5				9	0.3	1.5
	2	32	96	3.0	8.6	103	3.2	9.0	153	4.8	5.3
	3	36	840	23.3	55.3	219	6.1	12.0	517	14.4	11.5
	4	30	1,587	52.9	151.2	37	1.2	3.5	413	13.8	21.0

Table 4.14. Continued

Year	Quarter	No. Sets	Atlantic silverside			winter flounder		
			No. Taken	c/f	S	No. Taken	c/f	S
<u>30-ft trawl</u>								
1965**	3	1				5	5.0	*
	4	1	7	7.0	*	5	5.0	*
1971**	3	2				18	9.0	11.3
	4	6	94	15.7	36.9	186	31.0	53.8
1972	1	8				2	0.2	0.5
	2	12				96	8.0	7.2
	3	12	18	1.5	4.0	102	8.5	11.9
	4	13	27	2.1	4.4	14	1.1	1.3
1973	1	36	197	5.5	32.8	12	0.3	1.0
	2	34	1	<0.1	0.2	110	3.2	6.3
	3	23	253	11.0	23.0	72	3.1	4.6
	4	24	432	18.0	43.6	18	0.8	1.2
<u>49-ft trawl</u>								
1965	1	3				13	4.3	7.5
	2	2				630	315.0	21.2
	3	0						
	4	3				174	58.0	50.5
1971**	3	1				140	140.0	*
	4	3				601	200.3	152.9
1972	1	3				97	32.0	31.8
	2	6				1,317	220.0	55.1
	3	4				1,117	279.0	122.6
	4	6				2,269	378.0	318.1
1973	1	12				783	65.2	90.8
	2	11				1,947	177.0	121.8
	3	8				4,774	596.8	181.3
	4	6				2,948	491.0	363.8

* No standard deviation because all fish taken in one set.

**Sampling commenced in July

+ Standard deviation

® Quarter (1) Jan - March, (2) April - June, (3) July - August,
(4) October - December

4.3 Entrainment and Entrapment

Unit 3 cooling water intakes were monitored for 55 hours with subsequent removal of 40 finfish from the travel screens (Table 4.15). Rainbow smelt, Osmerus mordax, accounted for 55% of the finfish entrapped. All smelt, blueback herring, Alosa aestivalis, and threespine stickleback, Gasterosteus aculeatus, were killed.

Annual maintenance on Unit 4 was completed in late December. Monitoring will resume during the next quarter.

Table 4.15. Finfish species collected in the Unit sluiceway, Salem Harbor, October - December, 1973.

Species	(EST)	10/2	10/2	10/2	10/5	10/9	10/16	10/24	10/24	10/25	10/25	10/31	Totals*
		0800	1000	1200	1000	1400	1400	0800	1200	0800	1400	1100	
Tidal Stage (Hrs)		1000	1200	1400	1200	1600	1600	1000	1400	1000	1600	1300	
		L	L+2	L+4	H+5½	L	H+1	H	H+3½	L+5	H+5	L+4	
winter flounder		2									1		3

Species	(EST)	11/7	11/8	11/12	11/12	11/14	11/20	11/20	11/26	11/29	Totals
		1500	0700	1300	1500	0900	0800	1100	0700	0700	
Tidal Stage (Hrs)		1700	0900	1500	1700	1100	1000	1300	0900	0900	
		L+1½	L+5½	H+2	H+4	L+2½	H+1½	H+3½	L+2½	L+½	
Atlantic cod									1		1
blueback herring	2							1			3 (3)
rainbow smelt								1	1		2 (2)
winter flounder					3			1			4

Table 4.15. Continued

Species	(EST) Tidal Stage (Hrs)	12/5	12/11	12/12	12/14	12/18	12/18	12/18	12/20	Totals
		1100	1200	1300	1500	0800	1000	1200	1100	
		1300	1400	1400	1700	1000	1200	1400	1300	
		H+5½	H+1½	H+1	H+1½	H+3	H+5	L+1	H+4	
Atlantic cod			3							3 (3)
grubby							1			1
rainbow smelt							20			20 (20)
rock gunnel							1			1
threespine stickleback								1		1
winter flounder							1			1

*Number of dead fish shown in parenthesis.

