Bulletin 79

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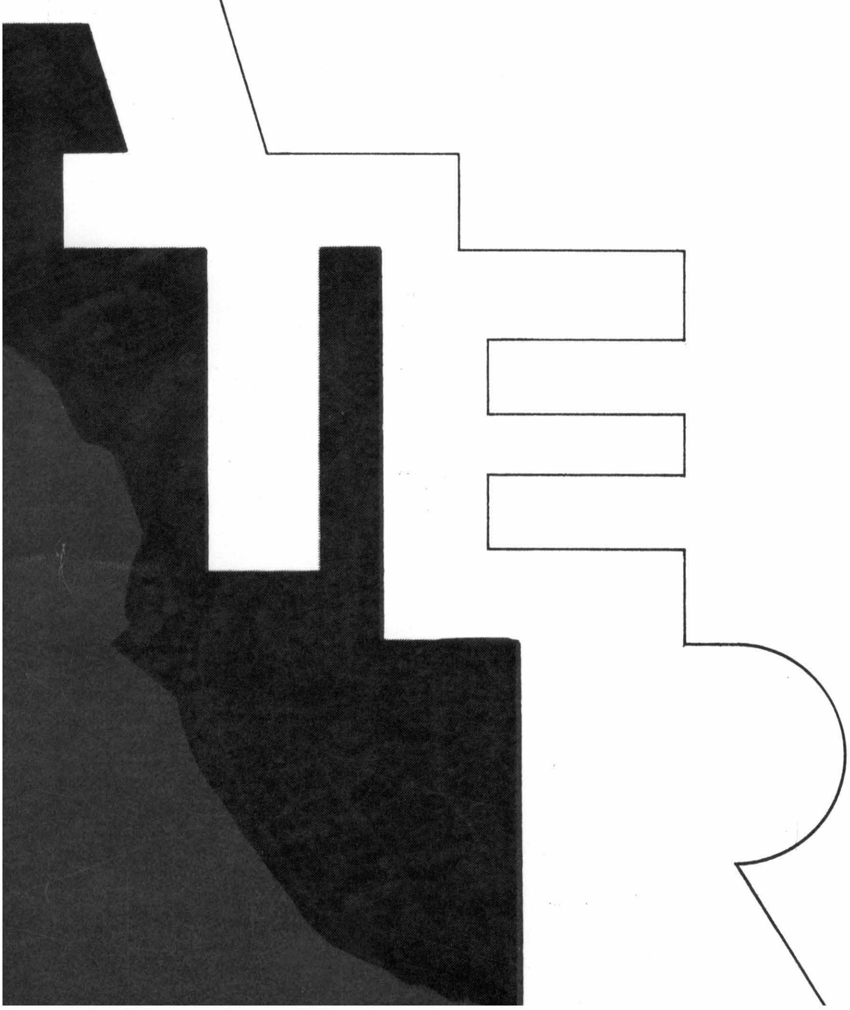

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January 1976

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The work upon which this report is based was supported by funds provided by the United States Department of the Interior, Office of Water Research and Technology, as authorized by the Water Resources Act of 1964

OWRT Project B-027-VA
VPI-VWRRC-BULL 79

A publication of
Virginia Water Resources Research Center
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

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ABSTRACT

Annual nitrogen, phosphorus and carbon budgets for two Virginia salt marshes were determined by monthly measurements of water discharge and constituent concentrations over tidal cycles.

Considering all three forms of phosphorus measured (total, dissolved organic and orthophosphate) there was a net loss from the estuary to the marches. The data reveal a loss of particulate phosphorus of estuarine origin to marsh sediments and mineralization of this phosphorus in the marshes with subsequent export of dissolved inorganic and organic phosphorus back to the estuary.

Nitrogen flux data show a loss of nitrate and nitrite to the marshes. Particulate nitrogen is imported to the marshes where it is mineralized and returned to the estuary as ammonia and dissolved organic nitrogen. The magnitude of nitrogen export suggests significant fixation of atmospheric nitrogen by marsh flora with subsequent export as dissolved species.

Carbon flux data show significant contributions of both particulate and dissolved organic carbon to the estuary from the marshes. Estimates of export, based on marsh grass productivity, suggest a loss of 36 and 49 percent of a year's primary production on the marshes as detritus for Ware and Carter Creeks respectively.

INTRODUCTION

Many roles have been attributed to marshes in estuarine systems. They serve in many instances as buffers to erosional processes and thereby protect fastland areas. They provide valuable habitat for many species of wildlife which feed, nest and reside in them. Their greatest importance to the estuary, however, lies in their potential to provide organic matter in the form of detritus and their effect upon nutrient budgets. The influence of marshes on estuarine productivity has been largely ascribed to the high primary productivity of marsh plants, much of which is exported to the estuaries where it is the basis for the detritus food chain. However, as mentioned above, another means by which the marsh ecosystem can affect estuarine productivity and water quality is by its interaction with the plant nutrients, phosphorus and nitrogen, contained in the estuarine waters which flush through the marshes. Phosphorus and nitrogen are the nutrients most often restricting autotrophic productivity in aquatic systems and both have been demonstrated to be capable of limiting primary productivity in estuaries. Therefore qualitative and quantitative changes in the forms and levels of these nutrients in estuarine waters brought about by processes in the marshes can have a far reaching influence on estuarine productivity.

Although the general processes involved in nutrient transformations within marshes are known, the result of the interacting processes remains to be elucidated.

The processes of greatest importance in cycling of nitrogen are: nitrogen assimilation by bacteria, benthic algae, phytoplankton, and *Spartina*, as well as bacterial nitrification, denitrification and detrital degradation.

Processes having the greatest influence on phosphorus cycling in salt marshes are: assimilation of phosphorus by bacteria, benthic algae, phytoplankton, and *Spartina*; degradation of detritus by bacteria and fungi; *Spartina* "pumping" of subsurface phosphorus into the water; and physical phosphate-sediment interactions.

The objectives of our investigation were to determine the flux of nitrogen, phosphorus and carbon in Virginia marshes, and to assess the results obtained in light of estuarine water quality. In support of these flux studies, a determination of the primary production in the Ware and Carter creek marshes was made under a joint program sponsored by VIMS and NSF.

LITERATURE REVIEW

Nitrogen Cycling in Salt Marshes

Nitrogen Cycles

In a North Carolina *Juncus roemerianus* dominated salt marsh, Byron (1968) found that forty-one percent of the nitrogen entering the system over several fall tidal cycles was not returned to the estuary. Flux calculations utilizing water discharge and nitrogen concentration data indicated that particulate nitrogen of estuarine origin was lost to the marsh. Low levels of nitrite and nitrate in marsh creek ebb tide waters suggested that this organic nitrogen was not mineralized in the marsh and subsequently returned to the estuary.

Nitrate concentrations of waters overlying two Delaware *Spartina alterniflora* dominated salt marshes were generally lower than concentrations within marsh creeks (Daiber, Gallagher and Sullivan, 1970). Measurements in creeks draining these marshes revealed the presence of maximal nitrate levels in winter and minimal nitrate levels in summer (Daiber, Aurand, and Shlopak, 1969; Aurand and Daiber, 1973).

The occurrence of winter nitrate concentration peaks at high slack water and summer nitrate concentration peaks at low slack water led Aurand (1968) to speculate that the Delaware marsh systems imported nitrate in winter but exported small amounts of nitrate in summer.

Salt Marsh Sediment-Nitrogen Interactions

Sampling over a year in two Louisiana *Spartina* marshes indicated that sediment interstitial water ammonia concentrations were many times greater than levels in the corresponding water columns. Highest interstitial water ammonia concentrations were found August through November and were attributed to increased detrital decomposition rates. Parallel concentration trends in the water column suggested diffusion of ammonia from sediments to water (Ho and Lane, 1973).

Maye (1972) found the highest interstitial water ammonia concentrations in sediments beneath the thickest *Spartina* growth and also proposed mineralization of *Spartina* detritus as the mechanism supplying ammonia to marsh sediments. Sediment cores taken in a Georgia marsh also revealed increased ammonia concentration with depth.

Nitrogen Cycling by Salt Marsh Biota

Evidence of algal nitrogen fixation was found in two Florida salt marshes. Epiphytic blue-green algae on dead *Spartina* and *Juncus* stems exhibited greater nitrogen fixation rates than did algae of surface sediments; the water column seldom displayed any activity (Green and Edmisten, 1972). More than sixty percent of the bacteria in Delaware salt marsh sediments were able to utilize molecular nitrogen as their sole nitrogen source. Large numbers of ammonifying, nitrifying and denitrifying bacteria were also isolated from these marsh sediments (Daiber and Gooch, 1968).

It was theorized that bacteria using characteristically nitrogen poor *Spartina* detritus as an energy source must assimilate their nitrogen requirements from marsh waters (Thayer, 1969). Ustach (1969) supported this theory by demonstrating increased heterotrophic utilization of *Spartina* detritus upon addition of nitrate to a detritus estuarine water system.

These nitrogen-marsh interactions described above are shown diagramatically in Figure 1.

Phosphorus Cycling in Salt Marshes

Phosphorus Cycles

The seasonal phosphorus cycle of several Delaware *Spartina* marsh creeks were characterized by elevated summer dissolved inorganic and organic phosphorus levels. Monthly measurements made over a year revealed higher dissolved phosphorus concentrations in marsh creeks at low slack than at high slack water, suggesting export of dissolved phosphorus from the marshes to the estuary (Reimold, 1969; Reimold and Daiber, 1970). Particulate phosphorus was the predominant phosphorus species of the Delaware marsh creeks and peak levels of this phosphorus form were also attained in summer and at low slack water (Daiber, *et al.* 1969; Daiber, *et al.* 1970). Waters overlying the marshes in areas of tall *Spartina* growth had higher dissolved inorganic phosphorus concentrations than did creek waters, but displayed seasonal concentration fluctuations similar to those of the marsh creeks (Reimold, 1969; Daiber, *et al.* 1971).

Blum (1969) theorized that high marsh *Spartina patens* was adapted to rapid absorption of nutrients when flooded by spring high tides. It was further suggested that the mesh of dead leaves and stalks beneath live growth could act as a filter system and remove particulate nutrients brought to the high marsh by these tides. Measurements over a June tidal cycle revealed that the waters overlying the marsh during flood tide had significantly lower dissolved inorganic phosphorus concentrations and significantly higher phosphorus concentrations compared to ebb tide.

Flux measurement over several fall tidal cycles utilizing phosphorus concentration, and water discharge data, indicated that two North Carolina *Juncus* dominated marshes exerted little effect on the estuary with respect to particulate and dissolved inorganic phosphorus. Dissolved organic phosphorus was the predominant phosphorus species of these marshes and calculations showed a small net export of this nutrient to the estuary (Byron, 1968).

Salt Marsh Sediment-Phosphorus Interactions

In two Louisiana *Spartina* marshes, yearly averages of sediment interstitial water dissolved inorganic phosphorus concentrations were many times greater than concentrations in corresponding water columns. Higher interstitial water phosphorus concentrations August through November were attributed to increased detrital decomposition rate. Parallel seasonal concentration trends in the water column suggested diffusion of phosphorus from sediments to water (Ho and Lane, 1973). Highest dissolved inorganic phosphorus concentrations in Georgia marsh sediment interstitial waters were found under thicker *Spartina* growth, again indicating detrital mineralization as the source of phosphorus to marsh sediments. Sediment cores taken in this marsh also revealed increased interstitial water phosphorus concentrations with increasing depth (Maye, 1972).

Gooch (1968) postulated a seasonal cycle of precipitation and solubilization of inorganic phosphorus from salt marsh sediments. In this cycle bacteria hydrogen sulfide production initiated inorganic phosphorus release from sediments. Thus it was believed that minimal hydrogen sulfide production in winter and maximal production in late spring caused dissolved inorganic phosphorus uptake in winter and release in spring.

Pomeroy, Smith, and Grant (1965) suggested that movement of dissolved inorganic phosphorus between undisturbed salt marsh – estuarine sediments and overlying water involved a two step ion exchange between clay and water, plus an exchange between interstitial microorganisms and water. In undisturbed sediments, abiotic exchange predominated, but in resuspended sediments biologically mediated exchange was of the same magnitude as physical exchange. Sediment – water exchange processes buffered estuarine water to a dissolved inorganic phosphorus level of about one microgram atom per liter.

Phosphorus Cycling by Salt Marsh Biota

Turnover rate of dissolved inorganic phosphorus was found to be significantly greater in salt marsh waters than in other aquatic environments (Pomeroy, 1960). High dissolved inorganic phosphorus levels in Georgia salt marsh waters were attributed to this rapid turnover rate. A cycle of uptake of sedimentary phosphorus by *Spartina*, with subsequent bacterial utilization of *Spartina* detritus, followed by assimilation of detritus and associated bacteria by detritivores and excretion by detritivores, introduces dissolved phosphorus to marsh waters (Pomeroy, Johannes, Odum, and Roffman, 1969). Another explanation for the high concentrations of dissolved inorganic phosphorus in marsh waters has been suggested by Reimold (1972) who indicated that *Spartina alterniflora* pumps sedimentary phosphorus from rhizomes to leaves, where phosphorus is released to marsh waters upon *Spartina* inundation by high tides. Seasonal variation in dissolved inorganic phosphorus concentration of marsh waters was ascribed to changes in rate of uptake and release of phosphorus from *Spartina*, as a consequence of seasonal changes in rate of *Spartina* productivity.

In a *Typha* dominated tidal marsh, periphyton communities were primarily responsible for removal of phosphorus from marsh waters. *Typha* competed with periphyton for the phosphorus of shallow marsh sediments but the importance of the angiosperm in phosphorus cycling was mainly that it provided increased surface area for periphyton growth (Correll, in press).

A phosphorus budget of a salt marsh mussel population indicated that the population removed particulate phosphorus from marsh waters with a turnover time of 2.6 days (Kuenzler, 1961). Investigation of phosphorus cycling by marsh arthropod communities revealed that the communities mineralized large amounts of organic phosphorus through their detrital and periphyton grazing activities (Marples, 1966; Pomeroy *et al.,* 1969).

The high carbon to phosphorus ratio of *Spartina alterniflora* detritus led Thayer (1969) to speculate that bacteria must assimilate phosphorus from marsh waters to completely utilize detrital carbon. Addition of dissolved inorganic phosphorus to estuarine water containing *Spartina* detritus increased detrital decomposition rate and thus supported this contention (Ustach, 1969).

The phosphorus marsh interactions described above are shown diagrammatically in Figure 2.

