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University of New Hampshire, Ph.D., 1973
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PHYSIOLOGICAL ECOLOGY OF FOUR SPECIES OF

POLYSIPHONIA

by

RICHARD A. FRALICK

B. A. SALEM STATE COLLEGE, SALEM, MASSACHUSETTS, 1967

M. S. UNIVERSITY OF NEW HAMPSHIRE, DURHAM, NEW HAMPSHIRE 1970

A DISSERTATION

Submitted to the University of New Hampshire

In Partial Fulfillment of

The requirements for the Degree of

Doctor of Philosophy

Graduate School

Department of Botany

July, 1973

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ACKNOWLEDGEMENTS

I wish to thank the following people who assisted me in this project: Dr. Arthur C. Mathieson for his stimulation and encouragement throughout this study and for his valuable assistance in the preparation of this dissertation; Dr. Albion R. Hodgdon, Dr. H. F. Mulligan, Dr. Richard W. Schreiber, Dr. Robert A. Croker, and Dr. Ruth D. Turner for their valuable suggestions during the research and for their diligent review of the manuscript; Stanley A. Riggs for his invaluable assistance in the field; Barry Hutchinson for his assistance with the figures; my wife Katy for her assistance with the maps, illustrations and for her overall enthusiasm throughout the entire period of the study.

Special thanks must also go to my fellow divers especially Kenneth W. Turgeon, Barry Hutchinson as well as Dr. A. C. Mathieson. In addition I would like to thank the staff of the Jackson Estuarine Laboratory, University of New Hampshire and in particular Mr. Donald Burnett and Ruth Jeralds. The Graduate School, University of New Hampshire must also be acknowledged for financial support in the form of a summer fellowship (1972) and a dissertation fellowship during my final semester (1973). I also thank Patricia Neff and the entire faculty and staff of the Botany Department for their support and encouragement in many ways.

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ABSTRACT

The photosynthesis and respiration of four species of the marine red alga Polysiphonia were evaluated under a variety of temperature and salinity conditions. The manometric results were compared with the local distribution and abundance of each species. The species can be separated into two distinct categories based on their overall distribution and temperature optima: (1) cold water plants (P. lanosa and P. elongata) with peak photosynthesis at 21 to 24°C, but with active photosynthesis as low as 5°C; (2) plants with warm water affinities (P. nigrescens and P. subtilissima) having photosynthetic optima at 27 to 30°C, and exhibiting little or no photosynthesis below 10°C. The plants from the first group exhibit thermal injury at temperatures of 25°C and show a narrow tolerance to low salinities during periods of high temperature. The plants from the second group show thermal injury at 30°C and have a wider tolerance to low salinities.

The horizontal distribution of the four Polysiphonia species within the Great Bay Estuary System is primarily governed by their varying tolerances to high temperatures and low salinities. The temperature optimum for each of the species is correlated with its differential estuarine distribution. Thus, Polysiphonia subtilissima, having the highest temperature optimum, exhibited the greatest penetration into the Estuary, while P. lanosa, having the lowest temperature optimum was primarily restricted to the more coastal stations. There was a good correlation between the natural distribution patterns and the manometric results.

INTRODUCTION

Environmental changes such as thermal enrichment, water diversion and dredging for marinas are significantly altering the natural state of Atlantic Coast estuaries. Such changes may alter the distribution, diversity, seasonal succession, reproduction, and biomass of benthic algal populations.

Relatively little is known about the causal factors determining the distribution and abundance of seaweeds in estuaries. Doty and Newhouse, (1954) studied the distribution of marine algae in the estuarine waters of Great Bay, New Hampshire; they found a successive decrease of marine species beyond stations exhibiting lower salinities. Taylor (1937), Abbott (1947), Osterhout (1905), Brown (1915), and Doty and Archer (1950) state that reduced salinities can restrict the distribution of benthic algae. The wide range of temperature in an estuary may also restrict the distribution of stenothermal forms (Emery et al., 1957).

Among others Braarud (1951), Ogata (1963), Ogata and Matsui (1965), Ogata and Takada (1968) and Vosjan and Siezen (1965) have studied the affects of salinity on the photosynthesis and respiration of marine algae. Respiration usually increases at low salinities, particularly at high temperatures. Montfort et al. (1955 & 1957), Schwenke (1959), Newell and Pye (1968), Biebl, (1972), and Hammer (in Biebl, 1972) studied the effects of temperature on photosynthesis and/or respiration of seaweeds. Few of these workers related the distribution and abundance of natural populations with experimental photosynthetic results.

Mathieson and Burns, (1971) studied the distribution and growth of Chondrus crispus and correlated their field investigations with manometric results. Mathieson and Dawes, (in press) conducted similar studies with four species of Euclima. Kjeldsen and Phinney, (1972) studied the effects of salinity and temperature on the photosynthesis of several algae from an Oregon estuary.

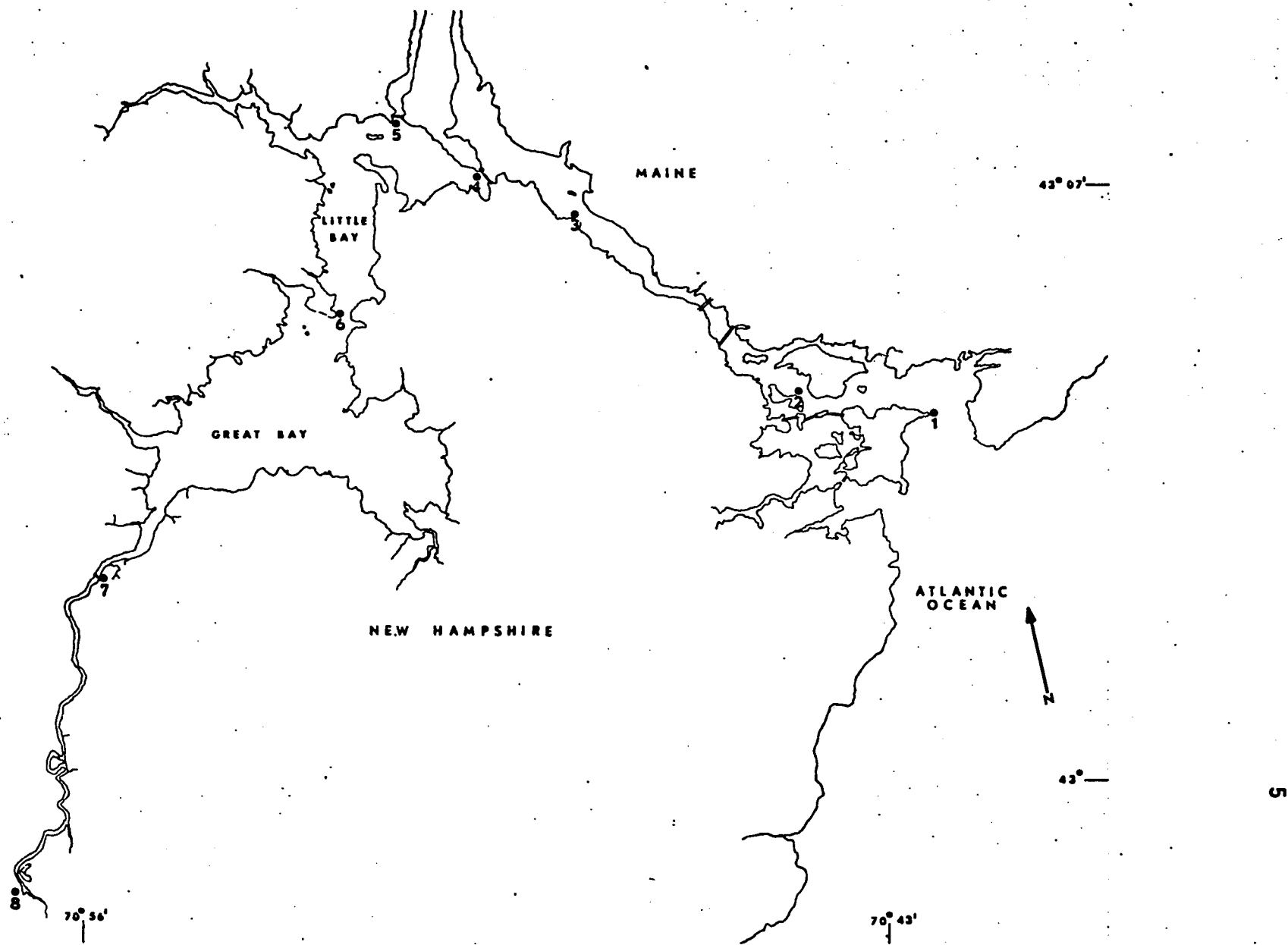
The present paper describes the horizontal distribution of four Polysiphonia species within the Great Bay Estuary System in relation to seasonal and spatial fluctuations of environmental parameters. It also relates the photosynthetic responses of the same species to temperature, salinity and light regimes, and attempts to correlate the local distribution of each species with these findings.

METHODS AND MATERIALS

Bimonthly records of hydrographic factors (surface water) were made at eight stations within the Great Bay Estuary System (Fig. 1) from June, 1971 to January, 1973. Station 1 was on the open coast while station 8 was 19.05 nautical miles inland. A description of each site is summarized in Appendix I. Surface water temperature was recorded with a laboratory grade, submersible mercury thermometer. Salinity was determined with a set of hydrometers (G. M. Manufacturing Co., N.Y.); the readings were corrected to 15°C.

The apparent photosynthesis of the four Polysiphonia species was determined with a Gilson Differential Respirometer (Model GRP-14). The instrument was equipped with fourteen 50 Watt, Champion incandescent lights. A supplementary water cooler (Neslab, Model PBC-4) was employed during some experiments. Prior to the photosynthetic experiments, the plants were incubated in the dark for 18-24 hours. A 0.3 ml solution of HCl and diethanolamine (60%) was used in the center well of the manometric flasks to provide a 2% carbon dioxide atmosphere, (Mathieson, 1965). The plants were incubated in the light prior to the initiation of the respiratory experiments. A 20% KOH solution was used to absorb excess carbon dioxide during respiration studies. The flasks were equilibrated for one hour prior to the initiation of a photosynthetic or respiratory run. Each run was made for one hour and readings were taken at ten minute intervals. Five or more replicates were used for each experiment. The manometric techniques employed are essentially the same

Figure 1. Map of the Great Bay Estuary System showing the eight study stations.



as those of Mathieson and Burns, (1971).

In the salinity experiments the plants were immersed in a series of different salinities (0.0 to 40.0 ‰) for four days prior to the actual runs. All of the experiments were completed within ten days after the plants were collected. The results of the photosynthesis and respiration experiments are expressed as microliters of oxygen evolved per gram dry weight, per unit of time.