Unit 4 was shut down for annual maintenance during this quarter.

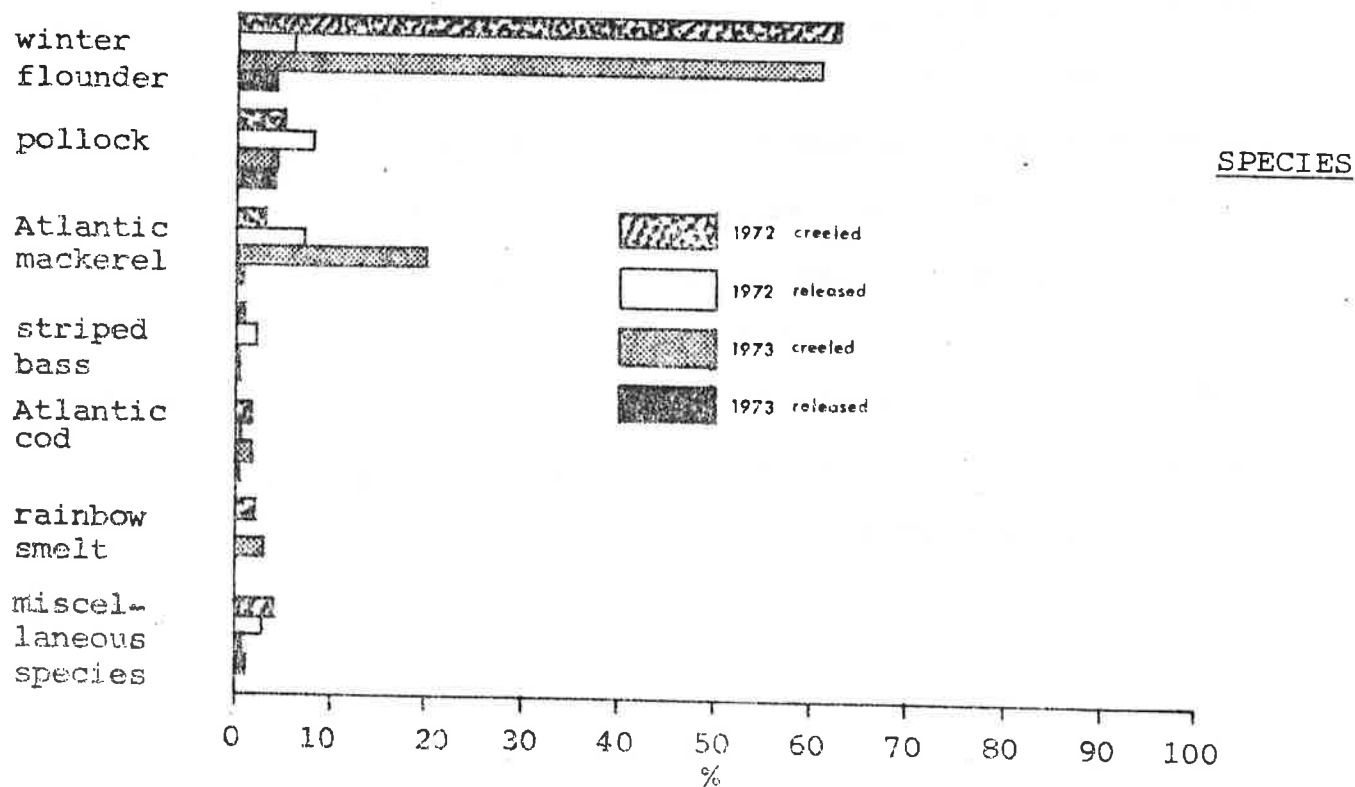