Detritus: Composition, Formation and Flux

Decomposition of Marsh Grasses

The decomposition of marsh flora has been documented by numerous authors (Burkholder and Bornside, 1957; De la Cruz 1965; Waits, 1967; Heald, 1969; Ustach, 1969; Kirby, 1971). Most of these studies have utilized some variation of a litterbag method, in which known amounts of marsh grass are placed in nylon mesh bags at various locations in a marsh. Decomposition is measured as the rate of loss from the bags. Kirby indicates that the loss of material from the litterbags is a function of several factors: (1) the size of the litterbag mesh (2) the area in which the bags are placed (3) the amount of flushing received (4) the temperature. The last three of these factors along with two others, the species of plant decomposing and the salinity, appear important in controlling decomposition rates in tidal marsh areas.

De la Cruz found the most rapid decomposition of *Spartina* occurred in bags that were continuously submerged in a creek. While there was a fifty percent loss of material from these bags in three months, those placed in the high marsh during the same spring period required seven months to reach fifty percent decomposition. Kirby found more rapid initial decomposition in material placed out in the marsh in June than in January. He also found considerably more rapid loss of material from bags placed in a tidal channel as compared to material placed in a high marsh area. Utach noted a relatively constant loss of one percent per day in his study area.

Kirby hypothesizes that grazing by amphipods and other invertebrates is initially responsible for reduction of the grasses to small particles. He cites as evidence, however, simply the abundance of amphipods in and around the bags. There is little documented evidence for mechanisms of biological degradation of marsh grasses. Heald (1969) and De la Cruz (1965) indicate as being important: simple fragmentation by tidal action with subsequent hydrolysis and oxidation of the particles, and microbial and fungal colonization. Burkholder and Bornside (1957) found aerobic, heterotrophic marine bacteria, analogous to those of freshwater lakes (Rodina, 1963; Pearl, 1973) to participate in the decomposition of *Spartina* with much of the loss in dry weight of the plant tissue taking place through diffusion of the metabolic products of the microorganisms.

In freshwater streams where a situation somewhat similar exists, that being the input of large amounts of allochthonous leaf-born organic material, there has been more extensive investigation of the degradation process (Nelson and

Scott, 1962; Egglishaw, 1964; Minshall, 1967; Kaushik and Hynes, 1971; Cummins, *et. al.,* 1973). Cummins, *et. al.*, in studying the microbial, animal successional pattern of various leaf species recognize the importance of large particle detritivore "shredders". However, they indicate that the shredders, through mechanical and/or chemical stimuli, select leaves that are maximally colonized by fungi and bacteria. Kaushik and Hynes (1971) also evidenced differential decomposition rates for fallen leaves of different species of trees and noted that fungi appeared to be more effective than bacteria in the breakdown of the leaves.

The Importance of Detritus as a Food Source

The fragmented, semi-decomposed material found in such abundance in the waters of marshes and estuaries includes besides material from marsh grasses, invertebrates, algae, plankton and allochthonous estuarine and wind blown materials (Teal, 1962), and is termed "organic detritus". It has been defined by Darnell as: ". . . all types of biogenic material in various stages of microbial decomposition which represent potential energy sources for consumer species."

De la Cruz (1965) suggested detritus particles to be highly active spheres of microbial organisms and that the adsorption of nutrients onto the particles may increase their food value. His studies showed increased protein content in successive stages of decomposition from *Spartina* marsh grass to detritus. This was possibly due to bacterial growth; however, the suggestion is still speculative. Hall, *et al.*, in a later work (1970) indicates a tenfold decrease in percent protein with *Spartina* in ebbing tides from that found in the living plant leaves. Burkholder and Bornside (1957) suggested microbial degradation would result in a more favorable essential amino acid distribution. However, this was not confirmed by Hall, who indicated that suspended solids contain smaller percentages of essential amino acids, and fewer of them than living marsh grasses.

Whatever the nutritional value of estuarine detritus, numerous authors have cited its utilization by organisms. Darnell (1958, 1961, 1967) has evidenced consumption in a Louisiana estuary; W. Odum (1970) in a mangrove-dominated estuary; E. P. Odum and Smalley (1959), Kuenzler (1961) and Teal (1962) in *S. alterniflora* marshes. Johannes and Satomi (1966) have reported the nutritive value of fecal pellets found also in detritus, and Jannasch (1954) indicated that a particle of detritus may be ingested several times by organisms before exhaustion of its microfauna.

Detritus, by Darnell's definition, also includes dissolved and colloidal material. Because of their nature and quantity it is these fractions that may be of most importance to the estuary. Dissolved and collodial organic materials in seawater are discussed by Kahailov and Finenko (1970) and the major works in this area reviewed by Riley (1963). It has been suggested that particles can be produced by the adsorption of dissolved matter on bubbles (Sutcliffe, *et. al.*, 1963; Menzel, 1966) and that both dissolved and bubble-formed particulate material can be a source of nutrition for organisms (Stephens, 1967; Stephens and Schinske, 1961; Fox, 1950).

Transport of Detritus

There are numerous studies which cite the importance of marshlands as sources of organic material for coastal areas. Teal (1962), for example, has estimated that 45 percent of the net production of a Georgia salt marsh is exported as organic detritus. There are few studies, however, that have actually attempted to measure this transport. De la Cruz (1965) is perhaps the most referenced work. His study indicated that the export of detritus from a Georgia salt marsh to be 3.4 tons ha^{-1} yr^{-1}, though one might easily criticize his rather limited sampling program. Mid-flood and mid-ebb tide detritus concentrations in a tidal creek obtained several times during a year were simply compared, and water discharges were only estimated. Nadeau (1972) measured water discharge and particulate carbon concentrations in a tidal creek draining a New Jersey salt marsh but found no significant particulate export. He did conclude that there was generally a loss of floating debris from the creek.

METHODS

Description of Study Areas

Two marshes in the York River watershed (Figure 3) were selected to serve as the study sites in the investigation. The areas were chosen because: 1) they were undisturbed; 2) they represented different salinity regimes and hence were dominated by different species of marsh plants; 3) background data on marsh grass production was being collected and 4) both were surrounded on three sides by higher ground which effectively minimized any unmeasured transport of water to or from the study areas.

Carter Creek

Carter Creek marsh (Figure 4) covered an area of 10 hectares, had a yearly mean high tide salinity of 12% and was dominated by saltmarsh cordgrass (*Spartina alterniflora*), salt grass (*Distichlis spicata*), and salt meadow hay (*Spartina patens*). The remaining vegetation consisted of threesquare (*Scirpus* sp.), narrow leaved cattail (*Typha angustifolia*), wood sage (*Teucrium canadense*), saltmarsh aster (*Aster tenuifolius*), sea lavender (*Limonium carolinianum*), arrowhead (*Spagittaria* sp.) and rushes (*Juncus* spp.).

Ware Creek

Ware Creek marsh (Figure 5) was 14 hectares in size, had a mean high tide salinity of 7% and was dominated by giant cordgrass (*Spartina cynosuroides*). Among the associated vegetation were rushes (*Juncus* spp.), smartweed (*Polygonum* sp.), saltmarsh cordgrass (*Spartina alterniflora*), threesquares (*Scirpus* spp.), saltgrass (*Distichlis spicata*), wood sage (*Teucrium canadense*), rice cutgrass (*Leerisa oryzoides*), narrow leaved cattail (*Typha angustifolia*), pickerel weed (*Pontederia cordata*), marsh hibiscus (*Hibiscus moscheutos*), marsh mallow (*Kosteletskya virginica*), and salt meadow hay (*Spartina patens*).

Field Measurements

A sampling platform was constructed in the major creek draining each marsh, located such that all tidal waters entering and leaving the marsh passed by the sampling station. Cross sectional profiles at the sampling sites were measured before and during the sampling year by determining creek depth below fixed marks at half meter intervals across the creek. No significant change in creek cross section profiles was detected over the study period.

Preliminary Measurements

To determine consituent concentration variation within the creeks, water samples were taken over a tidal cycle at various points on the creek cross section at the surface and one foot above the bottom. It was found that at any given time the water column was homogeneous with respect to nutrient and detritus concentrations.

In addition, to determine if the seston (detritus) could adequately be represented by sampling with a water bottle, experiments were conducted in each creek to determine the size distribution of seston particles. Triplicate one hundred liter water samples were taken at ebb tide from each creek and strained through 264μ and 64μ plankton nets. Water passing the 64μ net was filtered through 0.45μ Millipore* filters. In Carter Creek the percentages of seston within these size ranges were: 0.7% ($>264\mu$); 1.5% (64 to 264μ) and 97.8% (0.45 to 64μ). In Ware Creek the percentages were: 0.2% ($>264\mu$), 0.7% (64 to 264μ), and 99.1% (0.45 to 64μ). From these results it was presumed that sampling with a bottle would effectively capture the major portion of the suspended material in the water.

Another series of the tests was undertaken to determine if sample storage in crushed ice would affect the determination of ATP and organic carbon. Samples were taken and analyzed for these two parameters at 1, 3, 6, 12, 24 and 48 hours after sampling with subsequent storage in crushed ice. Statistical analysis of the data revealed no significant difference (α = .05) in the concentrations of either parameter as a function time.

Field Measurements and Sampling Procedures

Ware and Carter creek marshes were sampled for tidal constituents transport over day time tidal cycles several times during 1971 and approximately monthly from January 1972 to January 1973. In so far as possible, sampling periods were chosen to correspond to mean tides as predicted by National Ocean Survey tide tables.

During a survey period, water samples for nutrient and chlorophyll 'a' analysis were taken hourly from the marsh creek from low slack to high slack to second low slack water. Samples were taken in clean, one liter polyethylene bottles. The samples were stored at 0°C after preservation with 40 mg of $HgCl_2$. Samples for ATP and carbon determinations were also taken hourly but were not preserved.

*Registered Trade Mark.

Air and water temperatures were measured hourly to the nearest 0.5°C with a mercury thermometer. Samples for dissolved oxygen were taken hourly while salinity samples were collected every twenty minutes over a tidal cycle.

Current velocity was determined coincidental with the nutrient sampling and at twenty minute intervals over the tidal cycle using a ducted-impeller type current speed indicator (Byrne and Boon, 1973). The current speed sensor was centered in the marsh creek with respect to creek width and depth, while current speed determinations were made. Simultaneous with current speed measurement, a reading of tide height was taken to the nearest millimeter from a meter stick fixed at a known elevation above creek bottom.

Water for phytoplankton productivity determination was taken every two hours over a tidal cycle beginning at first low slack water. Three 125 ml glass bottles (two light bottles and one dark bottle) were filled to 100 ml from a well mixed liter sample. One milliliter of a stock solution containing one microcurie per milliliter activity of carbon-14 (^{14}C) as $NaH^{14}CO_3$, buffered to pH 9.5 with 10 mg/liter Na_2CO_3, was pipetted into each of the bottles. The light bottles were placed into the light compartment of an incubator illuminated by Westinghouse twenty watt "cool white", "warm white", and "plant gro" fluorescent lamps. The dark bottle was placed into the dark compartment of the incubator. Both incubator compartments were maintained at ambient temperature by water pumped from the marsh creek. After three hours the productivity samples were fixed with 1 ml 10% buffered formalin and stored in the dark at 0°C (Strickland and Parsons, 1968).

Laboratory Measurements

The morning following sampling, 500 ml of each of the nutrient samples were filtered first through a Gelman type A glass fiber filter and then a Millipore type HA 0.45 micron membrane filter. The 500 ml filtered and unfiltered fractions were then stored in a refrigerator at 4°C until analyzed. Glass fiber filters through which a measured 200 ml sample had been filtered were wetted with $Mg\,CO_3$ slurry, then placed in a dessicator and refrigerated at 4°C for later chlorophyll analysis. Light and dark bottle primary productivity samples were each filtered through a Millipore type HA 0.45 micron membrane filter, the filters rinsed with 50 ml distilled water and stored in scintillation vials at room temperature.

Dissolved inorganic phosphorus concentration was determined on duplicate filtered samples using a Technicon Autoanalyzer II system employing the single reagent method (EPA, 1971; Technicon, 1972). Total dissolved phosphorus concentration of filtered samples and total phosphorus concentration of unfiltered samples were determined, following persulfate digestion, by single reagent analysis of duplicate 50 ml sample aliquots (EPA, 1971). A Klett-Summerson photoelectric colorimeter calibrated with the standards of the autoanalyzer phosphorus method was used in the analysis. Particulate phosphorus concentrations were obtained by subtracting total dissolved phosphorus from total phosphorus measurements. Dissolved organic phosphorus was obtained by taking the difference between total dissolved phosphorus and dissolved inorganic phosphorus.

Nitrate and nitrite concentrations were determined on duplicate filtered samples using the Technicon Autoanalyzer II system. Nitrite was determined directly by colorimetry while nitrate was determined by cadmium-copper reduction of nitrate followed by colorimetric measurement of nitrite produced. Nitrate and nitrite standards were included in sample runs (EPA, 1971; Technicon, 1972). Fifty milliliter unfiltered water samples for total Kjeldahl nitrogen analysis, and filtered samples for dissolved Kjeldahl nitrogen analysis were digested with a sulfuric acid-mercuric sulfate mixture. Fifty milliliter filtered water samples for ammonia determination and the digested Kjeldahl samples were then analyzed by the distillation-titration technique (EPA, 1971). Ammonia standards were analyzed along with samples and several samples from each run were measured in duplicate. Standard titrant used was 0.001 n HC1. Particulate nitrogen concentrations were obtained by subtracting dissolved Kjeldahl nitrogen from total Kjeldahl nitrogen. Dissolved organic nitrogen was obtained by taking the difference between dissolved Kjeldahl nitrogen and ammonia.

Salinity was determined using a Beckman Model RS-7B portable induction salinometer. Dissolved oxygen concentration was measured using a modified Winkler titration (Strickland and Parsons, 1968).

Chlorophyll 'a' concentration uncorrected for phaeophytin was analyzed by the fluorimetric method (Strickland and Parsons, 1968). Glass fiber filters with their chlorophyll load were mixed with 90% acetone in a tissue grinder and pulverized. The produce was centrifuged, the extract brought to volume, and read on a Turner Model III fluorimeter calibrated for chlorophyll 'a' determination against a Cary 15 scanning spectrophotometer.

Phytoplankton production was measured by liquid scintillation counting of phytoplankton carbon-14 uptake. Ten milliliters of scintillation cocktail consisting of 100g napthalene and 5 grams PPO (2, 5 diphenyloxazole) per liter of dioxane was added to each Millipore filter and its phytoplankton load in a 20 ml scintillation vial. Activity of the cells was measured on a Beckman LS-150 Liquid Scintillation System. Counting efficiency was determined by spiking samples with known activity carbon-14 hexadecane. Producitivity was calculated using light and dark bottle phytoplankton carbon-14 uptake, counting efficiency, and the dissolved inorganic carbon concentration of the samples as obtained by Moore (1973), by use of the formula:

$$\text{Phytoplankton Productivity (mg carbon/liter-hour)} = \frac{\left[\frac{L_1 + L_2}{2} - D\right] (C)\ 1.05}{RTE}$$

where

L_1 = counts per minute of light bottle # 1

L_2 = counts per minute of light bottle # 2

D = counts per minute of dark bottle

R = distintegrations per minute carbon-14 added to light and dark bottles

T = time (hours)

E = counting efficiency

C = dissolved inorganic carbon (mg/1)

1.05 = isotope correction factor

Carbon analysis was performed on whole water samples to determine particulate organic carbon, dissolved organic carbon, and inorganic carbon using a dual-channel Dow-Beckman Carbonaceous Analyzer (Model No. 915). The procedure followed is outlined in "Methods for Chemical Analysis of Water and Wastes", EPA, 1971.