Specimens of Polysiphonia lanosa were collected intertidally at station 1 (Jaffrey Point), while P. nigrescens was collected at 6-8 m depths at the same site. Polysiphonia elongata was collected at 4-5 m depths at stations 3 and 4 and P. subtilissima was collected in the upper subtidal zone at station 7. All of the plants were collected in the summer and fall of 1972. The plants were transported to the laboratory in a styrofoam cooler, within a few hours after collection. The specimens were subsequently immersed in artificial seawater (Chapman, 1962) and retained near ambient temperatures and at light regimes of 300 to 500 foot candles.

HYDROGRAPHIC REGIMES WITHIN THE GREAT BAY ESTUARY SYSTEM

Figures 2-5 summarize spatial and seasonal fluctuations of surface water temperature and salinity at three representative sites (stations 1, 4 and 7) between June 1971 and December 1972. The values are based on low water readings. Specific details of temperature and salinity for the other five sites are summarized in Tables I and II. Temperatures of 1.0 to -1.0°C were recorded for stations 1, 4 and 7 during February and March, while maximal temperatures from 10°C (station 1), 17°C (station 4) and 26°C (station 7) were recorded during June and July (Figure 2). The summer temperatures were lowest at the most coastal stations and highest at the most inland stations (Table I).

Figure 3 shows the variation in surface water salinity at stations 1, 4 and 7 from June 1971 to December 1972. Salinities of 30 ‰ or higher were recorded from June through February at station 1. A salinity of 28 ‰ was recorded in May; it was associated with a period of spring run-off. Station 4 showed salinities of 26 ‰ or greater, except during March through June. Station 7 exhibited a maximum salinity of 21 ‰ in August, 1971. The salinities of the following year did not exceed 8 ‰. In general, the highest salinities at all sites occurred from June to March, while the lowest salinities were apparent in April and May. Salinities were lowest at the most inland stations and highest at the more coastal stations (Table II).

Figure 4 summarizes diurnal temperature variation at four sites, after the spring run-off, on July 14 and 15, 1971. Station 1 exhibited the narrowest fluctuations, ranging from 11.0°C at 1800 on June 14, to 16.0°C at 1500 hours on June 15. Station 4 exhibited a diurnal fluctuation of 11.0° to 20.5°C .

Figure 2. Variation in surface water temperature between June, 1971 and December, 1972 at stations 1, 4 and 7.

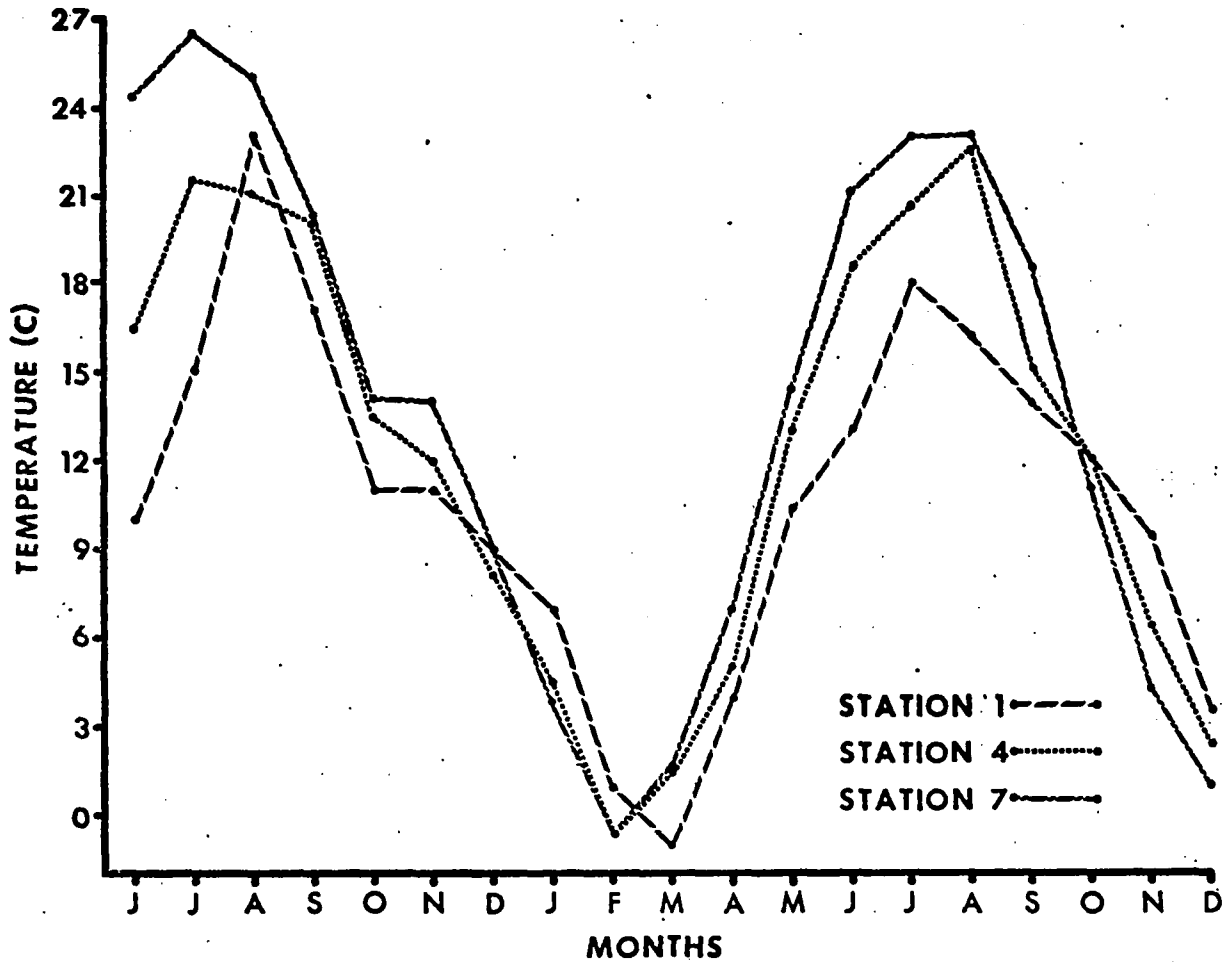


Figure 3. Variation in surface water salinity between June, 1971 and December, 1972 at stations 1, 4 and 7.

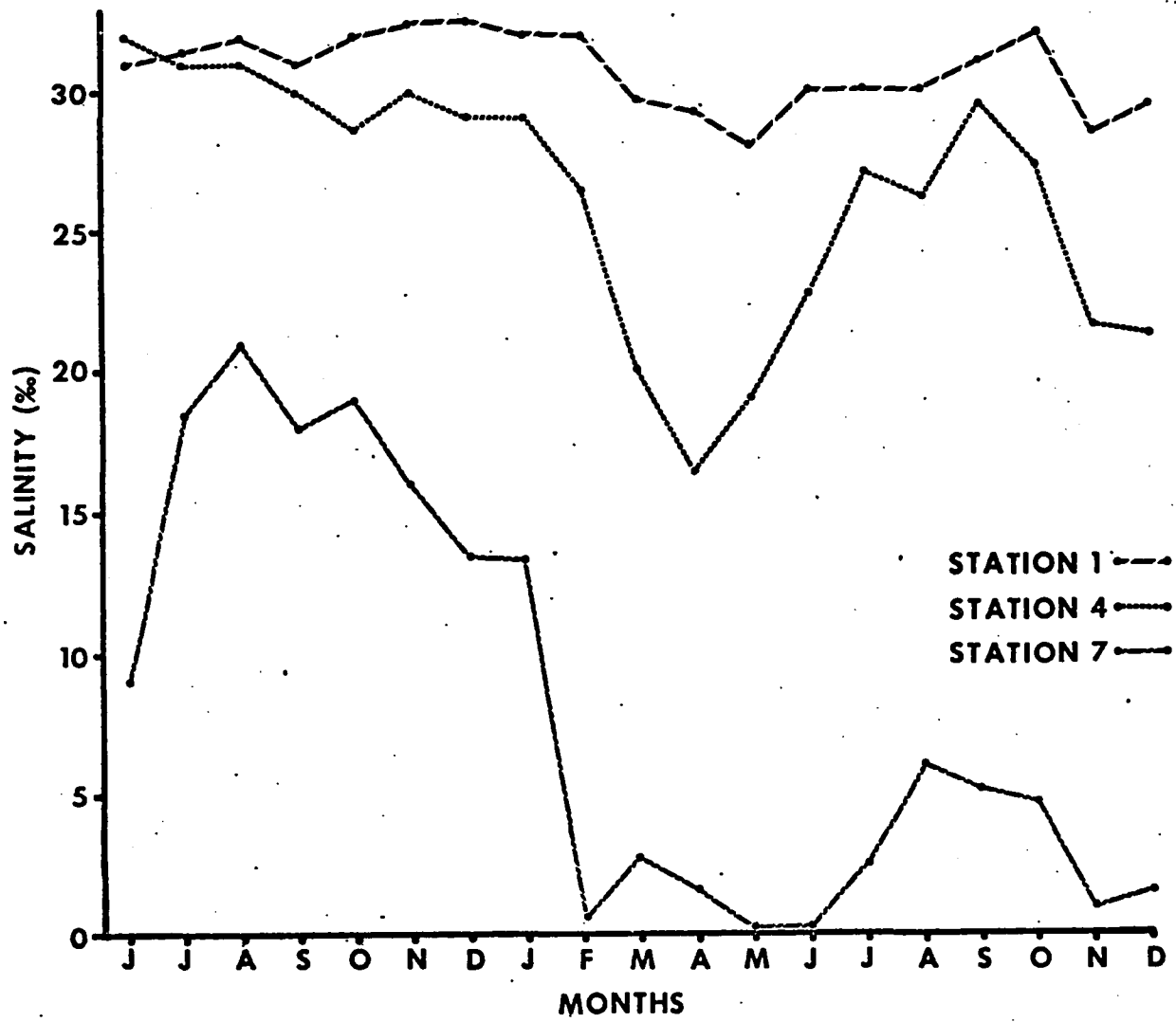


Figure 4. Diurnal variation in temperature at stations 1, 4, 7, and 8 on July 14 and 15, 1971.