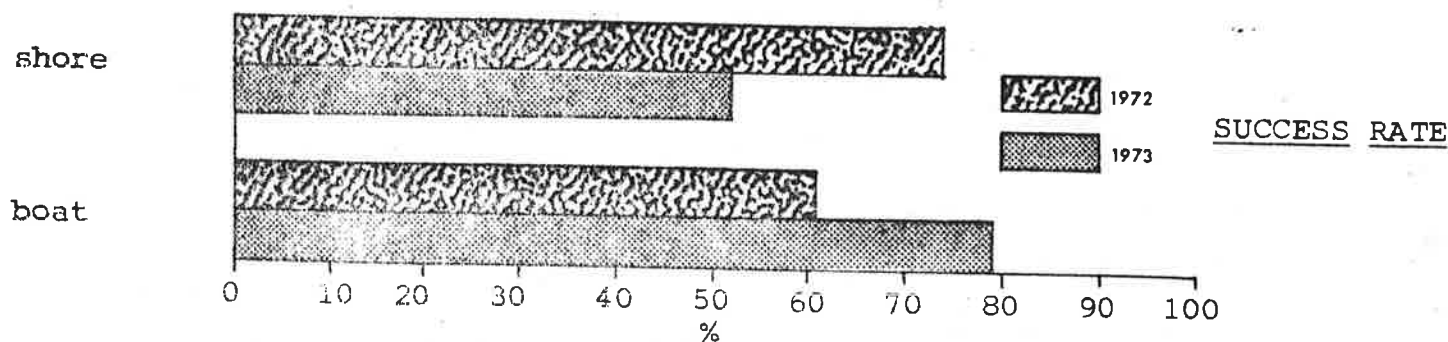
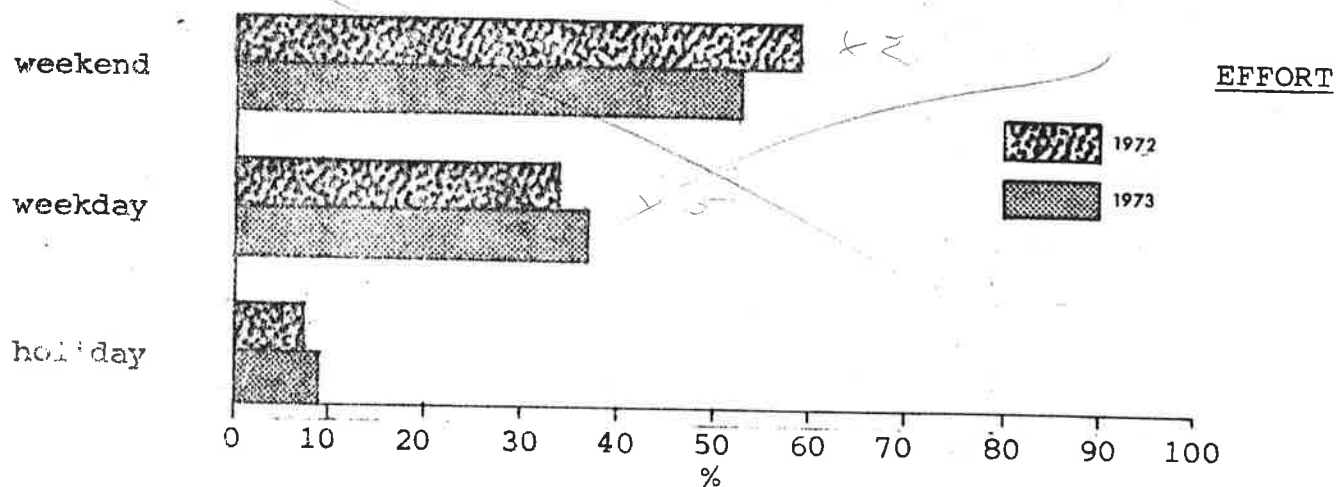
4.4 Sport Finfish Survey