ATP determinations were performed following the method outlined by Holm-Hansen and Booth (1966) using both a Beckman Liquid Scintillation Counter and a JRB Inc., ATP Photometer. Estimation of living carbon associated with ATP measurements was done by multiplying the ATP concentration by a factor of 250 (Hamilton and Holm-Hansen, 1967).

Tidal Nutrient Transport Calculation

For purposes of water discharge determination the creek cross sectional profiles at the sampling stations were drawn to a fraction of scale and the cross sectional area of water planimetrically determined at 10 cm tide height intervals from lowest to highest observed tide height. The data obtained were used to construct a regression line of water cross sectional area as a function of tide height. All tide height observations were converted to water cross sectional values in this manner. Water cross sectional area data were multiplied by corresponding current velocity data to produce instantaneous water discharge values. Water discharge data were matched with nutrient concentration and salinity data. Additional nutrient concentration data were generated by interpolating nutrient concentration against time so that all water discharge values had corresponding nutrient concentration values. With this data the tidal fluxes of water, salinity, and nutrients were calculated for each sampled tidal cycle using an IBM 1130 computer and a spline fit program (Boon, 1974) which:

1. multiplied nutrient concentration and salinity by instantaneous nutrient and salinity discharge;
2. plotted graphs of instantaneous nutrient and salinity discharge versus time and integrated the area under the flood tide and ebb tide halves of the curve;
3. subtracted flood tide nutrient and salinity transport from ebb tide transport and gave net flux for the complete tidal cycle.

Because salinity and water transport data indicated absence of significant non-tidal water input to the marshes, inequalities between flood tide and ebb tide water transport were attributed to a shift in the location of mean current velocity within the marsh creek channel as a consequence of the shift in direction of water flow, thus causing constant sampling bias. Therefore flood and ebb water transport were multiplied by constants which equated them to the mean of the measured flood and ebb tidal prisms over the tidal cycle. Tidal nutrient transport data were also corrected in this manner.

Annual Nutrient Transport Calculation

For calculation of annual nutrient flux between the marshes and the estuary, the sampling year was divided into eleven, approximately month long periods, each containing a sampled tidal cycle near its mid-point. Salt marsh nutrient transport over each "month" was computed using two equations based on contrasting assumptions. The assumption of the first calculation was that every tidal cycle within a given month imported or exported a quantity of nutrients equal to the net quantity transported over the tidal cycle sampled within that month. Thus net transport over each month was calculated by use of the equation:

$$T_m = NT_{tc}$$

where

T_m = net nutrient transport over the month

N = number of tidal cycles in the month

T_{tc} = net nutrient transport over the tidal cycle sampled during the month

The assumption of the second calculation was that net nutrient transport over a tidal cycle was directly proportional to marsh tidal prism. Thus, net transport over each month was calculated by use of the equation:

$$T_m = N\, T_{tc}\, \bar{P}/P_{tc}$$

where

$\bar{P}$ = mean salt marsh tidal prism for the month

P_{tc} = tidal prism of the tidal cycle sampled during the month

Data for computation of mean monthly salt marsh tidal prism was supplied by a continuously recording York River tide gauge. Regression equations relating marsh tidal prism to York River high water tide height were calculated from tidal prism and corresponding tide gauge data. Then, mean monthly York River high water tide heights calculated from tide gauge data were substituted into the regression equations and mean monthly salt marsh tidal prisms were computed.

Since it was not clear which assumption had greater validity, net monthly tidal nutrient transport was estimated by taking the mean of the transports calculated from the two equations. Annual net tidal nutrient transport between the salt marshes and the estuary was then determined by summing the monthly transports for each marsh over the year.

Statistical Analysis

Relationships between nutrient concentrations and physical parameters were determined by correlation analysis (Snedecor and Cochran, 1967) using a program devised for the IBM 360-50 computer (Dixon, 1968).

Multiple regression analysis (Snedecor and Cochran, 1967) with phytoplankton productivity to chlorophyll *a* ratio (assimilation number) as the dependent variable, and water temperature, dissolved inorganic phosphorus, nitrate, and ammonia concentrations as independent variables was also performed using the IBM 360-50 computer (Dixon, 1968). Assuming that marsh flood and ebb tide waters had similar phytoplankton assemblages, but that flood tide waters contained nutrients unaffected by the marshes while ebb tide waters contained nutrients that had interacted with the salt marsh ecosystem, separate regression equations for each half tidal cycle could then reveal the effect of marsh induced nutrient transformations on estuarine phytoplankton productivity.

RESULTS

Seasonal & Tidal Variations in Temperature & Salinity

Temperature

The seasonal range in temperature was from 4 to 29° C in Ware Creek and from 2 to 28°C in Carter Creek. Minimum temperatures were recorded in November on Ware Creek and in January on Carter Creek. Maximum recorded temperatures were observed in late June on Carter Creek and in September on Ware Creek (Figure 6).

Salinity

Salinity ranges at low and high slack water for Ware Creek and Carter creeks are shown in Figures 7 and 8, respectively. Ware Creek had a yearly mean high tide salinity of 7% while the mean for Carter Creek was 12%. Average low tide salinities were 1.0% and 5.6% for Ware and Carter creeks, respectively.

Seasonal and Tidal Nutrient Concentration Trends

In order to compare as concisely as possible the seasonal and tidal nutrient concentration trends observed over the course of this study, we have prepared two illustrations of the concentration variations in each parameter. The first depicts the mean high and low slack concentrations observed through the year while the second shows the hourly variations in concentration during a tidal cycle in winter and summer months.

Dissolved Inorganic Phosphorus

The seasonal range in dissolved inorganic phosphorus (DIP) concentration of marsh waters was 0.25 - 2.95 ug at/1 in Ware Creek and 0.22 - 5.06 ug at/1 in Carter Creek (Appendix A). High slack water concentrations varied much less with season than did low slack values. Mean high slack concentrations for both creeks were less than 1 ug at/1, ranging from 0.22 to 0.89 (Figures 9 and 10). Low tide concentrations were seasonally variable in both study areas ranging from 0.85 to 2.43 ug at/1 in Ware and from 0.09 to 5.06 ug at/1 in Carter. Concentrations of DIP increased from winter lows to summer highs in both creeks with maximum values being attained in July.

Over tidal cycles throughout the year (Figures 11 and 12), DIP concentrations usually peaked at low slack water and decreased with increasing tide height to concentration minima at high slack water, as indicated by the significant negative correlations between DIP concentration and tide height listed in Tables 1 and 2. Exceptions to this DIP concentration pattern were the Ware Creek tidal cycles of late September and October which displayed greater DIP concentrations at high slack than at low slack water (Appendix A, Tables A9 and A10).

Dissolved Organic Phosphorus

Annually, concentrations of dissolved organic phosphorus ranged from 0.19 - 1.40 ug at/1 in Ware Creek and from 0.17 - 1.19 ug at/1 in Carter Creek (Appendix A). As was the case with dissolved inorganic phosphorus, high slack water concentrations varied less with season than did low slack values, ranging from 0.19 - 0.68 in Ware and from 0.17 - 0.90 in Carter (Figures 13 and 14). Low tide concentrations were seasonally more variable in both study areas ranging from 0.43 - 1.31 ug at/1 in Ware and from 0.43 - 1.04 ug at/1 in Carter. Maximal DOP concentrations were detected in summer while minimal levels were found in winter and spring. Significant positive correlations were shown between DOP concentrations and water temperature (Tables 1 and 2).

Over tidal cycles throughout the year, peak DOP levels usually occurred at low slack water and concentrations generally decreased towards high slack water (Figures 15 and 16).

Concentration differences for this phosphorus form were less between the study areas than they were for dissolved inorganic phosphorus. Mean concentrations at high and low slack for DIP were between 0.57 - 1.51 ug at/1 and 0.48 — 2.17 ug at/1 for Ware and Carter creeks, respectively. The mean concentrations for the dissolved organic form were between 0.41 - 0.62 ug at/1 for Ware and 0.46 - 0.64 ug at/1 for Carter.

Particulate Phosphorus

Particulate phosphorus (PP) concentrations within the marsh creeks were maximal in summer and minimal in fall and winter (Figures 17 and 18, Tables 1 and 2). Annual concentration ranges were 0.61 - 8.79 ug at/1 and 0.18 - 19.52 ug at/1 in Ware Creek and Carter Creek respectively (Appendix A). Peak PP levels over tidal cycles usually occurred just before low slack water in Carter Creek but were often found at times of maximal water flow in Ware Creek as shown by Figures 19 and 20, by the significant positive correlations between Ware Creek PP concentrations and water flow in Table 1 and by the significant negative correlations between Carter Creek PP concentrations and tide height in Table 2. The highest sustained PP concentrations were measured in Carter Creek during a rain storm over the latter part of the July tidal cycle (Appendix A, Table A18).

Average concentrations of particulate phosphorus measured at high slack were similar in both study areas; however, low slack concentrations were considerably higher in Carter Creek — 4.39 ug at/1 vs. 2.92 ug at/1 in Ware. This was similar to the trend observed with dissolved inorganic phosphorus. Particulate phosphorus was the predominant phosphorus form observed in both study areas.

Nitrate

Nitrate (NO_3^-) concentrations ranged seasonally from 0.26 - 24.39 ug at/1 in Ware Creek and from 0.07 - 26.86 ug at/1 in Carter Creek. Highest concentrations were measured in winter while lowest levels were found in summer (Figures 21 and 22, Tables 2 and 3). This trend is opposite from that observed for dissolved inorganic phosphate where peak levels were observed during the summer months.

Concentration variations with tidal stage were also less regular than for dissolved inorganic phosphate. Low slack water NO_3^- concentrations were greater than high slack water concentrations from May through August in Ware Creek and from June through October in Carter Creek. At other times high slack water NO_3^- concentrations were greater than low slack water values. Concentration trends observed over the selected seasonal tidal cycles are shown in Figures 23 and 24. Although relationships between time and concentration are not as clear as they were with the various phosphate species, these cycles and others indicate a trend toward increasing levels at low slack water.

Nitrite

Nitrite (NO_2^-) concentrations ranged seasonally from 0.07 - 0.77 ug at/1 in Carter Creek and from 0.07 - 1.83 ug at/1 in Ware Creek. However, with the exclusion of the September sampling from Ware, concentrations ranged only from 0.09 - 0.71 ug at/1 (Appendix A). As shown in Figures 25 and 26 these seasonal changes were relatively small and low slack water NO_2^- levels were generally greater than or equal to the high slack water concentrations. Variations in nitrite levels within tidal cycles are shown in Figures 27 and 28, where a trend toward increasing concentrations as the tide ebbs is indicated.

Ammonia

Annual ammonia (NH_4^+) concentration ranges were 1.0 - 22.2 ug at/1 and 1.0 - 26.0 ug at/1 in Ware and Carter creeks respectively (Appendix A). The highest concentrations were generally measured in the early and late fall (Figures 29 and 30), although seasonal trends are less clear than for previously discussed nutrient species. Throughout the year ammonia levels were usually higher at low slack water than at high.

Over tidal cycles throughout the year peak ammonia levels usually occurred at low slack water and decreased towards high slack water (Figures 31 and 32). Average concentrations of ammonia measured at high and low slack water were similar in both study areas.

Dissolved Organic Nitrogen

Levels of dissolved organic nitrogen (DON) were generally highest in summer (Figures 33 and 34). Annual concentration ranges were 3.0 - 65.2 ug at/1 in Ware Creek and 7.6 - 82.2 ug at/1 in Carter Creek (Appendix A). High and low slack water concentrations generally parallel each other quite closely with slightly higher concentrations being observed at low slack.

The tidal cycle data for Ware Creek shown in Figure 35 do not indicate any consistent relationships between time and DON level. The data for Carter Creek shown in Figure 36 indicate that DON concentrations increase as the tide ebbs – a pattern shown for dissolved organic phosphorus in both areas.

Particulate Nitrogen

Particulate nitrogen (PN) concentrations of the marsh creeks followed a seasonal cycle similar to that of particulate phosphorus (Tables 1 and 2). Highest PN concentrations were measured in summer while lowest concentrations were found in winter (Figures 37 and 38). Seasonally, PN concentrations ranged from 5.0 - 74.6 ug at/1 in Ware Creek and from 3.4 - 174.6 ug at/1 in Carter Creek (Appendix A). Peak PN levels over tidal cycles usually occurred just before low slack water in Carter Creek but were often found at times of maximal water flow in Ware Creek (Figures 39 and 40), a pattern similar to that observed for particulate phosphorus. Highest sustained PN concentrations were measured during a rain storm over the July sampling of Carter Creek (Appendix A, Table A18).

Seasonal and Tidal Plankton Concentration Trends

Biomass

Chlorophyll 'a' was measured to follow changes in phytoplankton biomass during the study. The seasonal range in chlorophyll 'a' concentrations in the marsh creeks studied was 2.2 - 23.6 ug/1 in Ware Creek and 2.6 - 135.9 ug/1 in Carter Creek. Biomass increased from winter lows to peak concentrations in the late summer in both study areas (Figures 41 and 42). Generally high slack water concentrations were higher, suggesting transport of river phytoplankton populations into the marshes. However, as will be shown later, this is not the case since both marshes exported chlorophyll 'a'. The highest value observed apparently resulted from the suspension of periphyton organisms from the Carter Creek marsh during a thunderstorm in July.

Productive Potential

As described in the Methods Section, phytoplankton productivity was determined by incubation of the samples under constant light in an incubator. Hence, the values reported here are not intended to reflect the actual field conditions, but they should allow for a good comparison of the productive potentials of water taken during all sampling periods.

Carbon fixation by the phytoplankton varied on a seasonal basis from 0.2 - 13.5 mg C/m^3 - hr. in Ware Creek and from $<$0.05 - 29.6 mg C/m^3 - hr in Carter Creek. Productive potentials increased gradually from winter lows to late summer maxima in both systems (Figures 43 and 44). Carbon fixation potential followed the chlorophyll 'a' concentrations quite closely and was usually higher at high slack water than at low in both systems.

Seasonal Nutrient Flux Trends

Dissolved Inorganic Phosphorus

Export of DIP from the Ware Creek study area to the York River was recorded during 7 of the 12 sampling periods (Table 3). Ebb tide losses exceeded inputs from March through June but on three consecutive fall samplings the calculations indicated a net input of DIP to the marsh. Exports ranged from 36 - 245 grams per cycle and imports from 8 - 310 grams per cycle.