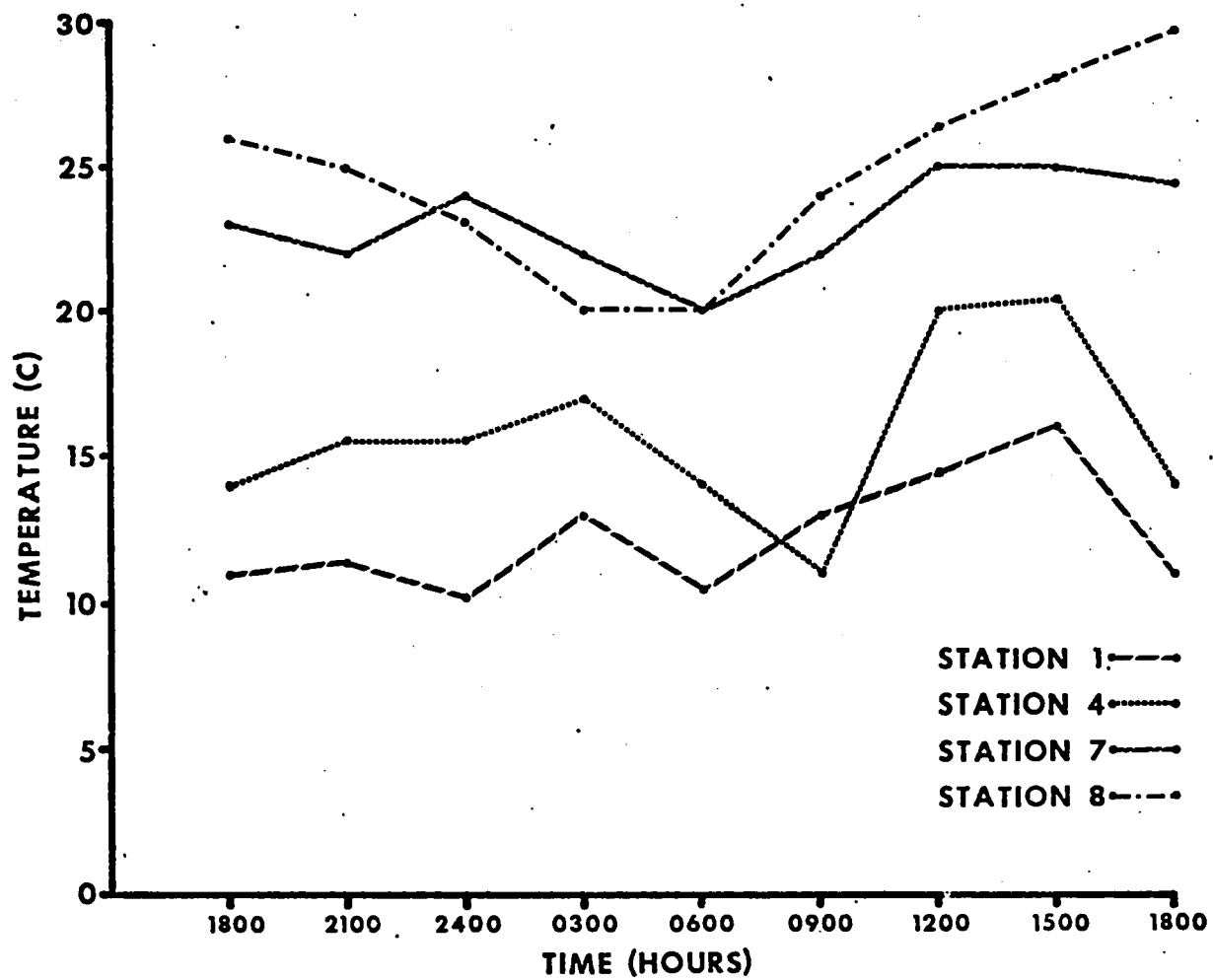
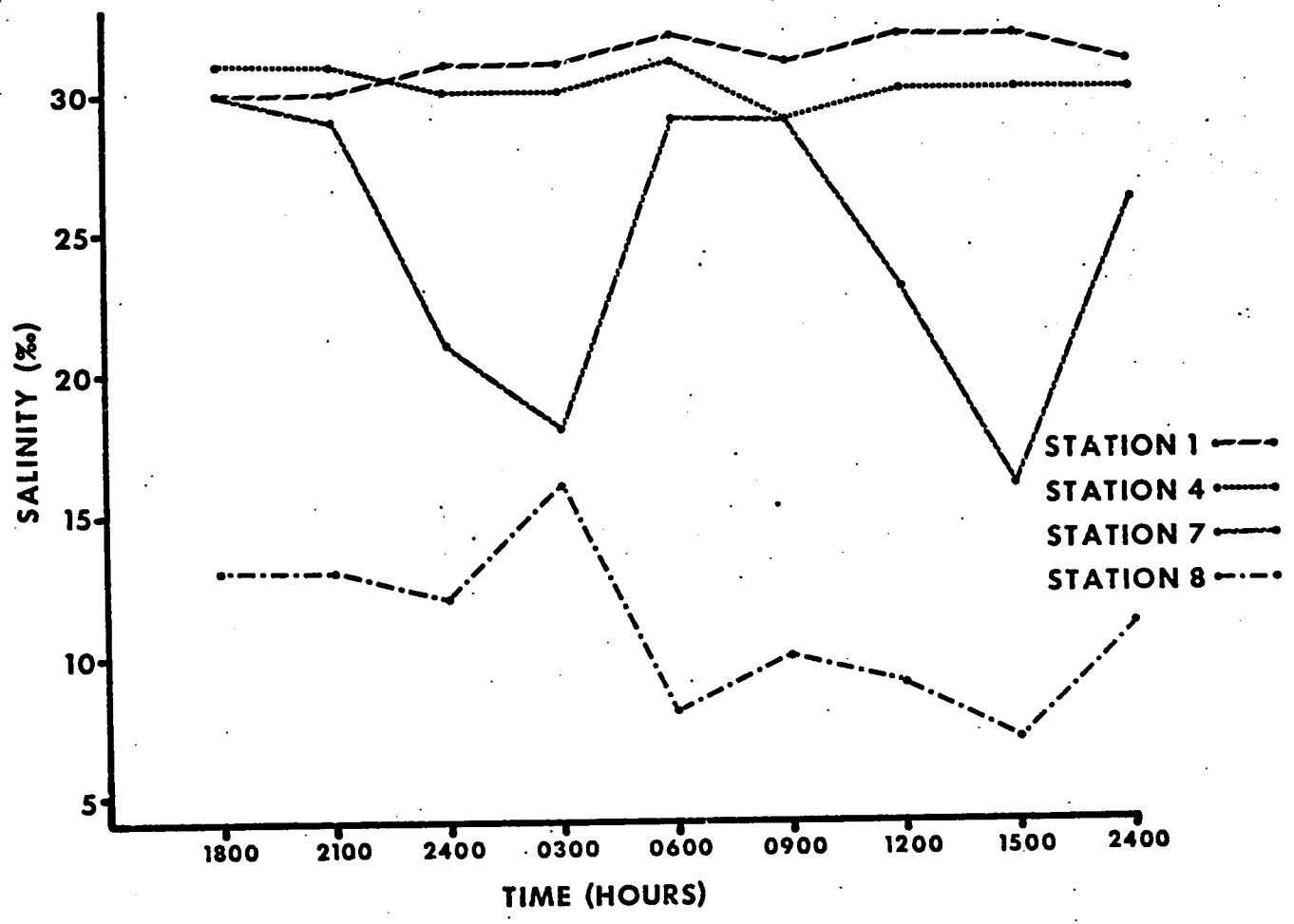


Figure 5. Diurnal variation in salinity at stations 1, 4, 7, and 8 on July 14 and 15, 1971.



There was a marked difference in temperatures between the first two sites and stations 7 and 8. A low temperature of 20.0°C and a maximum of 25.0°C was recorded at station 7. An even greater temperature range occurred at station 8, with a low of 20.0°C and a high of 29.5°C . A comparison between the stations shows a common warming trend which begins during the morning hours and continues until late afternoon.

Figure 5 shows the diurnal variations of salinity at stations 1, 4, 7 and 8 on July 14 and 15, 1971. Stations 1 and 4 showed minimal fluctuations from 29.0 to 32.0 o/oo. The salinities ranged from 17.0 to 29.0 at station 7, and 7.0 to 17.0 at station 8. At stations 7 and 8, the highest salinities occurred during high tides while the lowest salinities were apparent at low tides - the period of maximum run-off from the Squamscott River (Fig. 1).

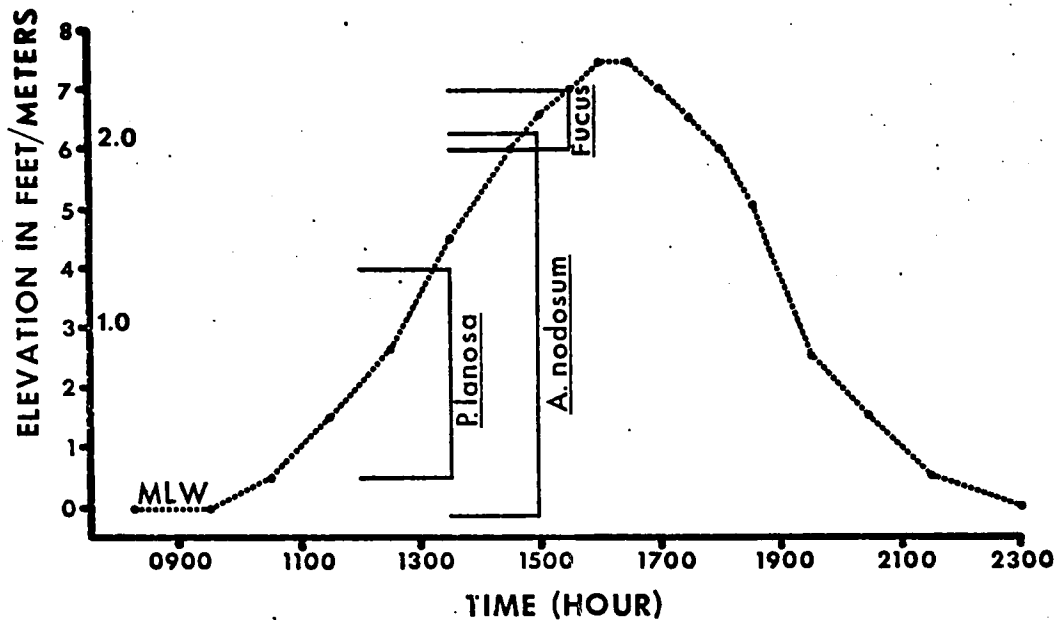
DISTRIBUTION AND ABUNDANCE OF POLYSIPHONIA SPECIES

Table III summarizes the local distribution and abundance of the four Polysiphonia species at eight stations in the Great Bay Estuary System. The mean values and ranges of temperature and salinity at each of the eight stations are also given. The relative abundance of the organisms is ranked numerically from zero to five.