A creel census was conducted from April 1 through October 31, 1973. A total of 669 fishing parties were interviewed, representing 649 shore fishermen and 367 boat fishermen. Fishing pressure (2,042 man hours) yielded 2,313 creeled fish. Mean catch per effort ratios (c/e) for boat and shore fishermen were 1.86 and 0.68 fish/hr, respectively. Based on instantaneous count data, the greatest fishing pressure occurred on weekends. A comparison of sport fish statistics for 1972 and 1973 is presented in Figure 4.10.

Fishing pressure from shore was greatest at the Salem Willows Pier. Few fishermen used the pier constructed by the New England Power Company. Shore fishermen in the plant area generally congregated along the eastern and northern slope of the riprapped groin which protects the docking facilities. Atlantic mackerel, Scomber scombrus, (54%) and winter flounder (35%) were the dominant species creeled by shore fishermen. Mackerel jigs and spreaders baited with clam worms, Nereis virens, were the most common gear types utilized.

Boat fishermen creeled 62% of the total sport fish catch. Fishing pressure from boats was greatest near navigation aids N"2" and N"22". Winter flounder was the dominant species taken (87%). The majority (74%) of boat fishermen fished the bottom with spreaders baited with clam worms.

Figure 4.10. Catch and effort statistics for sport fishermen in Salem Harbor, April - October, 1973.



4.5 Lobster Tagging

Of 876 tagged lobsters, Homarus americanus, released into Salem Sound and Salem Harbor during 1972 and 1973, tag returns totaled 38% and 17%. Data suggests limited movements from the release points (Figures 4.11 - 4.14). Recaptures occurred from the release point to 6.25 nautical miles.

Although 13 lobsters molted prior to recapture, growth data is available for only 4. Growth increments ranged from 8.8 to 20.2 mm (13.8 mm average), representing an 18% increase in carapace length.

Salem Sound

The release point at Bowditch Ledge consists of ledge or rock bottom and provides excellent lobster habitat. Movements were limited. Over 70% of the tag returns since 1972 indicate movements of less than one nautical mile.

Of 301 releases in 1972 and 232 releases in 1973, 125 (42%) and 41 (18%) have been recaptured. Average days of freedom were 51 and 53. Average movements for 1972 and 1973 were 0.45 and 0.71 nautical miles.

Salem Harbor

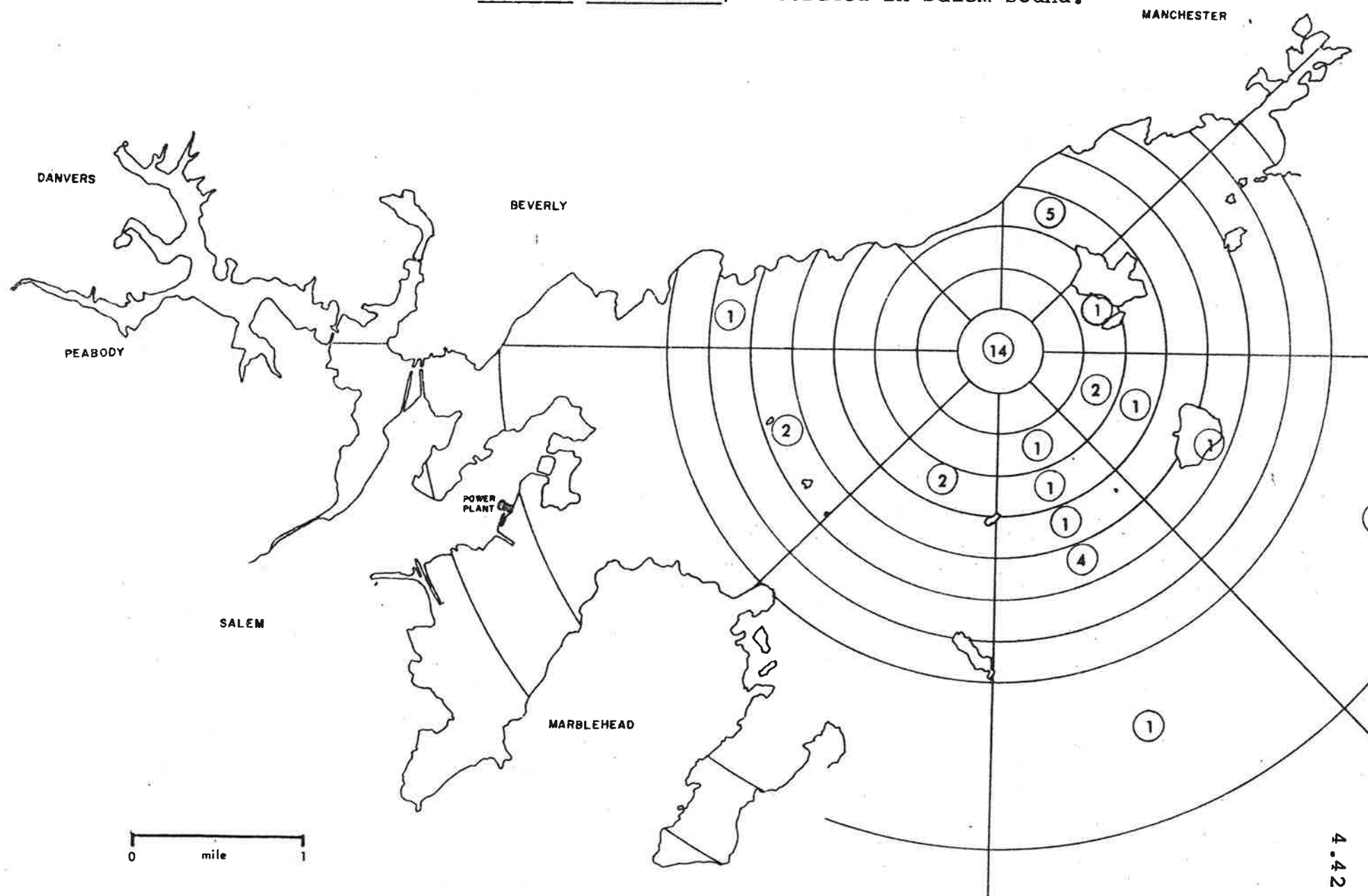
The release point at navigation aid N"2" is characterized by a sand, mud and silt substrate. Approximately 60% of the lobsters were recaptured within an area ranging 3/4 to 2 nautical miles from point of release.