Utilizing these data the yearly budget shown in Table 7 was constructed. The assumptions used to construct the yearly budgets were detailed in the Methods Section; however, we should reiterate here that they are extrapolations based upon monthly observations. Hence, fluxes resulting from extreme events which might have considerable impact on the yearly budgets are of course not calculable.

On an annual basis, 6,851 grams of dissolved inorganic phosphorus were transported to the York River from the study area.

Export of DIP from the Carter Creek study area to the York River occurred during all but one of the cycles studied. Exports ranged from 31 - 133 grams per cycle, while during the one cycle showing input, 8 grams were transported.

On an annual basis, 60, 491 grams of dissolved inorganic phosphorus were exported to the York River from the Carter Creek study area (Table 8).

Dissolved Organic Phosphorus

Export of DOP from the Ware Creek area was observed during 8 of the 12 cycles studied (Table 3). Losses to the river occurred from January through June and during August, October and November. Exports ranged from 4 - 204 grams per cycle and imports from 4 - 98 grams per cycle.

The annual budget (Table 7) showed a net export of 30,512 grams of this phosphorus form.

In the Carter Creek study area a similar pattern was observed with export occurring during 8 of the 11 sampling periods. The magnitude of the losses, shown in Table 4, were generally lower than those observed in Ware Creek, with exports ranging from 3 - 142 grams per cycle while imports ranged from 6 - 27 grams per cycle.

Annually 16,630 grams of dissolved organic phosphorus were transported from the Carter Creek marsh study area to the river.

Particulate Phosphorus

Import of particulate phosphorus to the Ware Creek area was observed during 6 sampling periods — in the winter and fall — with export occurring during spring and summer. Quantities of phosphorus imported ranged from 41 - 3,944 grams per cycle while exports varied between 67 - 1203 grams (Table 3).

On an annual basis 147,281 grams of particulate phosphorus were imported to the study area.

In Carter Creek the import of particulate phosphorus occurred continually from March through August with the exception of the July sampling which was carried out during a severe thunderstorm. Quantities of PP imported ranged from 52 - 575 grams per cycle while export varied between 40 - 1526 grams per cycle.

Over the year 83,823 grams of particulate phosphorus were imported to the study area from the river.

Total Phosphorus

Considering all three phosphorus species, on an annual basis phosphorus was imported to Ware Creek and Carter Creek marshes (Tables 7 and 8). The yearly net input of particulate phosphorus to the marshes was greater than the net output of dissolved inorganic and dissolved organic phosphorus from the marshes.

Nitrate

Import of nitrate (NO_3^-) from the York River to the Ware Creek study area occurred during every cycle studied, with inputs ranging between 50 - 872 grams per cycle. Highest inputs occurred during the fall and winter (Table 5).

On an annual basis 321,420 grams of NO_3^- were imported to the study area (Table 9).

In Carter Creek import of NO_3^- was observed during 7 of the 11 study periods. On one occasion input balanced output and export occurred during the June, September and January sampling periods. Nitrate transport was considerably lower in Carter than in Ware with imports varying from 20 - 153 grams per cycle and exports from 35 - 161 grams per cycle (Table 6).

Annually 31,191 grams of nitrate were imported from the York River to the study area.

Nitrite

Nitrite transport values were much lower than nitrate (Tables 5 and 6); however, overall inputs were recorded in both marshes.

In Ware Creek imports were observed on 8 of the 12 sampling dates. Exports occurred only during January, June and August. Net transport by flood tides varied between 6 - 184 grams while net ebbs ranged from 1 - 42 grams.

Annually 18,191 grams of nitrite were transported from the river to Ware Creek marsh (Table 9).

In Carter Creek imports were observed on 7 of 11 sampling dates (Table 6). As was observed with nitrate, nitrite transport values were considerably lower in Carter than in Ware, with imports varying from 1 - 30 grams per cycle and exports from 1 - 11 grams per cycle.

On an annual basis 2,397 grams of nitrite were imported to Carter Creek from the river.

Ammonia

In Ware Creek ammonia (NH_4^+) was exported from January through August with imports occurring during the September - December sampling periods (Table 5). Exports varied from 248 - 2786 grams per cycle with larger outputs in the spring and summer. Inputs ranged from 300 - 869 grams per cycle.

Annually 407,554 grams of (NH_4^+) were exported to the York River from the Ware Creek study area.

In Carter Creek 5 samplings revealed export and 5 import with one cycle showing no net movement. While a large net input of NH_4^+ was indicated for the Carter Creek storm tidal cycle of July, this input was discounted due to the anomalous transport of NH_4^+ relative to that of other nutrient species over this tidal cycle. Consequently, NH_4^+ transport over the "month" associated with the July sampling was calculated from the mean of the NH_4^+ transports of the preceding month and the following month.

In contrast to Ware Creek, on an annual basis Carter displayed an export of 28,665 grams of NH_4^+ to the York River.

Dissolved Organic Nitrogen

Export of DON occurred during 7 of the 12 sampling periods in Ware Creek. Maximum export periods were during late summer and fall with values ranging from 65 - 3122 grams per cycle. Relatively large imports were observed during the April and June cycles (Table 5).

In Carter Creek export of DON was observed during all but the August and November sampling periods. Export varied between 216,- 5,776 grams per cycle while values of 541 and 172 grams were observed for the August and November cycles, respectively.

Annually, there was significant net output of DON from both marshes with greater export from Carter (925,270 grams) than from Ware (324,835 grams).

Particulate Nitrogen

In Ware Creek particulate nitrogen was exported in the winter and spring and imported during the summer. Concentrations on net ebbs ranged from 450 - 2618 grams while net flood transports varied between 900 - 2778 grams.

The annual budget revealed an export of 3,765 grams of particulate nitrogen.

In contrast Carter Creek exported PN on only three occasions, during the July storm and during October and January. Exports ranged from 303 - 4,921 grams per cycle and imports from 405 - 2398 grams per cycle.

On an annual basis, there was a large net input of particulate nitrogen into the study area from the river (Table 10).

Total Nitrogen

Considering all nitrogen species, the marshes displayed significant annual export of nitrogen (Tables 9 and 10). The annual import of nitrate and nitrite to Ware Creek was exceeded by the annual export of ammonia, dissolved organic nitrogen, and particulate nitrogen from the marsh. For Carter Creek, the annual export of dissolved organic nitrogen exceeded the annual import of the other nitrogen species.

Diurnal Versus Nocturnal Tidal Nutrient Transport

The consecutively sampled day-night Ware Creek tidal cycles of June 1972 generally displayed similar net nutrient transport trends (Tables 3 and 5). Dissolved inorganic phosphorus was exported over both tidal cycles with greater export over the daytime tidal cycle. However, while dissolved organic phosphorus was exported from the marsh over the diurnal tidal cycle, a small quantity was imported to the marsh over the nocturnal tidal cycle. Particulate phosphorus was exported from the marsh over both tidal cycles with significantly greater nighttime export. Nitrate was imported to the marsh while nitrite was exported from the marsh over the two tidal cycles. There was greater nitrate import to the marsh over the diurnal tidal cycle and greater nitrite export from the marsh over the nocturnal tidal cycle. Approximately equal amounts of ammonia were exported over the two tidal cycles, however, more dissolved organic nitrogen was imported to the marsh over the daytime compared to the nighttime tidal cycle. A greater amount of particulate nitrogen was exported from the marsh over the diurnal than over the nocturnal tidal cycle.

Phytoplankton Productivity Correlations

Over the year, in Ware Creek and Carter Creek marsh waters, the ratio of phytoplankton productivity to chlorophyll 'a' concentration (assimilation number) was best correlated with water temperature for both flood and ebb tides. Partial correlations, with temperature held constant, calculated between phytoplankton assimilation number and dissolved inorganic phosphorus, nitrate, and ammonia, revealed no significant correlations over either flood or ebb tides (Tables 11 and 12).

Seasonal and Tidal Carbon Concentration Trends

Particulate Organic Carbon

POC concentrations in the marsh waters ranged from less than 1 mg/1 to over 20 mg/1 (Fig. 45). Seasonal differences in POC were not extraordinary, but generally suspended concentrations were highest in the summer and fall and lowest in the winter and spring periods. POC levels were higher throughout the year in Carter Creek than Ware Creek.

For comparison with previous studies, yearly mean mid-flood and mid-ebb levels of POC were calculated. In Carter Creek the mean mid-flood level of POC was 4.3 mg/1 while the mid-ebb level was 4.6 mg/1. For Ware Creek these values were 3.6 mg/1 and 3.9 mg/1 for flood and ebb, respectively.

POC concentrations within each tidal cycle (Appendix B) varied as a function of tidal stage. Highest values occurred near low slack or during mid-tide. Only occasionally were levels near the high slack period the highest.

During the July sampling in Carter Creek the marsh was subjected to a number of severe thunderstorms which began at approximately 1600 hours. The front of storms approached from the southwest and the area was subjected to severe rain squalls for approximately four hours. Maximum wind velocities recorded at the Virginia Institute of Marine Science continuously monitoring wind gauge situated less than five miles away were over 55 miles per hour. Considerable erosion of particulate material from the exposed marsh surface was observed during this period and greatly elevated water velocities and POC levels were recorded.

Dissolved Organic Carbon

DOC transport results were variable (Tables 13 and 14), indicating both gain and loss to the marshes. Ware Creek marsh demonstrated net loss of DOC over a number of tidal cycles, while significant influx of DOC occurred only during the June and September tidal cycles. Net tidal influx of DOC at samplings throughout the year in Carter Creek were small when compared to either the total ebb or flood tidal transports. Only during the April tidal cycle occurred what might be considered a significant net influx of DOC.

DOC concentrations on an annual basis ranged from approximately 2 mg/1 to 17 mg/1 (Fig. 46). Highest concentrations occurred during the summer and fall.

Levels of DOC did not change dramatically within the sampled tidal cycles (Appendix B). Highest levels were generally found near low slack and lowest at high slack water for both marshes throughout the year.

ATP-Carbon

ATP-carbon transport was characterized by loss from both marshes to the estuary during all sampled tidal cycles except the April and May Ware Creek sampling and the August Carter Creek tidal cycle. Comparison with the Chl *a* data suggests that these influxes may have been caused by elevated estuarine phytoplankton populations in the river.

Seasonal variation in ATP values (Fig. 47) closely parallels that obtained for Chl. *a* (Fig. 48), and it appears that there are slightly different "seasons" associated with the living material in both marshes. Maximum ATP levels occurred in Ware Creek marsh waters during July, but by September the standing crop of living material had dropped considerably to approximately the winter levels. Carter Creek marsh, on the other hand, continued with high levels until the October sampling.

ATP-carbon, measured as percent POC, varied throughout the year (Fig. 49). The living material in individual samples ranged from less than 5% of POC in the water during the winter, to greater than 20% during the summer. Variations from this high summer, low winter trend were a function of unusually high or low POC concentrations rather than fluctuating ATP-carbon levels.

Seasonal variations in detrital carbon levels (Fig. 50), determined by subtracting ATP-carbon values from POC, closely approximated that found for POC, and indicated the dominance of detrital carbon within the marsh system.

Chl *a* levels were recorded highest during the summer months (Fig. 48). There appeared to be two peaks, indicating seasonal blooms of phytoplankton, during the spring and again during the summer months. Trends evident for Chl. *a* are complicated, however, by the fact that the values are uncorrected for phaephytins. Carbon: Chl. *a* rations were extremely high as might be expected for these turbid waters and ranged from less than 100: 1 during the summer to over 500: 1 during the fall and winter (Fig. 51).

Dissolved Inorganic Carbon and Dissolved Oxygen

DIC transport data (Tables 13 and 14) indicated rather insignificant net flux during the winter period of November through March or April. Direction of flux during the summer months was variable.

Net efflux of oxygen to the river was generally recorded in both marshes throughout the year. This was most probably a function of sampling time within the day rather than any greater net production over respiration in the marshes. Water samples during the flooding tidal period were generally obtained during the morning. Reduced 0_2 levels would therefore be expected from nighttime respiration. Daytime photosynthesis in the water column and on the marsh surface resulted in higher levels of 0_2 which were then measured during the ebb tidal periods. During the 24 hour sampling in June at Ware

Creek this variation was most evident. The first tidal cycle which began with low slack during the morning indicated a net efflux of 0_2 from the marsh. The second tidal cycle which began during the night indicated a net influx of 0_2 to the marsh.

Levels of DO and DIC within the tidal cycles reveal that values for DO were generally lowest at low slack and highest at high slack; conversely, DIC levels were highest at low slack and lowest around high slack.

Seasonal changes in mean DIC concentrations in Ware Creek and Carter Creek marshes are presented in Fig. 52. Higher DIC concentrations resulting from the higher salinities in Carter Creek are evident in comparison to the Ware Creek concentrations. Seasonally, DIC concentrations are highest in both marshes during the summer months.

DO levels in both marshes throughout the year are presented in Fig. 53. Typically, levels are reduced during the summer months, and in comparison levels in Ware Creek appear lower than Carter Creek.

Net Carbon Transport

Tidal transport of each of the measured parameters for each of the observed tidal cycles are presented in Tables 13 and 14. Minimum water transport in both marshes occurred during period of minimum water temperatures during the winter. This was probably due to the stearic oscillations in sea level which result from the seasonal variations in specific volume of the ocean (Pattullo, Munk, Revelle and Strong, 1965).

The annual net transport calculations indicated that over the one year study period there was a net loss of 4945.7 kg of particulate organic carbon (POC) and 11156.2 kg of dissolved organic carbon (DOC) from Ware Creek marsh (Table 15). From Carter Creek there was a net loss of 11654.6 kg of POC and a net loss of 2535.1 kg of DOC (Table 16). Assuming that the annual net angiosperm productions of the marshes were 562 g/m^2 for Ware Creek and 572 g/m^2 for Carter Creek as determined by Mendelssohn (1973) during 1971-72, then 12.4% of this production was exported from Ware Creek in the particulate form and 28.0% as DOC. In Carter Creek, 40.7% was exported as POC while only 8.9% was lost from the marsh as DOC (Table 17).

Living carbon as estimated from the ratio of ATP to cellular carbon was equal to 0.5% of the net angiosperm production of Ware Creek (Table 17) and 1.8% of the Carter Creek production. These non-detrital fractions are equal to 8.4%

and 8.7% of the annual export of POC from Ware and Carter creeks respectively.