Polysiphonia lanosa (Linnaeus) Tandy is a dominant intertidal species of the open coast. The species is recorded from New Jersey to Newfoundland, Taylor (1937). Locally P. lanosa is relatively abundant at station 1, common at station 2, rare at station 4, and absent at station 5. Polysiphonia lanosa is a perennial that is a hemiparasite on Ascophyllum nodosum, Taylor, (1937). The local distribution of P. lanosa and its host A. nodosum differs markedly. The host is ubiquitous in The Estuary, while P. lanosa is distinctly coastal in distribution. Polysiphonia lanosa exists within a temperature and salinity range from 0.0⁰ to 25.0⁰C. and 15.0 to 32.5 o/oo, respectively in New Hampshire. The vertical distribution of the two species is also distinct. Figure 6 shows a zonation profile of A. nodosum, P. lanosa and associated furoid algae on the open coast. Polysiphonia lanosa is usually restricted to a narrow zone (0.2 to 1.3 meters above MLW), while A. nodosum extends much higher (0.0 to 2.3 M.). Polysiphonia lanosa is uncommon in the subtidal zone.

Polysiphonia elongata (Hudson) Sprengel is a perennial, subtidal alga distributed from New York to Newfoundland (Taylor, 1957; Mathieson, Dawes and Humm, 1969). The species is rare on the open coast of New Hampshire but abundant at stations 3 and 4. Polysiphonia

Figure 6. Zonation and immersion curve for Polysiphonia lanosa,
Ascophyllum nodosum and Fucus vesiculosus at station 1.



elongata occurs within a temperature and salinity range of 0.0° to 28.0°C and 6.0 to 32.5 o/oo respectively in the Estuary. It frequently grows as an epiphyte on Phyllophora broadae, Laminaria saccharina and Rhodymenia palmata. The vertical distribution of P. elongata extends from 0.0 to 8.0 M below MLW. Intertidal specimens of this species can occur to my knowledge only at station 4, where tidepools are continuously shaded by the General Sullivan bridge.

Polysiphonia nigrescens (Hudson) Greville is a perennial species, that is widely distributed from Florida to Newfoundland (Taylor 1957; Mathieson, Dawes and Humm 1969; Crowley and Dawes 1970). It is abundant at station 1, common at stations 2, 3, and 4, and absent beyond station 5. Polysiphonia nigrescens extends within a temperature and salinity range of 0.0 to 28.0°C and 6.0 to 32.5 o/oo respectively in New Hampshire. The species may occasionally be found in tide pools, but it is usually more abundant in the subtidal zone to 13-17 meters (personal communication, Mathieson). Deep water specimens (15 meters) are often 25% smaller than shallow subtidal plants.

Polysiphonia subtilissima Montagne is a perennial alga that is distributed from Florida to Nova Scotia (Taylor, 1957; McLachlan and Edelstein, 1971). Locally it is only present at station 7, where the temperature and salinity ranges from 0.0 to 29.0°C. and 0.0 to 22.0 o/oo respectively. In its northern distribution P. subtilissima is restricted to brackish water embayments, while in Florida it is present on the open coast (Hehre and Mathieson 1970 and personal communication with A. Mathieson). The plant reaches its maximum length (10.0 to 12.0 cm) in the late summer and by November only residual populations are evident. Thus, it can also be described as a pseudoperennial (Knight and Parke,

1931) since a small residual portion of the plant can regenerate the intact frond.

MANOMETRIC STUDIES

Light intensity:

Figure 7 illustrates the rates of apparent photosynthesis of Polysiphonia lanosa and P. subtilissima under a series of different light intensities. At 10.0°C the apparent photosynthesis of P. lanosa increases with an increase in light intensity up to approximately 850 foot-candles; above this a slight decrease is evident. Thus, light intensities in excess of 850 foot-candles are probably saturating, while those of less than 850 are limiting. The apparent photosynthesis of P. subtilissima at 15.0°C appears to be saturated at 1000 foot-candles and it remains level up to 3600 foot-candles. The apparent photosynthesis of Polysiphonia nigrescens and P. elongata is probably saturated at 1000 and 250 foot-candles respectively (Fig. 8). High light intensities appear to be inhibitory to P. elongata.

Temperature:

Figures 9 and 10 illustrate the apparent photosynthesis of the four species of Polysiphonia at various temperatures and 1000 foot-candles. The rate of apparent photosynthesis for P. lanosa (Fig. 9) increases with an increase in temperature to 22°C, and decreases about 24°C. At 35°C little apparent photosynthesis is evident. The optimal temperature range for P. lanosa is between 22 - 24°C. The optimal temperature for P. elongata is between 21 and 24°C. Active photosynthesis for both species was maintained at 5°C. Figure 10 illustrates the apparent photosynthesis of P. subtilissima at various temperatures. The rate of photosynthesis increases with an increase in temperature up to 27 C, thereafter it decreased. The optimal temperature range for

Figure 7. Apparent photosynthesis of Polysiphonia lanosa and P. subtilissima at different light intensities.

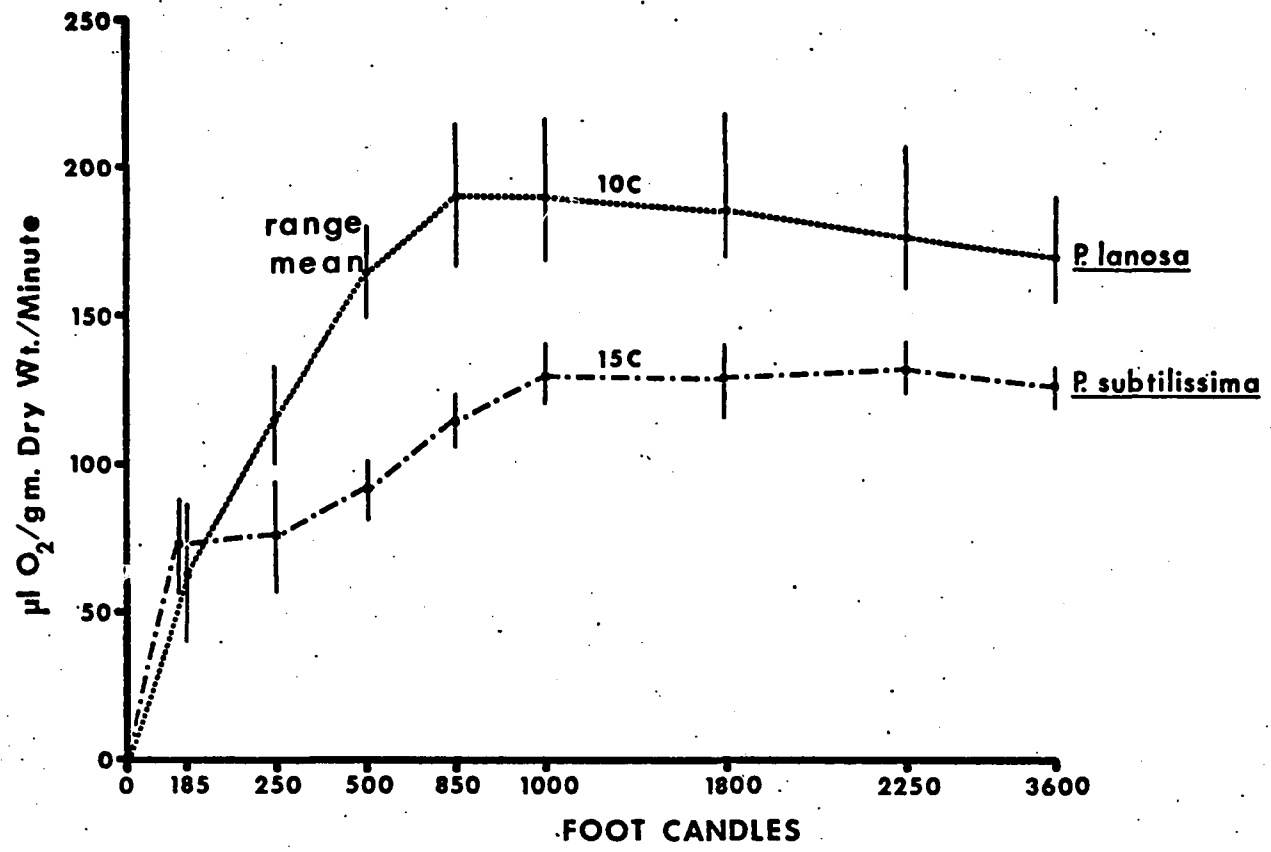


Figure 8. Apparent photosynthesis of Polysiphonia elongata and P. nigrescens at different light intensities.

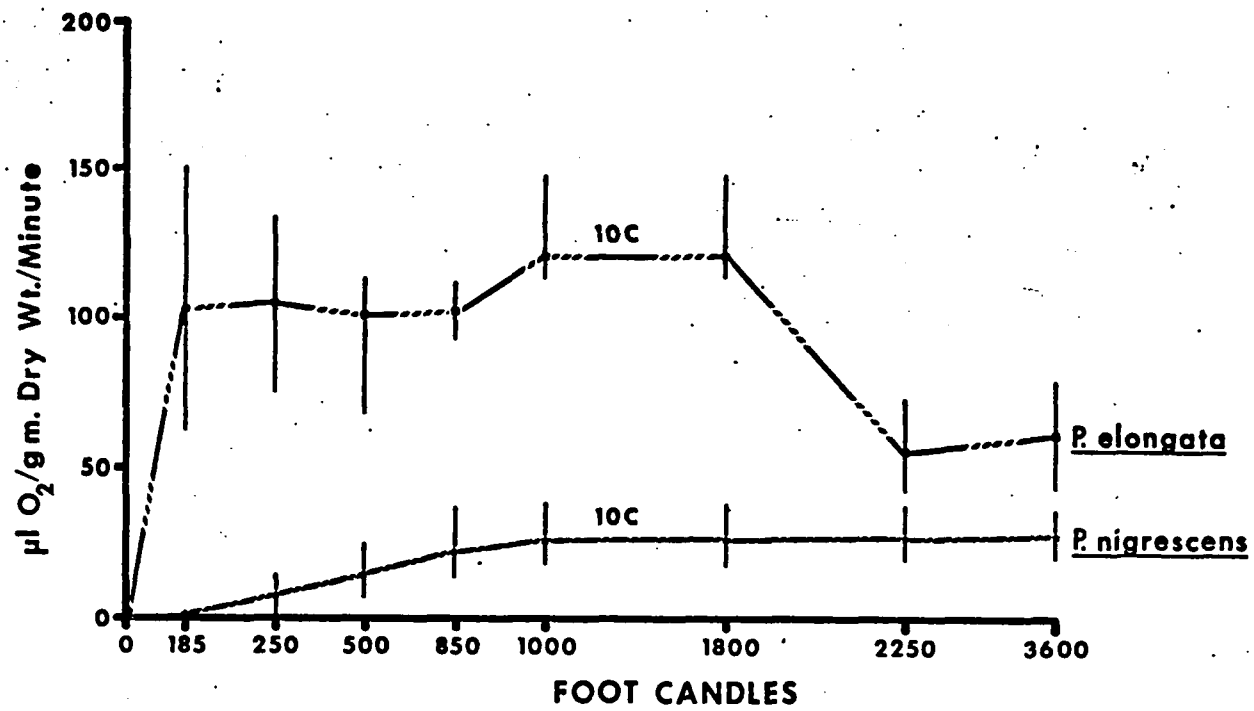


Figure 9. Apparent photosynthesis of Polysiphonia lanosa and P. elongata at various temperatures and 1000 foot-candles.