Returns from 143 releases in 1972 totaled 43 (30%) and 200 releases in 1973 totaled 31 (16%). Average days of freedom were 27 and 72. Average movements for 1972 and 1973 were 1 3/4 and 1 1/2 nautical miles.

Homarus americanus



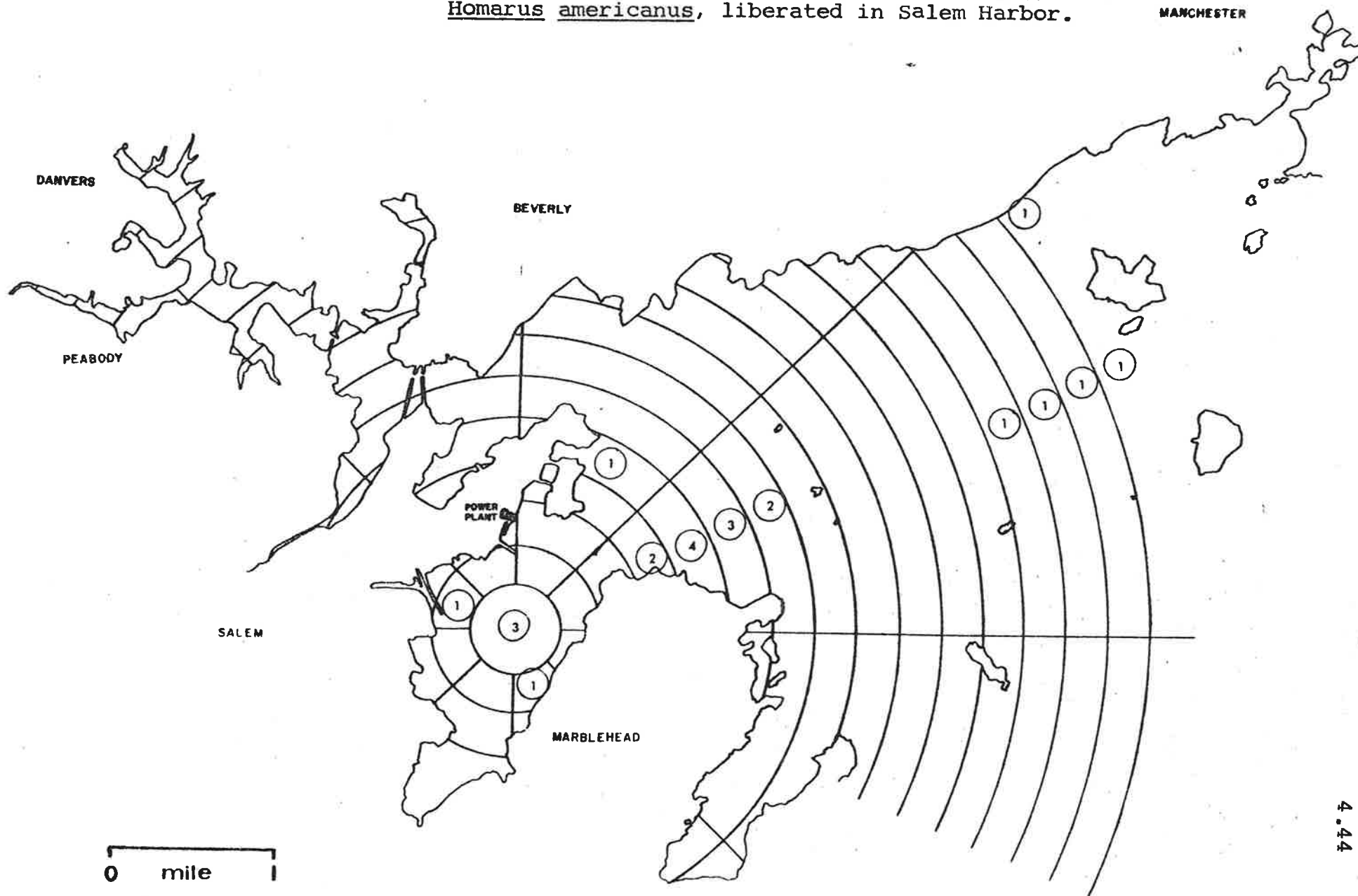
Figure 4.12. Recapture locations of 1973 tagged lobsters, Homarus americanus, liberated in Salem Sound.



MANCHESTER



Figure 4.14 Recapture locations of 1973 tagged lobsters,
Homarus americanus, liberated in Salem Harbor.



5.0 APPENDIX

SAMPLING PROCEDURES

CHLORINITY

Field Collection: 300 ml/sample of seawater.

Laboratory Analysis: Modified Knudsen method, from Strickland and Parson (1968).

SALINITY

Field Analysis: Direct reading from a G.M. hydrometer, calibrated from 0 - 45 ‰.

HYDROGEN ION

Field Analysis: Hach Chemical Company test kit, Model 17-N.

Samples collected from May 15 - December 1, 1972 were analyzed with a Hach test kit, Model CA-10. Prior to May 15 a Kontes mini-pH meter was employed.

CARBON DIOXIDE

Field Analysis: Hach Chemical Company test kit, Model CA-10.

DISSOLVED OXYGEN

Field Collection: 300 ml/sample of seawater fixed with 1 ml manganous sulfate reagent and 1 ml alkaline iodide reagent.

Laboratory Analysis: Titration by Winkler method.

BIOLOGICAL OXYGEN DEMAND

Field Collection: 300 ml/sample of seawater.

Laboratory Analysis: Titration by Winkler method following 7-day incubation.

COPPERField Collection:

Water - 1 liter/sample collected in a nalgene bottle.

Soft shell clam - 6/sample, approximately 2" in length.

Lobster - 1/sample, approximately 3" in carapace length.

Laboratory Analysis: Utilizing a modified Strickland and Parsons (1968) method, the soft portions of clams and 6 grams of lobster gills are digested and analyzed.

NITRATE

Field Collection: 300 ml/sample of seawater.

Laboratory Analysis: Ultraviolet spectrophotometric method from Standard Methods (1971).

NITRITE

Field Collection: 300 ml/sample of seawater.

Laboratory Analysis: Modified Griess Diazo reaction from Griess (1858).