DISCUSSION

Phosphorus Flux Through the Salt Marsh Ecosystem

The observed negative correlations between dissolved phosphorus concentrations, tide height, and water flow, along with the significant annual exports of dissolved inorganic and dissolved organic phosphorus from Ware Creek and Carter Creek marshes, suggest a release of dissolved phosphorus from marsh soils to the water column. This exchange may be mediated by phosphorus cycling within the salt marsh community (Pomeroy *et al.,* 1969; Pomeroy, 1960; Kuenzler, 1961; Marples, 1966; Reimold, 1972), or by sediment-water equilibrum processes (Pomeroy *et al.,* 1965; Upchurch, 1972). However, Pomeroy, Shenton, Jones, and Reimold, (1972) have indicated that metabolic processes predominate over sorption phenomena in the cycling of phosphorus within salt marsh-estuarine environments. With this information, and considering that: 1) the annual net output of dissolved phosphorus species from Ware Creek and Carter Creek marshes was exceeded by the annual net input of particulate phosphorus to the marshes, 2) sediments are accreting in salt marshes (Redfield, 1972, Meade, 1972) and salt marsh sediments are rich in phosphorus (Maye, 1972; Mendelssohn, 1973), 3) calculated atmospheric inputs of phosphorus to Ware Creek and Carter Creek marshes were small (Chapin and Uttormark, 1973), and 4) terrestrial influence on Ware Creek and Carter Creek marshes was negligible; a salt marsh phosphorus flux scheme can be hypothesized. The resultant annual phosphorus cycle is characterized by influx of estuarine particulate phosphorus to marsh sediments followed by biotic mineralization of a fraction of the particulate phosphorus compartment of the marsh and subsequent efflux of dissolved phosphorus from the marsh to the estuary.

The observed phosphorus concentration and transport trends of Ware Creek and Carter Creek marshes can be explained within the context of this hypothesis by considering environmental parameters and the findings of other researchers. Elevated dissolved phosphorus concentrations in Georgia salt marsh waters have been ascribed to both heterotrophic degradation of *Spartina* detritus (Pomeroy *et al.,* 1969) and to pumping of dissolved inorganic phosphorus from subsurface sediments by *S. alterniflora*, followed by release to marsh waters via guttation (Reimold, 1972; Pomeroy *et al.,* 1972). Pomeroy *et al.* (1972) further stated that because heterotrophic respiration in these salt marsh-estuarine environments is approximately equal in summer and winter, increased summer dissolved inorganic phosphorus concentrations of marsh waters are a result of increased rates of *Spartina* guttation. However, dissolved phosphorus concentrations of Ware Creek and

Carter Creek marsh waters related better to degree of sediment-water contact, as inferred from dissolved phosphorus concentration, water flow and tide height correlations, than to *Spartina alterniflora* standing crop. Therefore, ingestion of detritus and associated microorganisms by marsh meiobenthos followed by excretion of dissolved inorganic and dissolved organic phosphorus by meiobenthos with diffusion of this phosphorus from marsh soils to the water column would appear to be the mechanism of primary importance in the movement of dissolved phosphorus all year in these marshes. The generally greater exports of dissolved phosphorus from the marshes in summer could be a result of increased temperature causing biotic mineralization rates to further increase over rates of dissolved phosphorus assimilation by photautotrophs and *Spartina* detritus-degrading microorganisms.

The greater annual efflux of dissolved inorganic phosphorus from Carter Creek as compared to Ware Creek marsh was a result of the influx of dissolved inorganic phosphorus to Ware Creek during fall. These differences imply that marshes may vary with respect to nutrient flux. However, the September and October phosphorus inputs to Ware Creek were also associated with elevated dissolved inorganic phosphorus concentrations in Ware Creek at high slack water (reflecting estuarine concentrations) that exceeded low slack water concentrations. The fact that for essentially all other sampled Ware Creek and Carter Creek tidal cycles, dissolved inorganic phosphorus concentrations at low slack water were greater than high slack water concentrations and dissolved inorganic phosphorus was exported from the marshes, indicates that salt marsh sediments and biota may act to buffer estuarine waters with respect to dissolved inorganic phosphorus as suggested by Pomeroy *et al.*, (1965). Significant net input of dissolved inorganic phosphorus into Ware Creek was also observed over the post-Hurricane Agnes tidal cycle of July, 1972. While this seemingly abnormal phosphorus influx to Ware Creek may have been a result of the hurricane, the rain storm over the corresponding Carter Creek July sampling negated any opportunity of observing a residual effect of Agnes on Carter Creek. However, the Carter Creek July rainstorm did serve to reaffirm the hypothesis contending that metabolic processes predominate over sediment-water equilibrium processes in the release of dissolved inorganic phosphorus to marsh waters. This was evidenced by the apparently normal dissolved inorganic phosphorus concentrations and exports over the July tidal cycle in spite of the large quantities of marsh sediments that were suspended in the marsh water column.

Tidal variation in particulate phosphorus concentrations of Ware Creek and Carter Creek marsh waters was primarily a function of marsh physiography and tidal distribution of current velocities. Seasonal differences in salt marsh particulate phosphorus concentrations and flux can be explained on the basis of seasonal changes in marsh angiosperm detrital export and temporal variation in estuarine detrital and phytoplankton concentrations. Mendelssohn (1973) found significantly greater angiosperm litter standing crop in Ware Creek as compared to Carter Creek in the spring, but equally low angiosperm litter standing crops in the marshes in late summer. The fact that the annual angiosperm productivities of the two marshes were equivalent (Mendelssohn, 1973) suggests that Ware Creek marsh exported much of its angiosperm biomass in spring and summer while Carter Creek marsh exported more detritus in fall and winter. In general agreement with these observations were the Ware Creek export of particulate phosphorus in spring and summer (with the exception of the post-hurricane July tidal cycle), and the Carter Creek export of particulate phosphorus in fall. The large influx of particulate phosphorus to Ware Creek in fall may have indicated that this marsh served as a sink for detritus generated by other marshes or by a possible autumn estuarine phytoplankton die off. The fact that Carter Creek had significantly lower mean annual dead angiosperm standing crop than Ware Creek, while the two marshes had equivalent annual angiosperm productivities (Mendelssohn, 1973), may indicate that Carter Creek exported much of its angiosperm production shortly after its death. Seasonal particulate phosphorus transport trends of Carter Creek support this conclusion in that particulate phosphorus was exported only in fall even though estuarine detrital concentrations were high at that time, and estuarine particulate phosphorus inputs to the marsh exceeded marsh particulate phosphorus outputs over the remainder of the year. In light of the apparent dissimilar seasonal patterns of angiosperm detritus export from these two marshes of differing salinity regime and floral composition, it is to be expected that seasonal variation in influx-efflux of particulate material from a given salt marsh will be influenced by the seasonal patterns of angiosperm detritus export from other salt marshes within the same estuarine system.

Considering all three phosphorus species, the annual budgets indicated significantly greater import of phosphorus to Ware Creek than to Carter Creek marsh. This discrepancy is largely due to the great efflux of particulate phosphorus from Carter Creek over the July storm tidal cycle. The storm undoubtedly had a disproportionate influence on the calculated annual phosphorus budget due to the fact that rain storms of equally great magnitude did not constitute as large a fraction of the year's tidal cycles as they did of the sampled tidal cycles. Were the particulate phosphorus transport over this July tidal cycle commensurate to either the June or August Carter Creek particulate phosphorus imports, the net annual inputs of phosphorus to Ware Creek and Carter Creek would have been more comparable. However, it is not meant to discount the obvious perturbation in particulate phosphorus flux through salt marshes induced by storms. Though it is probable that the substantial detrital efflux from salt marshes over storm tidal cycles is followed by detrital influx to the marshes over succeeding tidal cycles, as elevated estuarine seston concentrations again attain equilibrium levels, the quantitative aspects of storm induced detrital export from salt marshes over the long term remains to be elucidated.

Nitrogen Flux through the Salt Marsh Ecosystem

The magnitude of annual input or output of nitrogen to or from the salt marsh ecosystem is controlled by the seasonally varying rates in the concomitant processes of nitrogen assimilation, nitrogen mineralization (ammonification, autolysis, and excretion), nitrification, dissimilatory nitrogen reduction, and nitrogen fixation in the marsh and estuarine systems. Ware Creek and Carter Creek nitrogen flux data indicate that the annual salt marsh nitrogen cycle is characterized by 1) import of estuarine particulate nitrogen to the marsh from the estuary, 2) fixation of molecular nitrogen by marsh flora, 3) spring-summer ammonia export and year round dissolved organic nitrogen export from the marsh to the estuary, 4) fall, or fall and winter import of ammonia to the marsh from the estuary, and 5) year round nitrate and nitrite import to the marsh from the estuary.

The year round influx of both nitrate and nitrite to Ware Creek and Carter Creek could have been a result of photoautotrophic and bacterial nitrate and nitrite assimilation or bacterial dissimilatory nitrogen reduction in the marshes. Assimilation of these nitrogen species by marsh angiosperms, phytoplankton, edaphic and epiphytic algae undoubtedly accounts for some of the nitrate and nitrite import to the marshes. The increased fall, winter, and spring nitrate and nitrite import to the marsh could possibly be due to the increased nitrogen assimilation by marsh edaphic algae occurring at this time. This is a result of decreased marsh angiosperm standing crop allowing greater light penetration to the marsh soil and yielding increased edaphic algal production (Gallagher, 1971). Assimilation of nitrate and nitrite by microorganisms utilizing nitrogen poor *Spartina* detritus as an energy source could also explain the nitrate and nitrite imports to the marsh (Thayer, 1969; Ustach, 1969). Decreased nitrate and nitrite import to the marsh in summer might thus be a result of the lower organic carbon concentrations of marsh soils in summer causing a reduction in bacterial activity (Day, Smith, Wagner, and Stowe, 1973). However, considering the large denitrifying bacterial populations of salt marsh sediments (Daiber and Gooch, 1968), the rapid rate of denitrification as compared to assimilation (Painter, 1970), the high concentrations of ammonia in salt marsh waters and the preferential assimilation of ammonia-nitrogen by bacteria and photoautotrophs (Painter, 1970; Riley and Chester, 1971), it is hypothesized that nitrate losses to the marshes were predominatly due to denitrification. Further evidence of the significance of denitrification in salt marshes was provided by data indicating high rates of bacterial dissimilatory sulfate reduction in marsh soils (Gooch, 1968), a process which does not occur to a large extent until denitrification has depleted nitrate and nitrite (Horne, 1969).

Assuming that denitrification is of significance in marshes, the quantitative aspect of nitrate loss to Ware Creek and Carter Creek would be primarily a function of the importance of denitrification as opposed to nitrification in the marshes. The relative significance of these processes is dependent on the biochemical reaction rates as well as the abundance of the microorganisms responsible for denitrification and nitrification. Biochemical reaction rates and population densities of these bacteria are influenced by many factors, some of which are temperature, and availability of ammonia, nitrate, nitrite and organic carbon. Though nitrification and denitrification rates of several bacterial species have been found to increase with increasing temperatures to rate maxima at about 30°C (Dawson and Murphy, 1972; Painter, 1970), increased temperatures also correlate with increased estuarine phytoplankton productivity and decreased estuarine and consequently salt marsh nitrate concentrations (Figures 7, 16, 17, 26, 27, 28, and 29). Thus, the relative seasonal importance of the processes of denitrification and nitrification is not clear.

The fact that the processes of nitrification and denitrification require different environments within the marshes explains the seeming paradox of nitrate import to the marshes though low slack water nitrate concentrations were greater than high slack water concentrations (May to September in Ware Creek, and June to November in Carter Creek). The greater annual import of nitrate to Ware Creek than to Carter Creek together with the annual export of ammonia from Ware Creek and the annual import of ammonia to Carter Creek indicate that nitrification may have been of greater importance in Carter Creek than in Ware Creek marsh.

Ammonia concentrations in the waters of Ware Creek and Carter Creek marshes were significantly higher than York River estuarine ammonia concentrations as measured by Patten and Lacey (1961). Marsh ammonia concentrations correlated positively with dissolved inorganic phosphorus and concentrations of both nutrients correlated negatively with tide height such that the monthly marsh fluxes of the two nutrients were most often in the same direction. A cycle explaining these phenomena is the grazing of meiobenthos on detritus and associated microorganisms with concurrent release of ammonia and dissolved inorganic phosphorus via excretion. The generally greater later spring and summer exports of ammonia from the marshes could thus be a result of the temperature dependence of metabolism. Variation in the flux direction between ammonia and dissolved inorganic phosphorus may have been due to seasonal differences in the relative adsorption of ammonia and dissolved inorganic phosphorus on sediments, in detrital nitrogen to phosphorus ratios, in relative assimilation of ammonia versus phosphorus by photautotrophs, and in nitrification rates. Though nitrification has been theorized as the cause of ammonia loss to the marshes in fall-winter, uptake of nutrients by marsh photoautotrophs or Thayer's (1974) hypothesis that *Spartina* detritus degrading microorganisms assimilate dissolved nitrogen and phosphorus from marsh waters, also provide possible explanations for the fall ammonia and dissolved inorganic phosphorus imports to Ware Creek and the fall-winter ammonia imports to Carter Creek. While these theories are plausible, the detection of increased nitrifying bacterial population densities from summer to fall (Daiber and Gooch, 1968) also evinces nitrification as a possible mechanism for the ammonia losses to the marshes in fall-winter. However, the influx of nitrate as well as ammonia to the marshes at this time indicates that a nitrogen cycling reaction in addition to nitrification was transpiring in the marshes. In light of the findings of Patrick and Tusneem (1972), that a significant amount of ammonia was lost from flooded soils through nitrification followed by denitrification, it is proposed that in Ware Creek and Carter Creek marshes, estuarine ammonia was oxidized to nitrate and nitrite in aerobic sediments, then with anaerobiosis of the sediments as a result of rising tide, or diffusion of nitrate and nitrite to anoxic sediments, nitrate and nitrite were denitrified to molecular nitrogen.

The significant correlation between dissolved organic nitrogen and dissolved organic phosphorus concentrations in Ware Creek and Carter Creek marsh waters along with the annual export of both nutrient species from the marshes suggest that like mechanisms were responsible for their production and export. Since evidence has been presented that marsh dissolved organic phosphorus export were a result of excretion by marsh heterotrophs, it is also possible that the excretion of dissolved organic nitrogen (urea, uric acid, amines, amino acids) by marine heterotrophs (Webb and Johannes, 1967; Campbell, 1973; Stanier, Doudoroff and Adelberg, 1963) was responsible for the dissolved organic nitrogen exports from the marshes. Thus, the generally greater late spring and summer dissolved organic nitrogen efflux from the marshes could have been a result of the increased biotic activity at that time.

The extremely high correlations between particulate nitrogen and particulate phosphorus concentrations in Ware Creek and Carter Creek waters and the generally parallel monthly transport trends of these nitrogen and phosphorus forms, indicate that flux of detrital nitrogen was controlled primarily by the processes influencing detrital phosphorus inputs and outputs to and from the marshes. However, while there was annual net input of particulate phosphorus to both marshes and particulate nitrogen input to Carter Creek, Ware Creek was essentially at steady state with respect to particulate nitrogen. Possible reasons for these differences are the seasonally varying ratio of nitrogen to phosphorus in marsh and estuarine detrital materials and the differences in relative adsorption of nitrogen and phosphorus on sediments. The annual imports of particulate phosphorus and import or small export of particulate nitrogen to the marshes together with the observed significant annual exports of particulate carbon from the marshes suggest that on an annual average basis the particulates imported to the marshes from the estuary.