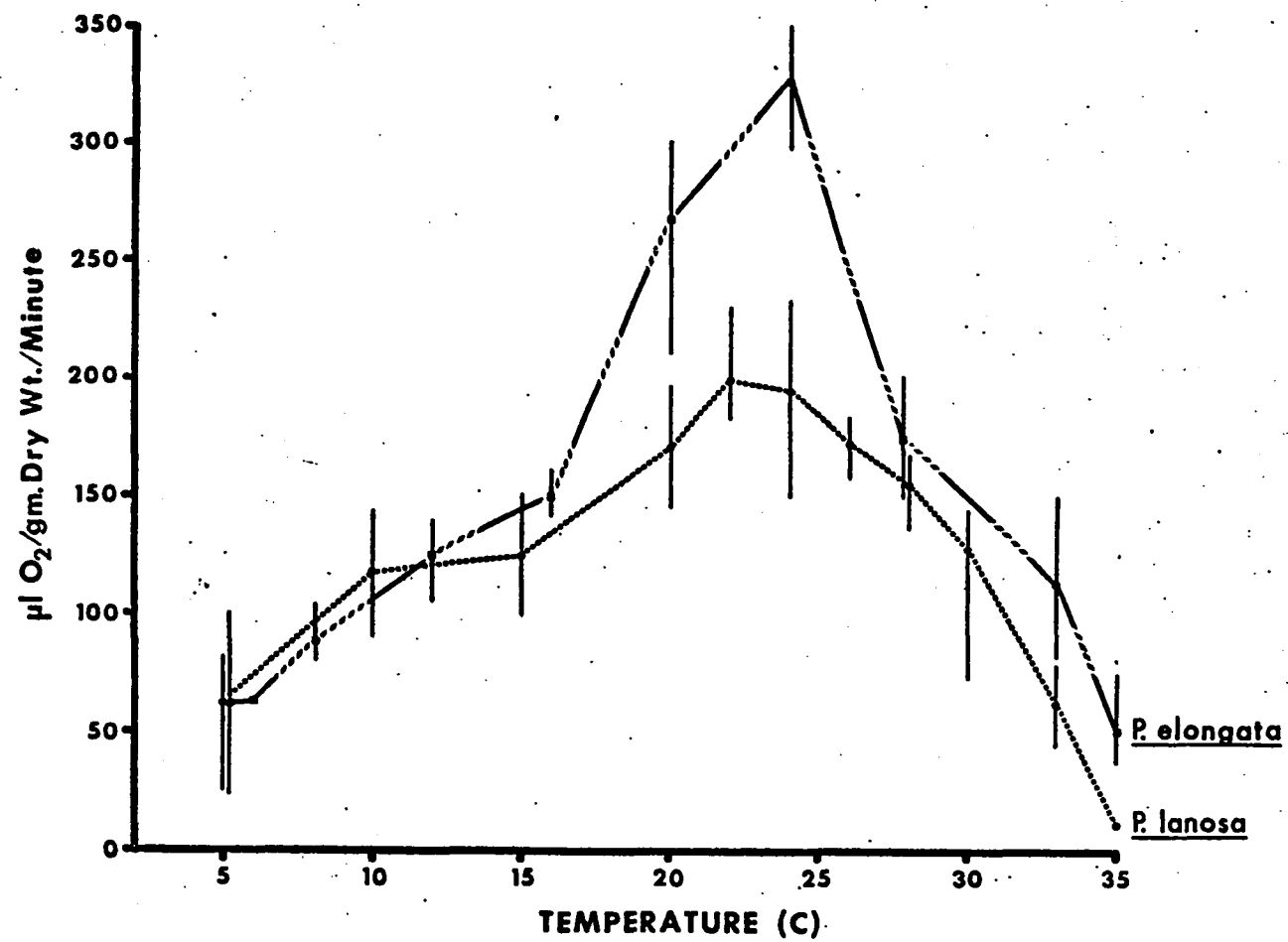
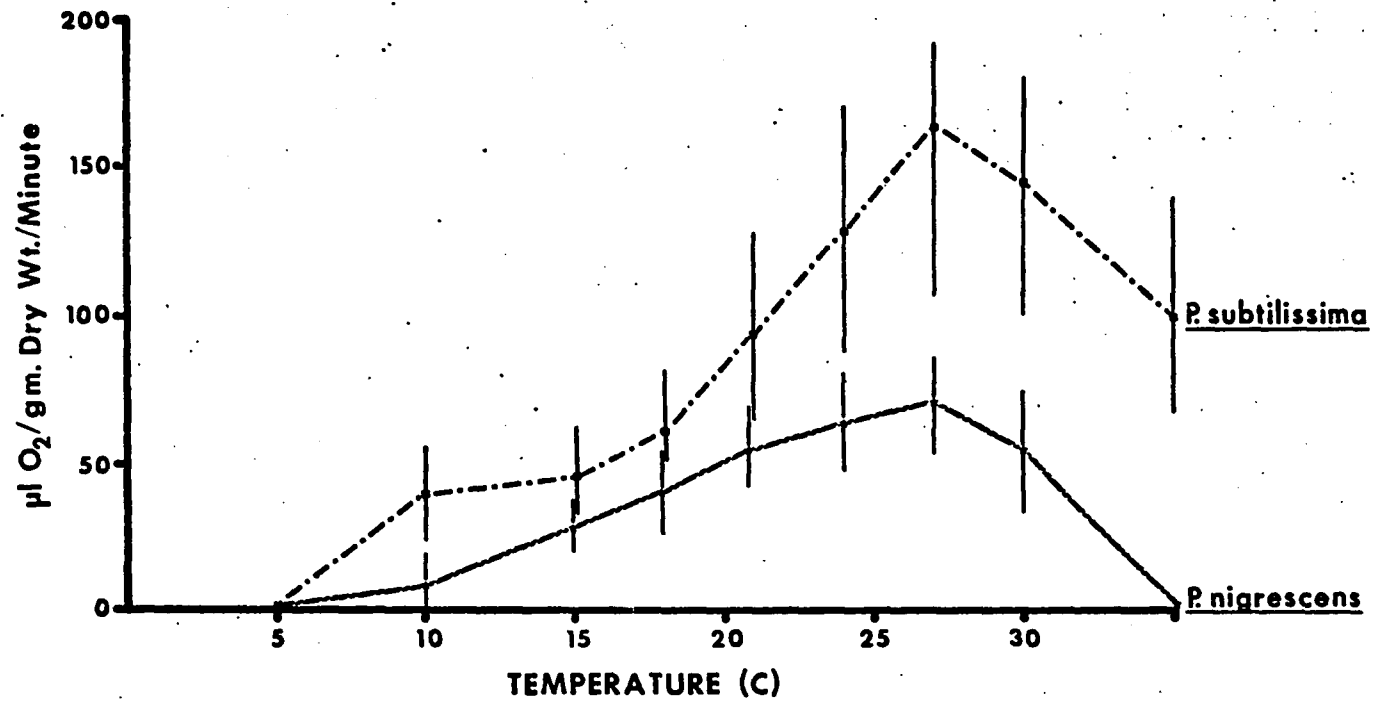


Figure 10. Apparent photosynthesis of Polysiphonia nigrescens and P. subtilissima at various temperatures and 1000 foot-candles.



photosynthesis of P. nigrescens and P. subtilissima is between 24 and 27°C. Photosynthesis decreases at temperatures greater than 27°C. Little or no photosynthesis was recorded for both species below 10°C.

Figure 11 shows the respiration of Polysiphonia lanosa and P. elongata at various temperatures. The respiration rates of P. lanosa are low between 5 and 15°C; thereafter they increase with an increase in temperature particularly above 30°C. A rapid increase in respiration is also evident in P. elongata at temperatures greater than 30°C. The high respiration rates at temperatures greater than 30°C is attributed to thermal injury, or enzyme denaturation (Kanwisher, 1966). Figure 12 shows the respiration of Polysiphonia nigrescens and P. subtilissima at various temperatures. The respiration rates for P. nigrescens increase rapidly above 20°C. In contrast the respiration rates of P. subtilissima are relatively stable until 32°C.

Salinity:

Figure 13 illustrates the apparent photosynthesis of Polysiphonia lanosa and P. elongata at 5 and 15°C, 1000 foot-candles and after 4 days immersion in a variety of salinities.

At 15°C the maximum rate of photosynthesis for P. lanosa was evident at 30 o/oo, and there was a conspicuous decrease in photosynthesis at salinities higher and lower than 30 o/oo. No photosynthesis was recorded at salinities less than 5 o/oo. At 5°C the rate of photosynthesis of P. lanosa was relatively uniform between 25 and 40 o/oo. A decrease in photosynthesis was apparent at salinities of 10 to 15 o/oo, and no photosynthesis was recorded at salinities lower than 10 o/oo. The maximum rate of photosynthesis with P. elongata occurs between 20 and 40 o/oo. A decrease in photosynthesis was recorded at salinities of 15 o/oo.

Figure 11. Respiration of Polysiphonia lanosa and P. elongata at various temperatures.