INORGANIC PHOSPHATES

Field Collection: 300 ml/sample of seawater.

Laboratory Analysis: Colorimetric determination of reduced phosphomolybdate complex from Fiske and Subba Row (1925).

BENTHIC

Field Collection: Benthic algae and invertebrates are sampled at sites selected at various depth contours. Quadrats are established by attaching a 12-ft line to the site marker and swinging a circle of 10-ft radius. The first quadrat is located 2 ft from the marker, and subsequent quadrats are located 2 ft and 70° counter-clockwise from the former. This procedure is repeated until 5-1/4m² samples are collected within each circle. Samples are stored and frozen in plastic bags until analyses.

PLANKTON

Field Collection: Phytoplankton is collected in a water sample bottle (Van Dorn or Nanson). Zooplankton is collected in an 80 micron mesh nytex plankton net. Tows are made for 1 minute at selected sites and strained water volume is recorded on an 8.5 cm T.S. flow meter attached to a one meter ring. Samples are transferred to 250 ml nalgene bottles containing a 5% glutaraldehyde solution, and refrigerated until analyses.

CHLOROPHYLL

Field Collection: Surface seawater is filtered through a 316 micron mesh nytex cloth into a one gallon nalgene bottle and stored in a light-proof box for transport to the laboratory.

Laboratory Analysis: Samples are stored in a cool dark place not exceeding eight hours from collection. Estimation of extracted algae cell pigments is made spectrophotometrically using the SCOR/UNESCO method outlined by Strickland and Parsons (1968).

FINFISH

Field Collection: Duplicate sets are made at selected sites with gear of the following desing:

50 x 4 ft seine, with 1/8 in mesh;

120 x 8 ft seine, with 1-1/2 in mesh wings and 3/4 in mesh bag;

30 x 25 ft trawl with 1-1/2 in mesh wings and 1 in mesh cod end;

49 x 38 ft trawl with 5 in mesh wings and 4 in mesh cod end.

Seines are set parallel to shore with the aid of a skiff and drawn to the shore by lines of approximately 75 ft. Trawl cruises are along a fixed course. Where obstructions occur, cruise lines are altered. Fishing time is five minutes with the 30 ft trawl and 20 minutes with the 49-ft trawl.

Gill nets are set at selected sites for 24 hours. All gill nets are constructed of monofilament and measure 100 x 10 ft. Stretched mesh size range from 1-1/2 to 3-1/2 in.

Finfish collected are separated by species, enumerated, and measured for total length in millimeters.

SPORT FISH SURVEY

Starting Date: mid-April

Ending Date: mid-October

Area: Salem Harbor, inside or west of a line drawn between Fort Pickering Light on Winter Island to Naugus Head in Marblehead; and the easterly shorelines of Winter Island and Salem Neck from the Fort Pickering Light to, and including, the public pier at the north end of Salem Neck.

Procedure: Instantaneous fishermen counts are conducted three times during each survey day at randomly selected hours.

Fishermen interviews are conducted throughout the survey day. Survey data is recorded on forms provided for a minimum of 10 percent of all shore and boat fishermen.

Children who are fishing are included in the instantaneous counts, and a separate tally noted. Children are not interviewed when fishing in the accompaniment of an adult.

Schedule: One weekday and one weekend day is surveyed each week. All holidays are surveyed. Selection of day, and 8-hour shift (6 - 2 or 10 - 6), is made at random. Changes in routine are made only at time of schedule selections.

FISH EGG AND LARVAE

Field Collection: Procedures employed in collecting and handling fish egg and larvae are identical to zooplankton except for use of a 153 micron mesh nytex net.

SLUICeway INVESTIGATIONS

Field Collection: Finfish, invertebrates and marine vegetation are sampled in the intake sluiceways to Units 3 and 4. Traps, constructed of 1/2 in welded steel rod and covered with 3/16 in stretched mesh nylon net, are periodically placed in the respective sluiceways for one hour intervals. All organisms are identified, enumerated and measured. Water temperature and salinity is recorded during each sampling interval.