Considering the annual transports of all nitrogen species, there was a net export of approximately 400 kg of nitrogen from both Ware Creek and Carter Creek marshes to the estuary. Nitrogen inputs to the marshes from rainfall would amount to less than 10 kg/ha-yr (Chapin and Uttormark, 1973), or 140 kg to Ware Creek and 100 kg to Carter Creek marsh. Therefore, a significant quantity of the nitrogen output from the marshes must have entered the system by a process other than tidal transport or rainfall. The detection of nitrogen fixation by bacteria and algae in salt marsh environments (Daiber and Gooch, 1968; Green and Edmisten, 1972) suggest this process may have been responsible for nitrogen contributions to the marshes. Taking the net marsh nitrogen effluxes less the nitrogen inputs from rainfall as minimal estimates (since nitrogen outputs via denitrification or detrital nitrogen incorporation into marsh sediments are ignored) of the rates of nitrogen fixation, Ware Creek marsh fixed 209 μg N/m^2-hour and Carter Creek marsh fixed 340 μg N/m^2-hour. These figures compare well with the mean rate of fixation measured by Brooks, Brezonik, Putnam, and Keirn (1971) of 3.07 ng N/g sediment-hour in the top 2-5 cm stratum of Florida estuarine sediments (sediments actively fixing nitrogen), which, assuming 2.6 g/cm^3 for estuarine sediment (Meade, 1972) is equivalent to 239 μg N/m^2-hour.

Effects of the Salt Marsh Ecosystem on Estuarine Productivity

The influence of salt marshes on estuarine productivity has been largely ascribed to the high productivity of marsh angiosperms, much of which is exported to the estuaries where it is the basis for the detritus food web (Odum and de la Cruz, 1967; Darnell, 1964; Teal, 1962; Day *et al.*, 1973). However, salt marsh nutrient transformations and the resultant marsh nutrient budgets, as determined in this study, indicate that the marshes by exporting dissolved nitrogen and phosphorus function to sustain the high rate of primary production in the estuaries. In doing so, the salt marshes increase productivity of the higher trophic levels of the estuary and also serve to maintain estuarine community homeostasis (Caperon, Cattell, and Krasnick, 1971).

Though there were no detectable relationships between phytoplankton productivity indices and dissolved inorganic phosphorus and nitrogen concentrations in estuarine waters flooding into or ebbing from Ware Creek and Carter Creek marshes, the phosphorus and more notably the nitrogen limitation of phytoplankton productivity (i.e. the stimulation of phytoplankton productivity upon nutrient addition) in the York River estuary and other coastal waters is well documented (Fournier, 1966; Thayer, 1969; Copeland and Hobbie, 1972; Ryther and Dunstan, 1971). Therefore, it is significant that the time of peak potential estuarine phytoplankton productivity (May to October), Ware Creek and Carter Creek marshes displayed greatest export of dissolved inorganic and dissolved organic phosphorus, ammonia and dissolved organic nitrogen, nutrient species determined to be assimilable by marine phytoplankton (O'Kelley, 1973; Johannes, 1964; Keeney, 1972; McCarthy, 1972; Hellebust, 1970). Nitrate, another nitrogen species utilized by phytoplankton, was imported to the marshes year round. However, there are few documented instances in which nitrate was assimilated by phytoplankton in the presence of ammonia (Harrison, 1973; Eppley, Coatsworth, and Solórzano, 1969) and it is generally accepted that ammonia is the nitrogen species preferentially assimilated by marine phytoplankton (Riley and Chester, 1971). Furthermore, during the growing season, ammonia exports from the marshes to the estuary generally exceeded nitrate imports to the marshes. Therefore, based on the observed nutrient exports, it is probable that salt marshes promote phytoplankton productivity in estuarine systems.

There are several ways, in addition to salt marsh nutrient contributions to the estuary, that the marshes can influence estuarine primary productivity. For example, the nutrient depleted state of *Spartina* detritus exported from marshes led Thayer (1969; 1974) to speculate that bacteria utilizing this detritus as an energy source must assimilate nitrogen and phosphorus from estuarine waters and thereby compete with phytoplankton for nutrients. However, it can be argued that these bacteria by converting cellulose into organics utilizable by other trophic levels and thus function as primary producers.

Luxury uptake, the uptake of nutrients by phytoplankton in excess of the quantities required for optimal growth, has been demonstrated for both phosphorus and nitrogen (Foree, Jewell, and McCarthy, 1971). Phytoplankton in nutrient rich environments can thus store nutrients for utilization at times of low nutrient availability. It has not yet been demonstrated, however, whether estuarine phytoplankton tidally transported to the marshes can take advantage of the elevation in nutrient concentrations brought about by salt marsh nitrogen and phosphorus additions to estuarine waters within the marshes.

There has been much speculation concerning the capability of salt marshes to remove excess nitrogen and phosphorus from estuaries receiving municipal sewage discharges (Wass and Wright, 1969; Broome, Woodhouse, and Senaca, 1973; Flemer, 1972; Gosselink, Odum and Pope, in press; Valiela, Teal, and Sass, 1973; Nixon and Oviatt, 1973; Grant and Patrick, 1970; Bender and Correll, 1974). This study has revealed that natural marshes export dissolved nitrogen and phosphorus to the estuaries. It is possible that increased estuarine biomass caused by nutrient enrichment of estuaries would result in greater estuarine detrital nitrogen and phosphorus imports to the marshes with consequent increased export of dissolved nitrogen and phosphorus from the marshes. However, this study has also provided evidence that marshes serve to buffer estuarine waters with respect to inorganic nitrogen and phosphorus. The apparent increase in scale of some marsh nutrient cycling reactions and reversal in direction of nutrient flux through the marshes in response to natural variation in estuarine nitrogen and phosphorus concentrations suggest that marshes might, during certain periods of the year, function to reduce excessive estuarine nutrient loads.

Carbon Flux Through the Saltmarsh Ecosystem

The annual net transport of carbon as determined for both marshes in this study indicates that there is a net movement of total organic carbon from both areas to the York River throughout much of the year. This data supports the work of Odum (1971), Teal and Teal (1969) and others who have hypothesized that marshes are a source of organic material for estuaries.

The calculations presented in Table 17, which indicate the percent net angiosperm production exported from the study areas may be biased, however, by several factors. These include the fact that marsh grass may account for only 65 to 70 percent of the net primary production of the system (Stowe, Kirby, Brkich and Gosselink, 1971; Udell, Zarudsky and Doheny, 1969) and that there may be an import of particulate carbon in the form of sediments from the estuary which has not been accounted for in this budget (Meade, 1972).

Although annual net losses of both dissolved and particulate organic carbon from both marshes were observed, there was comparatively greater organic carbon lost from the Ware Creek study area in the dissolved fraction and greater lost from Carter Creek study area in the particulate fraction. These results too may be biased to a degree since much of the loss of particulate material from Carter Creek occurred during the July storm cycle, an event which did not occur during any Ware Creek sampling.

The sampling during the July cycle, however, presented a good opportunity to observe and record the flux of organic material during an extreme thunderstorm. Approximately 6.5 times as much POC was recorded lost from the marsh during this tidal cycle as during the next highest recorded loss for the rest of the year. Hence, erosion of particulate material from the marsh surface during rainstorms may play a major role in the loss of organic material from the marsh to the estuary.

Large seasonal variation in loss of POC was not evident from Ware Creek, suggesting that most of the plant material remains to decompose on the marsh surface. There was significant loss of POC from Carter Creek, however, from July through November, indicating possibly more rapid scouring from this area.

Mendelssohn (1973) reported that there was a higher dead standing crop throughout the year in Ware Creek marsh as compared to Carter Creek marsh. Considering that the net angio-sperm productivities of the two areas were also reported by Mendelssohn (1973) as being approximately the same, it is further suggested that significantly greater on-marsh decomposition is occurring in the Ware Creek study area with a resultant greater loss of DOC to the estuary. Our data suggest that a loss of organic material from marshes along the York River occurs throughout the entire size range from dissolved to particulate, with those areas having higher dead standing crops losing more of their organic production in the dissolved form, while others which may be more readily scoured lose much of their material in the particulate form.

Data from other investigators indicate that maximum loss of marsh grass production may occur through different size fractions. Nadeau (1972) found little export of particulate carbon from his Nacote Creek salt marsh in New Jersey. He did not measure the dissolved organic carbon fraction but did collect floating debris which he concluded was lost in large quantities. These results are unlike the results reported here and in the work of De la Cruz (1965), where floating material was found to be contributing much less to the total net export of organic material. These differences may have been due to the fact that Nadeau observed significant ice formation within his marsh system and significant foraging activities by muskrats and migratory birds. All of these could assist in rapid scouring of large material from the marsh. Ice formation had been observed by Redfield (1972) and Teal and Teal (1969) to be important in the scouring of dead standing material from the more northern Atlantic coastal marshes. In the two Virginia marshes reported on in this study, ice was observed only during the January, 1973 sampling date in Carter Creek. The ice sheet covering the marsh was thin and short-lived, and appeared ineffectual in scouring any dead standing plant material. Perhaps during unusually cold winters ice may play a more significant role in the removal of material from these marshes.

The measured export of ATP-carbon during twenty of the twenty-three sampled tidal cycles indicates that marshes are contributing significant amounts of living material to the York River estuary, year-round. Possibly this loss of ATP-carbon is largely in the form of benthic algae which are being lifted from the marsh surface and exported. Assuming that there is a significant year-round production of algae on the marsh surface (Pomeroy, 1959; Schelske and Odum, 1961) there appears a ready supply of material for export. General microscopic observations of the constituents of the particulate matter from these two study marshes revealed that a significant fraction of the algae present consists of benthic pennate diatoms that had apparently been resuspended by the tidal currents.

There was generally good agreement between the ATP-carbon flux and Chl *a* flux for both study marshes. The direction and magnitude of the movement of these two parameters was complicated, however, by the fact that the Chl *a* values are uncorrected for phaeophytins. Therefore, subtraction of Chl *a*-carbon from ATP-carbon to determine non-algal "living" carbon was not possible. During several tidal cycle samplings when the directions of net ATP-carbon and Chl *a* flux did not agree there was significant net movement of POC in the same direction as the Chl *a*.

Increases in the standing crop of living material for both marshes in the summer were evident. It appears that the ATP bioassay effectively measured the living material present in the marsh water. Assuming, for the sake of comparison, that the ATP was associated only with photosynthesizing algae, the primary productivity values determined for a number of the same hourly sampling points indicated that only during the January 1972, Ware Creek tidal cycle might the ATP-carbon values be considered too low to account for the primary production in the water column.

Increases in the standing crop of living material for both marshes in the summer compare, interestingly, with the seasonal variation of ATP levels for both marshes (Fig. 47). Maximum concentrations of ATP in the waters flushing the Ware Creek study area occurred during the July sampling, while ATP levels in the Carter Creek waters reached a maximum during August. Fall die-off of living material as measured by the ATP levels again occurred earlier in Ware Creek and appears to parallel the somewhat different growing seasons and periods of peak marsh production recorded by Mendelssohn (1973) for these same marshes. He found that the Ware Creek angiosperm plant community matured by the middle of July but that the Carter Creek plant community did not mature until the middle of September. This variation in angiosperm production between the two marsh areas was explained by the fact that the Ware Creek plant community contains many freshwater species which reach peak standing crops in May and June. Comparison of the ATP-carbon values with those of water temperature suggests that the dissimilar seasonal trends between the two marshes found in this study were not temperature related.

SUMMARY

Annual nitrogen, phosphorus and carbon budgets for two Virginia salt marshes were determined by monthly measurements of water discharge and constituent concentrations over tidal cycles.

Phosphorus Cycle

In both *Spartina cynosuroides* dominated Ware Creek marsh and *Spartina alterniflora* dominated Carter Creek marsh, the phosphorus cycle was characterized by elevated summer phosphorus concentrations. Dissolved inorganic phosphorus was exported from Carter Creek to the estuary throughout the year and from Ware Creek except during fall. Over a year there was net dissolved inorganic phosphorus export from both marshes to the York River estuary. Dissolved organic phosphorus was exported from both marshes at all times during the year, but on an annual basis particulate phosphorus was lost from the estuary to the marshes. Considering all three phosphorus forms, there was net phosphorus loss from the estuary to the marshes. This phosphorus budget suggests a cycle of both loss of estuarine particulate phosphorus to marsh sediments and mineralization of estuarine particulate phosphorus in the marshes with subsequent export of dissolved inorganic and organic phosphorus to the estuary.

Nitrogen Cycle

The salt marsh nitrogen cycle was characterized by elevated winter nitrite and nitrate levels and elevated summer ammonia, dissolved organic nitrogen, and particulate nitrogen concentrations. Nitrate and nitrite were lost to both marshes from the estuary throughout the year. Ammonia was exported from Ware Creek except during fall and imported to Carter Creek except during spring. On an annual basis there was a strong export of ammonia to Carter Creek. Dissolved organic nitrogen was exported from both marshes at all times during the year while particulate nitrogen was exported only during fall and winter. Annually there was a strong net export of dissolved organic nitrogen from both marshes and a net import of particulate nitrogen into Carter Creek from the estuary, while in Ware Creek there was a small net export of particulate nitrogen.

Nitrogen flux data thus indicate a cycle of loss of nitrate and nitrite to both marshes via denitrification and conversion to molecular nitrogen. Particulate nitrogen imported to the marshes from the estuary is mineralized and returned to the estuary as ammonia and dissolved organic nitrogen. Ammonia entering the marshes from the estuary is nitrified to produce nitrate and then perhaps denitrified. Considering all nitrogen species, there is a strong net export of nitrogen from the marsh to the estuary. This suggests significant fixation of atmospheric nitrogen by marsh flora and subsequent export of some of this nitrogen.

Detritus

Concentrations of seston in the water generally followed seasonal trends. Particulate organic carbon, dissolved inorganic carbon and dissolved organic carbon levels were highest in the summer and early fall and lowest in the late winter and early spring. ATP levels and chlorophyll 'a' concentrations indicated that much of the standing crop of living material in the water was autotrophic.

Flux calculations indicated a net export of carbon from the marshes. In Ware Creek the majority of the carbon was exported in the dissolved organic form, while the major portion exported from Carter Creek was in the particulate form.

Impact on Water Quality

The salt marsh ecosystem thus influences estuarine primary productivity by mineralizing particulate organic nitrogen and phosphorus of estuarine origin, exporting these nutrients in a dissolved form that can be assimilated by estuarine autotrophs.