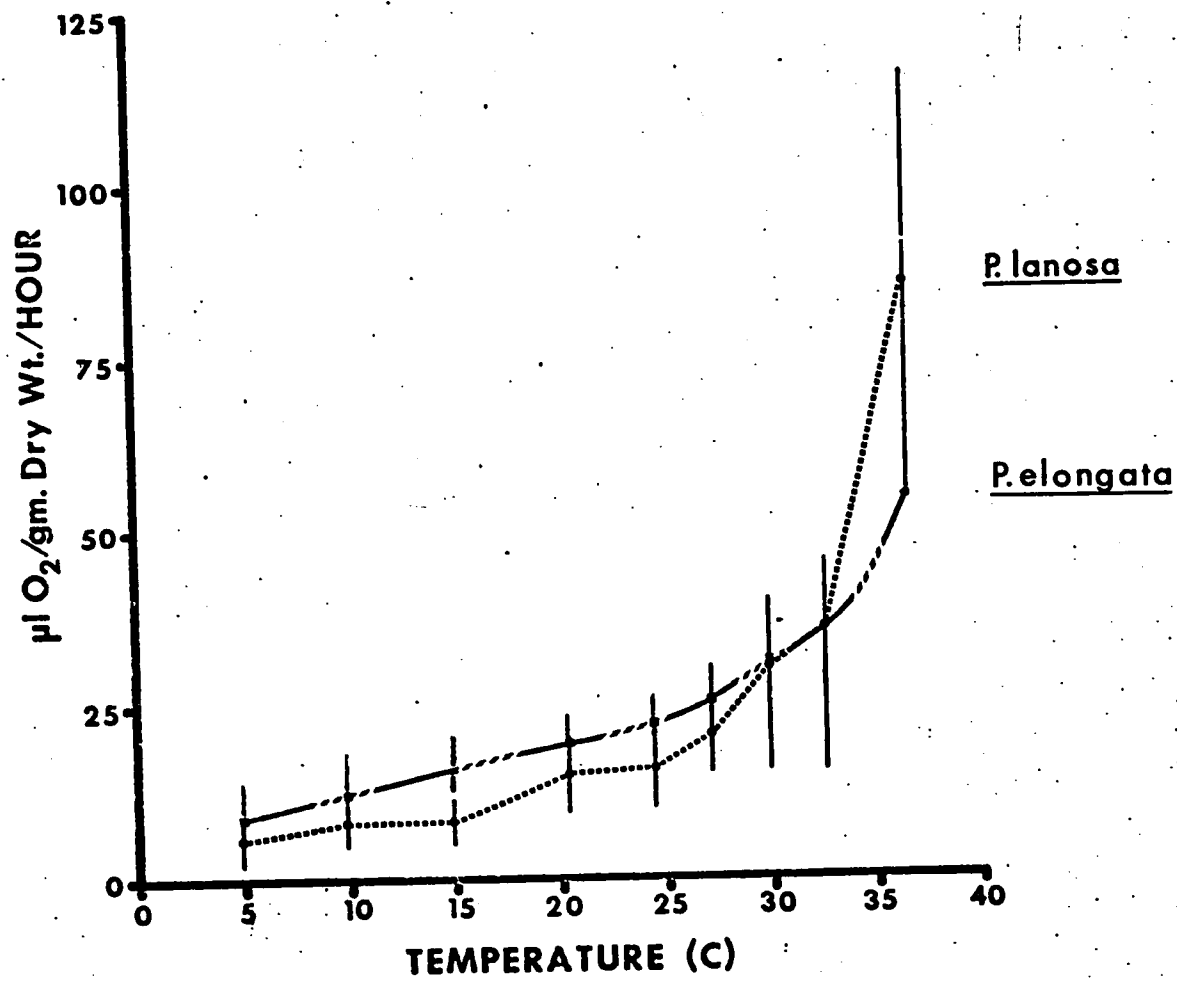


Figure 12. Respiration of Polysiphonia nigrescens and P. subtilissima at various temperatures.

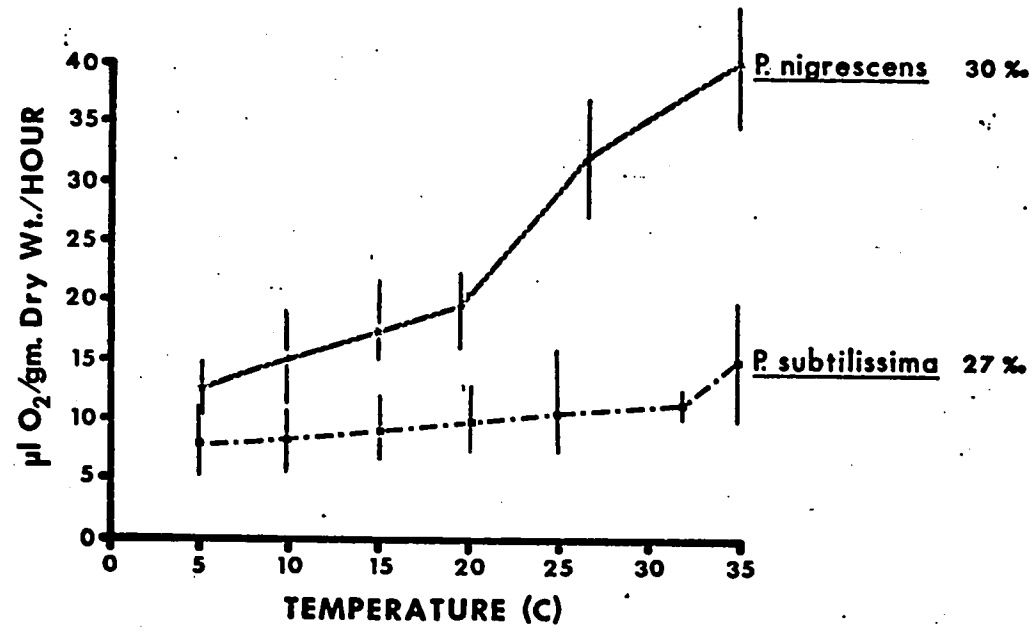
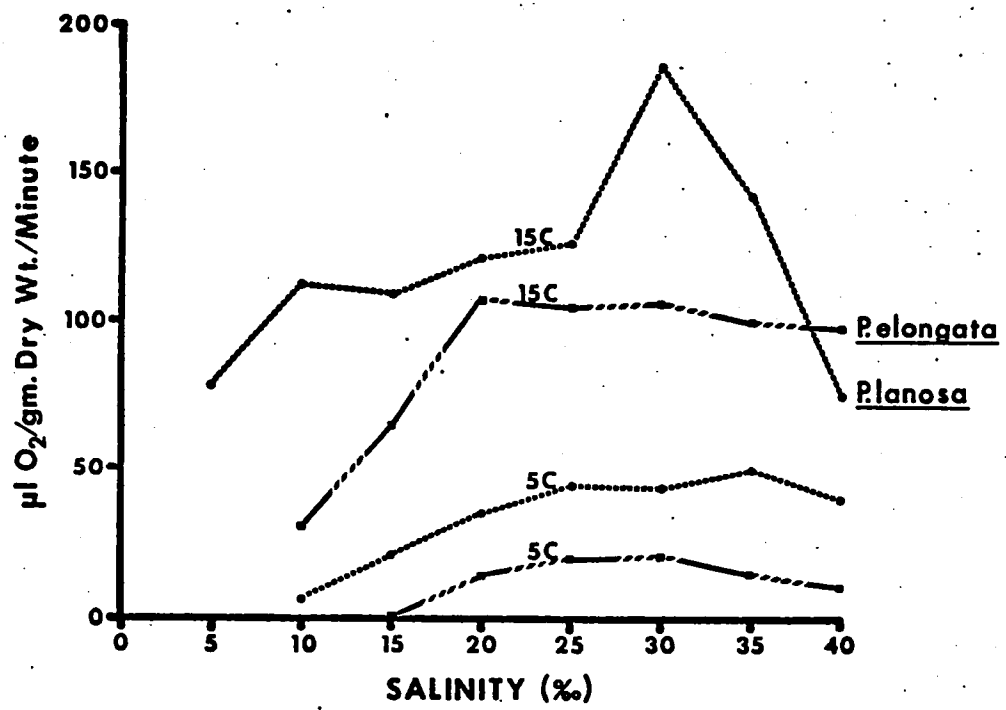


Figure 13. Apparent photosynthesis of Polysiphonia lanosa and P. elongata at different salinities, 1000 foot-candles, and 5 and 15°C.



Comparable experiments were conducted with Polysiphonia subtilissima at various salinities, 1000 foot-candles and 15 and 25°C. The higher temperature was used to conform with the more optimal temperature range of P. subtilissima (Fig. 14). At 15 and 25°C the photosynthesis of P. subtilissima was fairly uniform throughout a salinity range of 10 to 40 o/oo. No photosynthesis was recorded after 4 days immersion in salinities of less than 10 o/oo. A general decrease in photosynthesis was indicated at 25°C and at salinities greater than 30 o/oo, but it was not apparent at 15°C and similar salinities.

Salinity experiments were performed on Polysiphonia nigrescens at 5 and 15°C and 1000 foot-candles. The maximum rate of apparent photosynthesis was evident between 20 to 35 o/oo at 15.0°C. Little or no photosynthesis was recorded at 5°C, and no photosynthesis was measured at either temperature at salinities of 0 o/oo.

Figure 15 shows the respiration rates of Polysiphonia lanosa and P. elongata at various salinities and 5 and 15°C. At 5°C P. lanosa exhibited a low respiration rate at salinities of 15 to 40 o/oo. In contrast, at 15°C P. lanosa showed a high respiration rate at 25 to 40 o/oo. At 5°C the respiration rate of P. elongata was relatively low at salinities of 5 to 35 o/oo. In contrast, at 15°C high respiration rates were evident at 5-15 o/oo.

Figure 14. Apparent photosynthesis of Polysiphonia nigrescens and P. subtilissima at different temperatures, salinities and 1000 foot-candles.