LOBSTER TAGGING

Field Collection: Division personnel, aboard commercial vessels, collect sub-legal sized lobsters (3 - 3-1/8 in) from Beverly and Salem Harbors. Lobsters are then transferred to a Division boat or returned to our Cat Cove Laboratory for tagging with a fluorescent orange sphyron tag.

Tagging Procedure: Tags are attached by securing a stainless steel anchor (.014 dia.) in the body muscle beneath the abdomen with the aid of a #20 hypodermic needle. Each tag is imprinted with a number and the legend "Div. Mar. Fish., Salem, Mass." Tagged lobsters are then released at selected sites in Beverly and Salem Harbors. Sex, carapace length (in millimeters), date, and release point are recorded.

Return Procedure: Through a public awareness program, including personal letters to commercial lobstermen known to fish Beverly - Salem Harbors; distribution of posters and tag reporting forms; and articles in the local news media; individuals are requested to return lobster tags to our laboratory or to a cooperating fish dealer. All returns are acknowledged in writing, and tags are placed on a map designating the point of capture. Records are updated on growth and movements of each recapture.

THERMAL BIOASSAY

Field Collection: Finfish species are collected by seines and trawls and transported to the laboratory in aerated containers of seawater.

Laboratory Experiment: Following acclimation to room temperature (about 18°C), 96 hour tolerance levels for each species are determined for abrupt and gradual changes in water temperature. Effects are noted for each 2.8°C gradient over the range -1.0 to 32.0 °C.

HYDROGRAPHIC SURVEYS

Tidal direction and velocity are recorded with an Endeco 110 remote current meter. Direct readout data is collected at varied depths along prescribed transects bisecting Salem Harbor. Attempts are made to monitor seasonal current patterns at varied tidal stages. Data interpretation is performed by project personnel.

TEMPERATURE MONITORING

In situ monitoring is conducted with Endeco 109 continuous recording thermographs. Thermographs are installed at prescribed locations and depths by personnel utilizing SCUBA. Temperature data is retrieved at approximately 30-day intervals and delivered to Environmental Devices Corporation for reduction and verification.

ADENOSINE TRIPHOSPHATE

Field Collection: Following removal of zooplankton with an 80 micron mesh net, water is filtered through a 2.4 GF/A millipore filter retained in a Swinex 25 filter holder locked between two 50ml disposable syringes. After filtration the filter pad is removed, quick frozen on dry ice, and placed in a labeled glass vial for transport to the laboratory. All samples remain frozen until analyzed. Triplicate samples are collected at each sampling site.

Laboratory Analysis: ATP is assayed enzymatically using the luciferin-luciferinose bioluminescence system outlined by Strehler (1968).

¹⁴C

Field Collection: At depths determined by a portable photometer (100, 50, 25, 12 and 0% relative light intensity) unfiltered water is incubated for 4 hours in 300 ml BOD bottles containing a solution of radioactive carbon. Duplicate samples are collected in light and dark bottles. Immediately following incubation all samples are placed in a light proof container for transport to the laboratory.

Laboratory Analysis: Following filtration of phytoplankton from seawater samples, the uptake of fixed radioactive carbon is determined by the liquid scintillation technique outlined by Strickland and Parsons (1968).

Project expenditures as of December 31, 1973 were:

	<u>Total Allotted</u>	<u>Total Expended</u>	<u>Balance</u>
Salaries	\$135,800.00	\$120,414.97	\$15,385.03
Travel	3,375.00	2,236.63	1,138.37
Office and Laboratory Supplies	8,875.00	5,870.76	3,004.24
Equipment	23,500.00	19,996.45	3,503.55
Maintenance and Miscellaneous Supplies	6,100.00	2,995.37	3,144.63
Overhead	<u>39,920.00</u>	<u>23,121.89</u>	<u>16,798.11</u>
Subtotal	\$217,570.00	\$174,596.07	\$42,973.93
Contracts	<u>79,280.00</u>	<u>33,160.00</u>	<u>46,120.00</u>
TOTAL	<u>\$296,850.00</u>	<u>\$207,756.07</u>	<u>\$89,093.93</u>

6.0 LITERATURE CITED

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