Organic carbon is exported to the estuary in both dissolved and particulate form. The extent to which this material is utilized by specific autotrophs, heterotrophs and other consumers is not known. However, it would seem reasonable to assume that this contribution adds significantly to the productive potential of the estuary by supplying a source of energy.

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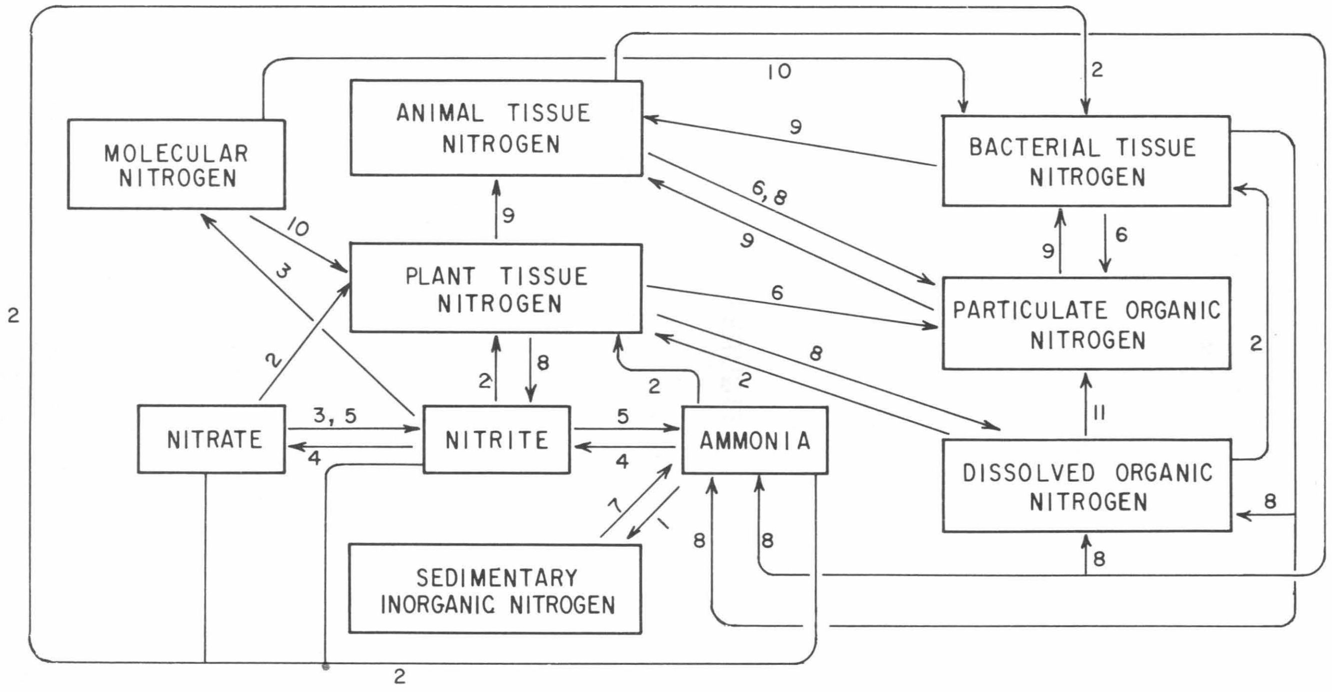
FIGURES

Figure 1

The marine biogeochemical nitrogen cycle. Modified from Riley and Chester, (1971).



1. Adsorption
2. Assimilation
3. Bacterial Denitrification
4. Bacterial Nitrification
5. Bacterial Nitrogen Reduction
6. Death
7. Desorption
8. Excretion
9. Grazing
10. Nitrogen Fixation
11. Precipitation

Figure 2

The marine biogeochemical phosphorus cycle.
Modified from Riley and Chester, (1971).

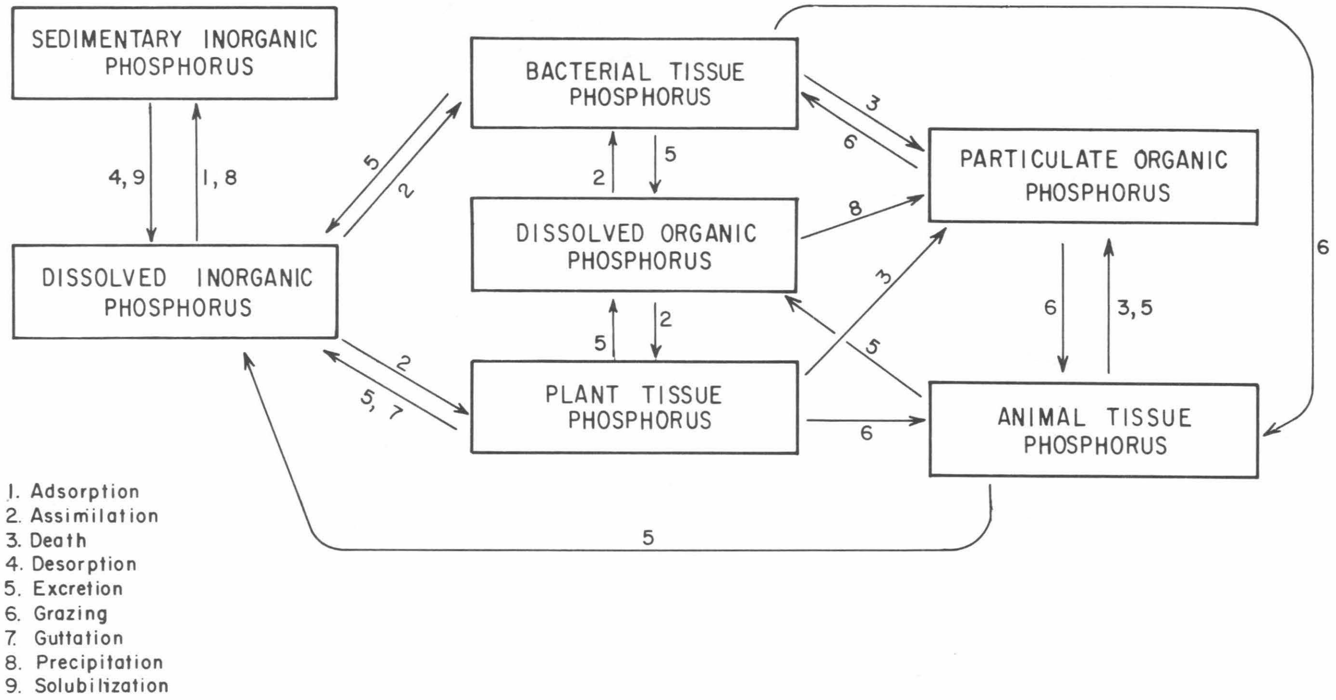


Figure 3
Ware Creek and Carter Creek in relation to the York River.