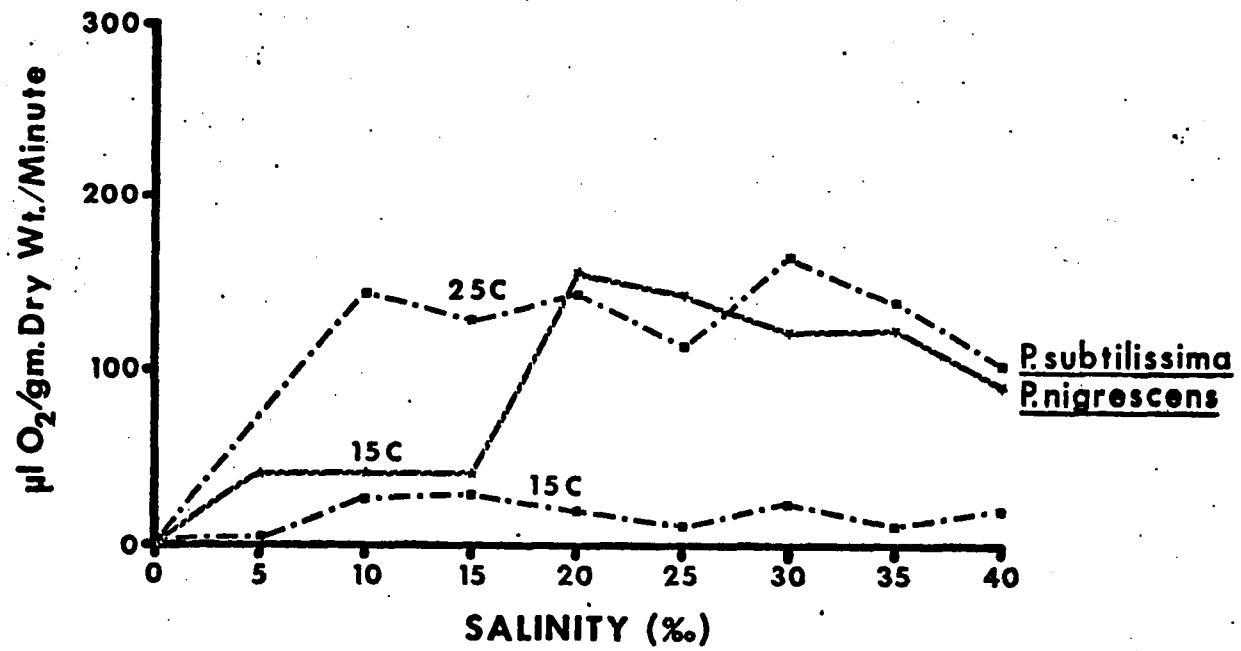
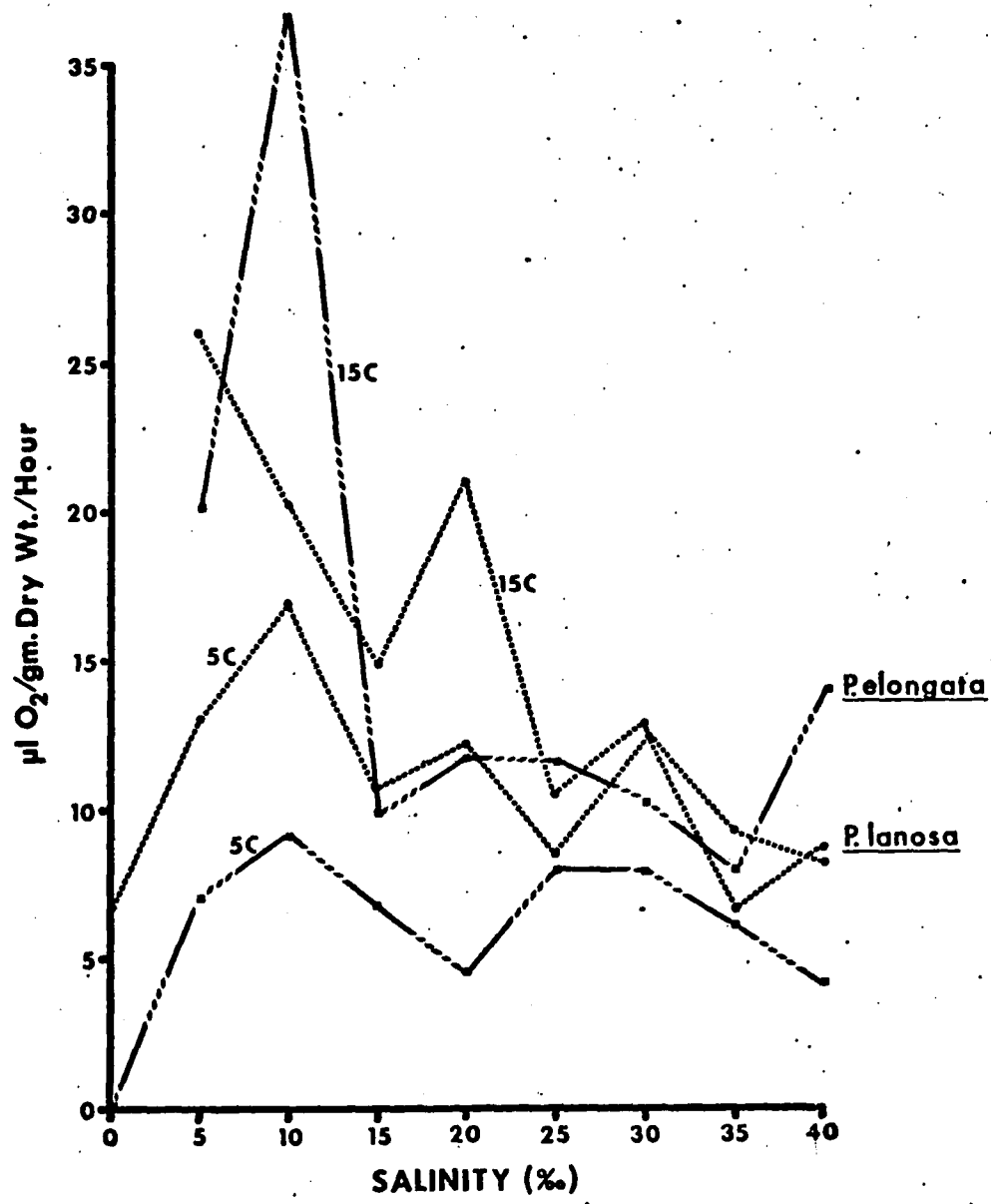


Figure 15. Respiration of Polysiphonia lanosa and P. elongata at 5° + 15° C temperatures and salinities.



DISCUSSION

The present investigation has evaluated the effect of different light intensities, temperatures and salinities on the apparent photosynthesis of four species of Polysiphonia. The physiological differences among the species were correlated with their natural distributional patterns and the environmental conditions within the Great Bay Estuary system.

Polysiphonia elongata has the lowest light requirement of the four Polysiphonia species, since it is saturated at 185 to 250 foot-candles. The intertidal occurrence of P. elongata in the Estuary (station 4) is probably related to the shading effect of the General Sullivan bridge, for this is the only site where it is known to grow intertidally. Polysiphonia lanosa is primarily restricted to the intertidal zone, and its relatively high light requirement (850 foot-candles) may be a competitive advantage. Polysiphonia subtilissima is found in the upper subtidal zone, while P. nigrescens may extend much deeper into the subtidal zone. Both species show similar light optima (i.e. 1000 foot-candles). The light optima for the four Polysiphonia species (in respect to their habitats) are comparable to other intertidal and subtidal red algae (Mathieson and Burns 1971, and Stocker and Holdeheide 1938).

The four Polysiphonia species can be placed into two separate categories according to their temperature optima and tolerances: (1) cold water plants (P. lanosa and P. elongata) with peak photosynthesis at 21 to 24°C, and active photosynthesis at temperatures as low as 5°C. (2) plants with warm water affinities (P. nigrescens and P. subtilissima) having photosynthetic optima at 27 to 30°C, and exhibiting little or no

photosynthesis below 10⁰C. Temperatures in excess of the optima cause thermal injury in both groups.

The salinity regimes at stations 1 to 6 would not preclude the presence of Polysiphonia lanosa. Thus, its coastal distribution may be primarily due to temperature, since temperatures greater than 22⁰C inhibited photosynthesis and increased respiration. The zonation of P. lanosa may also be primarily governed by temperature. As suggested previously, the vertical distribution of Ascophyllum nodosum is much greater than P. lanosa; in addition, A. nodosum has a much wider estuarine distribution (stations 1 to 6) than P. lanosa (stations 1 to 3). Differential temperature tolerances between the host and P. lanosa may be operational in determining their contrasting horizontal and vertical distributions, since A. nodosum is known to have a higher temperature optimum (Kanwisher, 1966) than P. lanosa. Biebl (1970) indicates that high intertidal algae often have a wider temperature tolerance than low intertidal and subtidal forms. These results confirm Biebl's findings.

If the vertical distribution of Polysiphonia lanosa is governed primarily by temperature, then one would expect to find an expansion of its zone where optimal temperature conditions prevail, such as at station 1. In contrast, at station 2, where P. lanosa is very uncommon, its zonation is very compressed. A comparison between the zonation of P. lanosa and A. nodosum at Nobska Point, Woods Hole, Massachusetts, which is a warm water site, also shows a major compression of the zonation for both species.

Ganning (1971) indicates that some open coastal, intertidal algal species may insulate other species from desiccation and freezing.

Ascophyllum nodosum may insulate P. lanosa against summer heat injury as well as from desiccation and winter freezing. Thus, insulation may enhance the vertical distribution of P. lanosa.

The more restricted estuarine distribution of Polysiphonia elongata, as compared to P. lanosa, is probably governed by its higher temperature optima (22 to 24°C) and broader salinity tolerances (20 to 40 o/oo). A similar interpretation can be given for the estuarine distribution of P. subtilissima, for its temperature optima is 27°C and it has an even broader salinity tolerance than P. lanosa and P. elongata (10 to 40 o/oo). Polysiphonia nigrescens has approximately the same temperature optima as P. subtilissima, but it has a more restricted salinity tolerance (20 to 40 o/oo). Thus, it does not extend into the Estuary as far as P. subtilissima, but it has an estuarine distribution similar to P. elongata.

Warm water plants having a high photosynthetic optima must be able to withstand the low winter temperatures of their habitats. Among others, Kanwisher (1966) and Biebl (1970) discuss "cold hardiness"; they note a winter acclimatization that functionally reduced metabolic rates in winter as compared to summer. Fralick and Mathieson (1972 & 1973) have shown that although winter fragmentation occurred in Codium fragile, which is a warm temperate plant at its northern distributional limits, the plant was able to withstand low winter temperatures and regenerate intact fronds in the spring and summer. Polysiphonia nigrescens and P. subtilissima are cosmopolitan plants, and they are recorded from the Canadian Maritimes to Florida (Croley and Dawes, 1970). The persistence of "southerly plants" at their northern distributional limits must, in part, be related to their ability to tolerate

and/or acclimatize to winter temperatures.

Several workers (Druehl 1967, Kjeldsen and Phinney 1972, and Mathieson and Dawes 1973) have shown an interrelationship between salinity optima and temperature. For example, Mathieson and Dawes (1973) working with photosynthesis and respiration of Eucheuma species showed that salinity optima were temperature dependent. The same workers also showed that the salinity tolerances of Eucheuma species were greater at low than at high temperatures. Each of the four Eucheuma species studied showed thermal injury at 30 C. Kjeldsen and Phinney (1972) and Druehl (1967) have shown that high temperatures and low salinities are major factors restricting the distribution of seaweeds. The estuarine distribution of the four Polysiphonia species is probably governed by their inability to tolerate both high temperatures, and low salinities. The high temperature optimum for each of the species is positively correlated with its local estuarine distribution. Thus, Polysiphonia subtilissima, having the highest temperature optimum, exhibited the greatest penetration into the Estuary, while P. lanosa having the lowest temperature optimum was primarily restricted to the more coastal stations.

Polysiphonia subtilissima which is found only at station 7 appeared to be able to tolerate a wide range of salinities. However, low salinities at this station occurred at a period when temperatures were consistently low (5 to 10⁰C) and the metabolic activities of the plant were suppressed due to temperature. Conversely, P. lanosa is similarly restricted to coastal stations due to adaptation to even lower temperatures than P. subtilissima.

The results of this study may have, in addition to academic interest, some practical application in evaluating the effects of heated thermal effluents on various marine floras. It is apparent, that temperature is a major consideration for the distribution of Polysiphonia and other marine algae. Additional studies should be conducted to extend the principles defined in this study to larger portions of marine and estuarine algae communities. Further studies should also be conducted to evaluate the effects of temperature on seasonal and diurnal photosynthetic rhythms.

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Table I. Surface Water Temperatures (°C) at Eight Stations
Between June 1971 and December 1972

Date	STATIONS							
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
6/23/71	10.0	14.0	14.0	16.5	20.0	21.0	24.5	-
7/ 7/71	14.0	13.0	17.0	21.0	22.5	22.5	26.0	-
7/29/71	16.0	17.0	20.0	22.0	27.0	24.0	26.5	28.1
8/17/71	23.0	18.0	20.0	21.0	25.0	23.0	25.0	27.0
9/23/71	17.0	18.5	19.0	20.0	22.0	20.0	20.0	19.0
10/ 7/71	11.0	13.5	13.5	14.5	14.0	16.5	16.0	18.5
10/21/71	10.7	11.0	11.0	12.0	12.0	16.0	13.0	12.0
10/ 4/71	11.0	12.0	12.0	12.0	12.0	14.0	14.0	11.0
12/17/71	7.0	6.2	5.5	4.5	4.5	4.0	4.0	0.0
2/25/72	1.0	0.0	-0.5	-0.4	ice	-1.0	-0.5	ice
3/ 4/72	1.0	-0.5	1.0	2.5	2.0	2.0	1.0	ice
3/10/72	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	ice
3/17/72	3.0	2.0	1.5	3.0	2.0	2.0	2.0	ice
3/24/72	1.5	3.5	4.0	3.8	3.8	3.5	1.5	ice
4/ 1/72	1.0	2.0	2.0	4.0	4.0	4.0	4.0	3.0
4/ 8/72	4.0	4.0	5.0	6.0	4.5	6.0	7.0	6.0
4/14/72	3.0	3.0	4.0	4.0	4.0	4.5	4.0	4.0
4/21/72	10.5	7.5	9.5	9.0	9.8	9.0	9.0	9.0
4/28/72	3.0	1.5	3.0	2.0	7.0	8.0	10.0	10.0
5/ 6/72	12.0	11.0	10.5	12.0	14.1	10.4	12.5	13.0
5/12/72	5.0	8.5	9.0	8.0	8.0	9.0	10.0	9.0
5/20/72	11.0	11.0	12.5	13.0	13.5	14.0	15.0	15.0
5/28/72	14.0	13.5	18.0	19.0	21.0	17.5	20.0	21.5
6/ 3/72	12.0	18.5	21.5	23.0	24.0	20.0	21.2	21.5
6/10/72	15.0	13.0	14.0	14.5	16.5	16.5	18.0	17.5
6/16/72	15.5	16.5	18.0	18.0	20.0	19.5	22.0	22.0
6/29/72	10.0	16.5	17.5	19.0	20.0	21.5	23.0	26.5
7/ 8/72	19.0	17.0	18.0	18.0	19.0	21.0	21.0	22.5
7/12/72	12.0	12.0	16.0	17.5	18.5	28.0	25.0	23.5
7/19/72	19.0	17.5	20.5	22.0	23.5	25.0	22.0	27.0
7/30/72	22.0	21.5	24.0	25.5	27.0	23.5	24.0	27.0
8/ 5/72	20.0	19.0	22.0	24.0	24.5	24.0	24.0	-
8/19/72	17.5	16.5	18.5	20.0	22.0	21.0	23.0	26.5
8/29/72	21.0	23.0	20.0	24.0	25.0	26.0	22.0	22.0
9/ 8/72	15.0	16.0	17.0	17.0	16.0	20.0	21.0	22.0
9/24/72	13.0	13.0	13.0	13.0	13.0	16.0	16.0	16.0
10/ 6/72	12.0	12.0	12.0	12.0	12.0	14.0	11.0	9.0
10/14/72	12.0	12.0	12.0	12.0	12.0	14.0	11.0	9.0
11/10/72	10.0	8.0	7.0	7.0	7.5	7.0	7.0	6.0
11/17/72	9.0	7.0	6.0	6.0	5.0	3.0	2.0	1.0
12/11/72	3.5	3.0	3.0	2.0	2.0	2.0	1.0	ice
12/27/72	4.0	3.0	2.0	3.0	2.0	2.0	1.0	ice

Table II. Surface Water Salinities (‰) at Eight Stations Between June 1971 and December 1972

Date	STATIONS							
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
6/23/71	31.0	32.0	30.0	32.0	27.0	27.0	9.0	-
7/ 7/71	31.0	30.0	31.0	32.0	30.0	29.0	16.0	-
7/29/71	32.0	31.0	31.0	30.5	32.0	31.5	21.0	14.0
8/17/71	32.0	31.0	30.0	31.0	32.0	31.0	21.0	6.0
9/23/71	31.0	30.0	30.0	30.0	31.0	30.0	18.0	1.0
10/ 7/71	32.0	32.0	31.0	29.0	31.0	31.0	22.0	20.0
10/21/71	33.5	33.5	31.5	28.0	31.0	30.0	16.0	2.0
11/ 4/71	32.5	31.0	31.0	30.0	30.0	29.0	16.0	2.0
12/17/71	33.5	33.5	30.5	29.0	29.0	28.0	13.5	0.0
2/25/72	32.0	30.0	26.0	26.5	ice	19.0	1.0	ice
3/ 4/72	31.0	26.0	23.0	22.5	22.0	19.8	1.8	ice
3/10/72	31.0	30.0	27.0	20.0	22.0	18.0	7.0	ice
3/17/72	29.0	25.2	23.8	23.0	18.0	19.0	1.0	ice
3/24/72	28.0	19.0	16.0	15.0	8.0	9.0	1.0	ice
4/ 1/72	30.0	27.0	18.2	16.0	13.0	8.0	1.0	1.0
4/ 8/72	30.0	22.5	17.0	15.5	11.0	8.8	1.0	1.0
4/14/72	28.8	22.0	18.3	18.1	14.0	13.2	4.8	1.0
4/21/72	30.0	20.0	18.0	17.0	6.0	11.5	1.0	1.0
4/28/72	28.5	19.5	16.2	15.2	14.1	12.0	1.0	1.0
5/ 6/72	29.2	21.0	18.0	17.8	15.8	12.0	0.0	0.5
5/12/72	29.0	21.5	19.3	19.9	19.9	13.9	1.0	1.0
5/20/72	26.0	26.0	19.0	19.0	18.0	11.0	0.0	0.0
5/28/72	27.8	25.8	19.8	19.5	18.0	18.5	0.0	0.0
6/ 3/72	30.0	22.9	20.2	19.0	17.9	18.4	0.0	0.0
6/10/72	30.5	29.8	25.8	26.0	22.8	20.5	0.0	0.0
6/16/72	31.5	26.3	24.4	24.1	23.5	21.6	0.0	0.0
6/29/72	28.0	27.2	23.6	22.1	20.7	19.4	0.0	0.0
7/ 8/72	30.1	27.7	26.4	25.4	24.9	22.5	2.1	0.0
7/12/72	30.4	30.3	28.1	28.2	26.0	24.4	21.0	0.0
7/19/72	31.0	30.0	28.5	28.2	28.0	26.6	7.9	0.0
7/30/72	30.2	27.7	25.9	26.6	25.9	23.4	0.0	0.0
8/ 5/72	29.6	30.0	26.9	24.5	23.9	27.0	1.4	0.0
8/19/72	31.0	30.0	27.0	27.0	26.0	24.0	7.0	0.0
8/29/72	29.8	28.9	28.8	27.2	27.2	26.0	10.1	0.0
9/ 8/72	31.0	31.0	29.0	29.0	28.0	27.0	6.0	4.0
9/24/72	31.0	30.0	30.0	30.0	29.0	27.0	4.8	0.0
10/10/72	32.5	29.4	27.8	27.2	27.2	26.8	4.8	0.9
11/10/72	26.8	26.5	23.5	19.6	18.6	18.1	1.0	1.0
11/17/72	29.9	26.5	22.5	23.7	20.0	18.0	1.0	1.0
12/11/72	28.1	19.9	16.3	15.3	15.1	10.0	0.9	ice
12/27/72	30.7	29.2	23.8	27.0	25.0	25.0	2.0	ice

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UNIVERSITY MICROFILMS.

APPENDIX I

Description of stations:

Station 1, Jaffrey Point, at Newcastle, N.H. is designated as a semi-exposed open coastal site (Mathieson, Hehre and Reynolds, in press). The substrate is primarily composed of massive rock outcrops.

Station 2, Pierce Island, is located approximately 2 nautical miles from station 1, and opposite the Portsmouth Naval Shipyard. The substrate is composed of a large rock outcropping, layers of broken sidewalk bricks and a muddy substrate.

Station 3, Newington Town Landing, is located approximately 5.5 nautical miles from station 1. The substrate has some rock associated with a boat launching ramp; otherwise it is entirely muddy.

Station 4, Dover Point, is located approximately 7 nautical miles from station 1. Large rock outcroppings are interspersed with mud and silt. The area is a tidal rapid site (Reynolds, 1971).

Station 5, Cedar Point, is located in Little Bay, approximately 8.3 nautical miles from the open coast. The substrate is exclusively composed of mud and silt.

Station 6, Adams Point, is located in Furber Strait at the junction of Great and Little Bays. It is approximately 10.7 nautical miles from the open coast. The substrate is primarily composed of mud and silt with scattered rock outcroppings, as well as shale and cobble.

Station 7, Chapmans Landing, is located on the Squamscott River approximately 15.2 nautical miles from the open coast. The substrate is primarily composed of mud; some rocks and boulders are also present at a nearby bridge.

Station 8, Exeter, is located on the Squamscott River, 19.05 nautical miles from the open coast and adjacent to Sears, Inc. The substrate is composed of mud and silt.