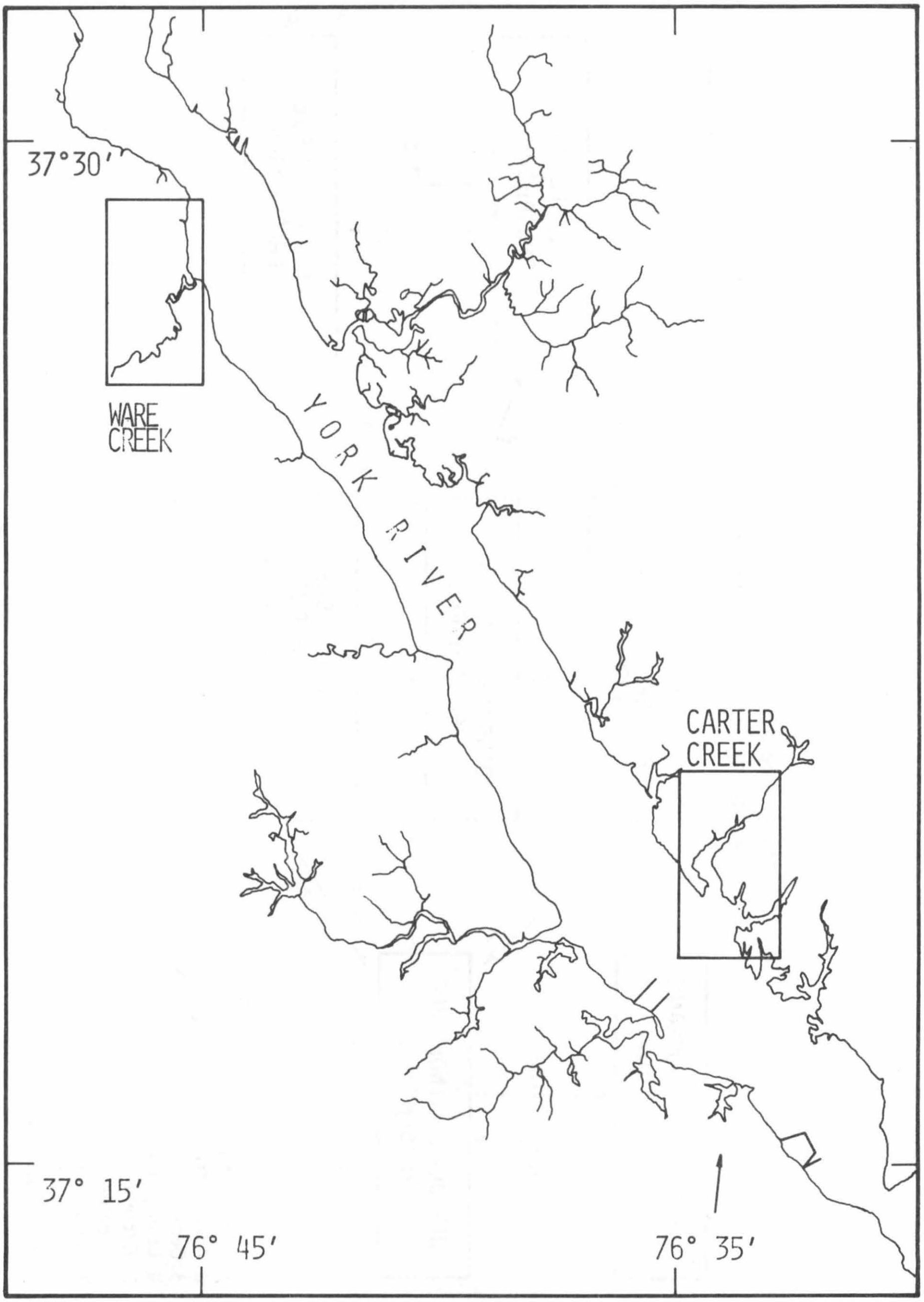


Figure 4

Carter Creek Marsh

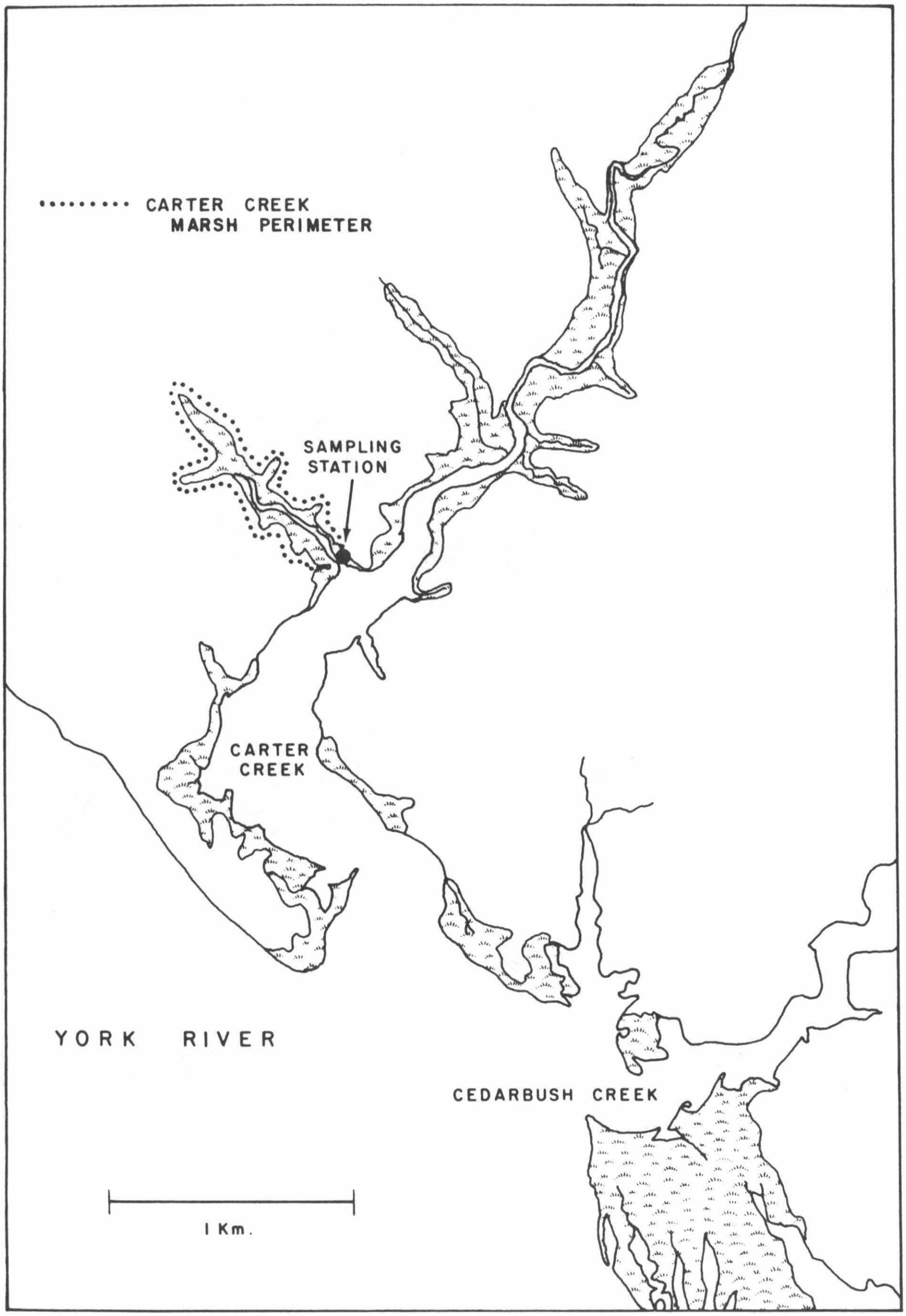


Figure 5

Ware Creek Marsh

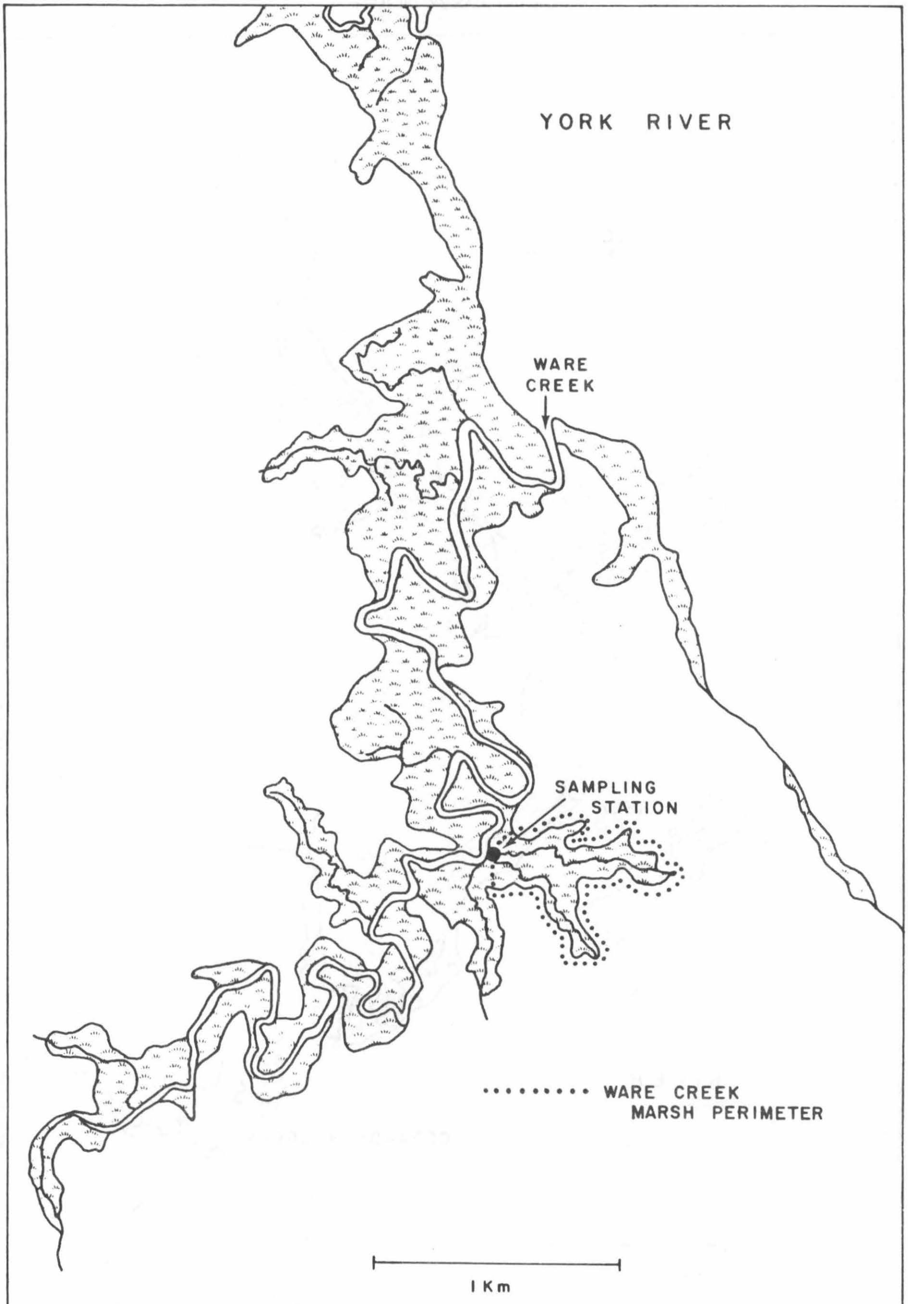


Figure 6

Annual variation in mean water temperature over a tidal cycle for Ware Creek and Carter Creek marshes.

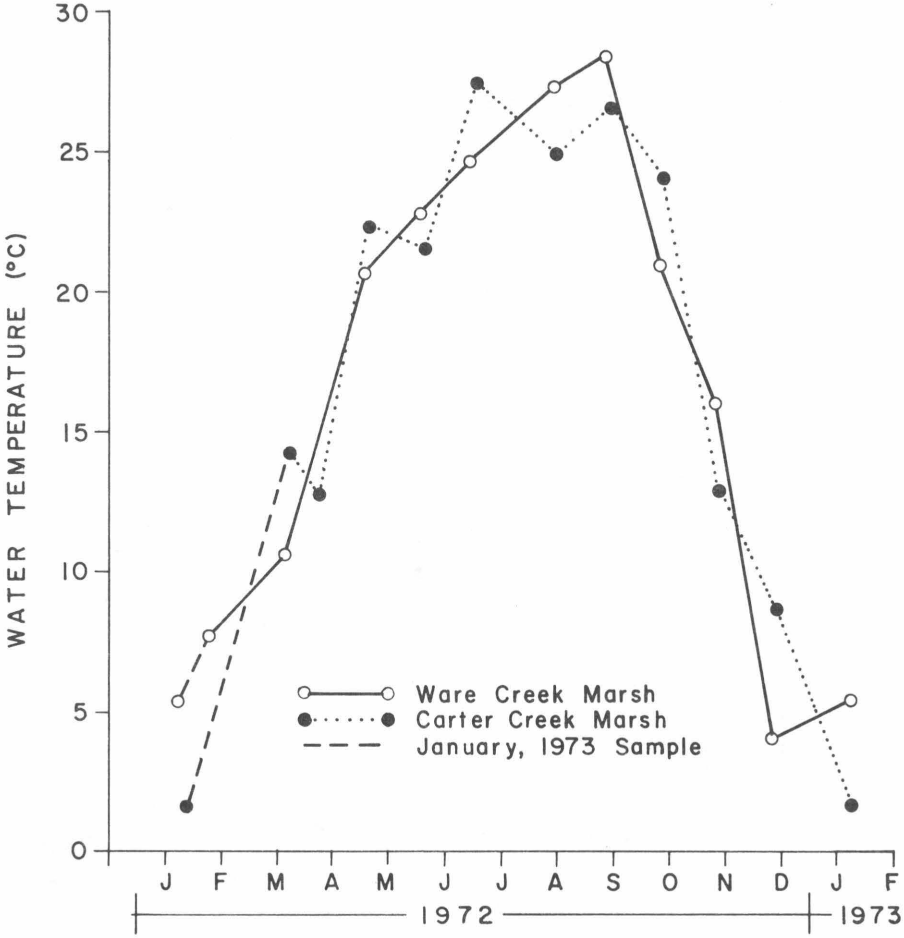


Figure 7

Annual variation in Ware Creek marsh high slack water and low slack water salinity.

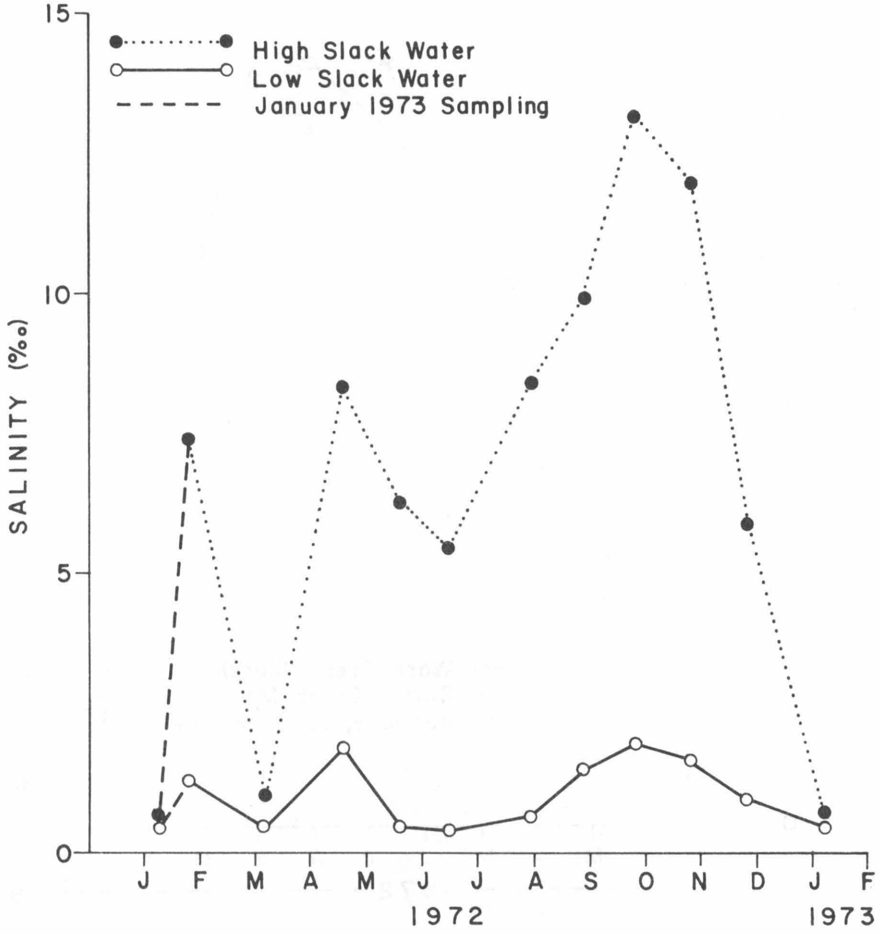


Figure 8

Annual variation in Carter Creek marsh high slack water and low slack water salinity.

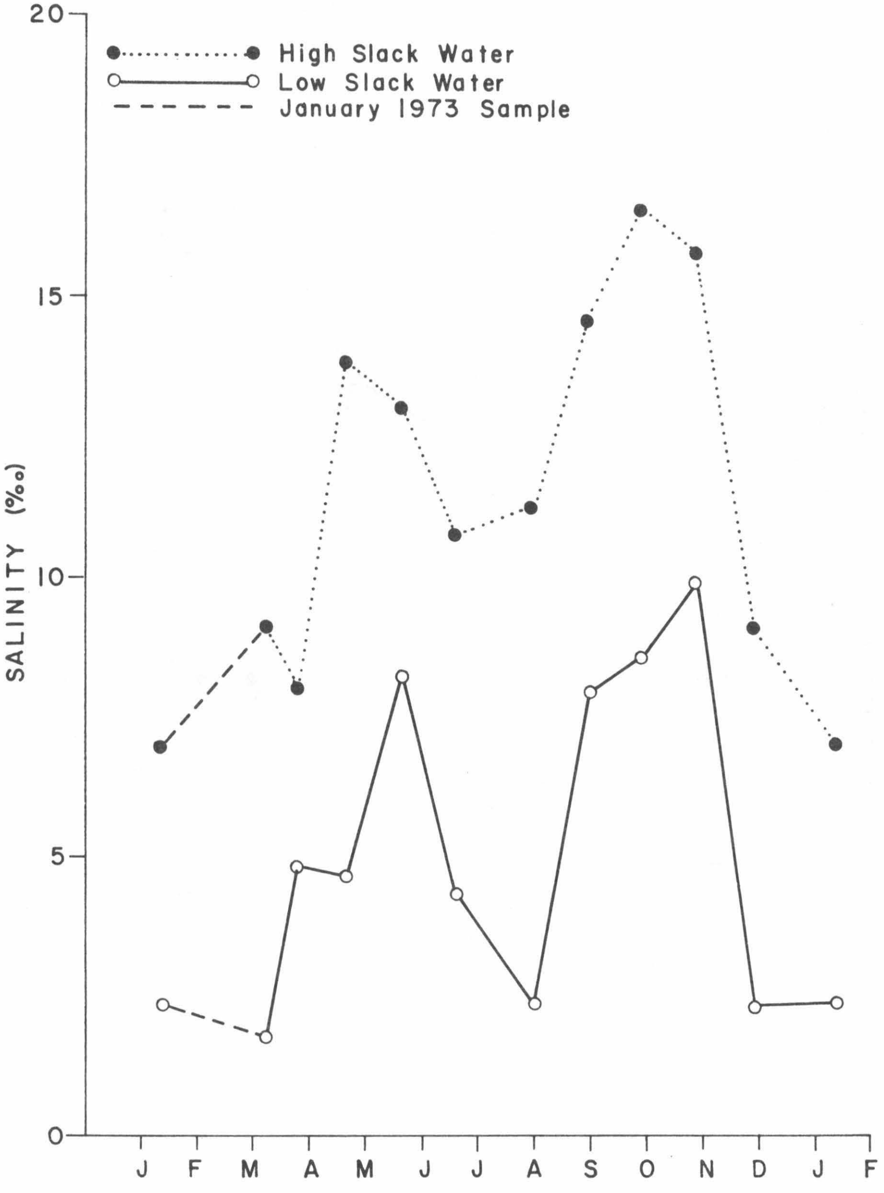


Figure 9

Annual variation in Ware Creek marsh high slack water and low slack water dissolved inorganic phosphorus concentration.

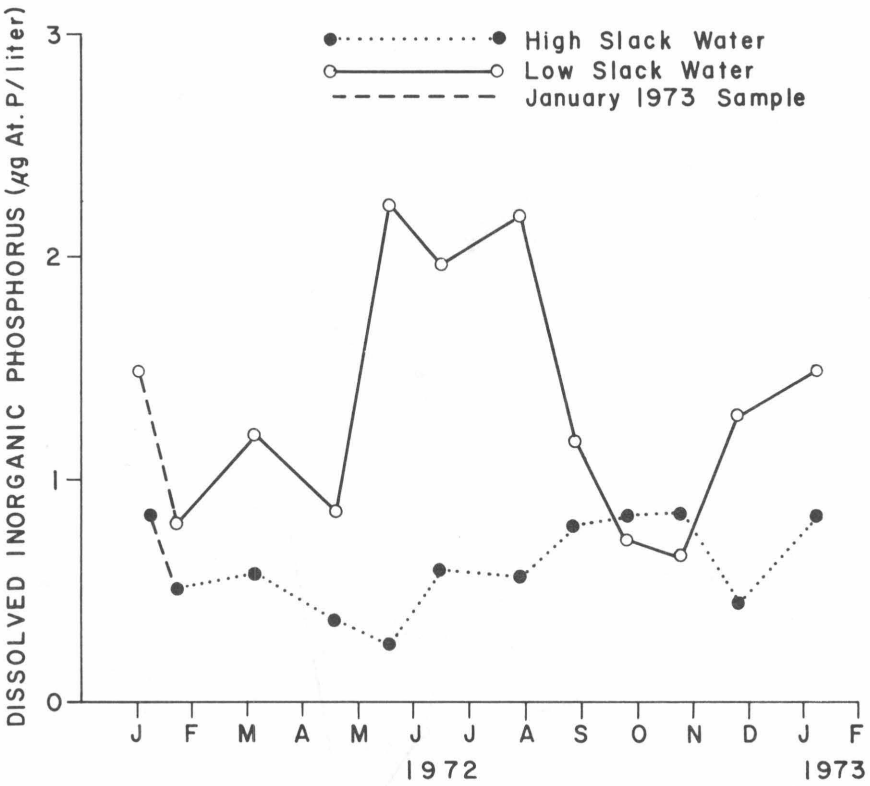


Figure 10

Annual variation in Carter Creek marsh high slack water and low slack water dissolved inorganic phosphorus concentration.

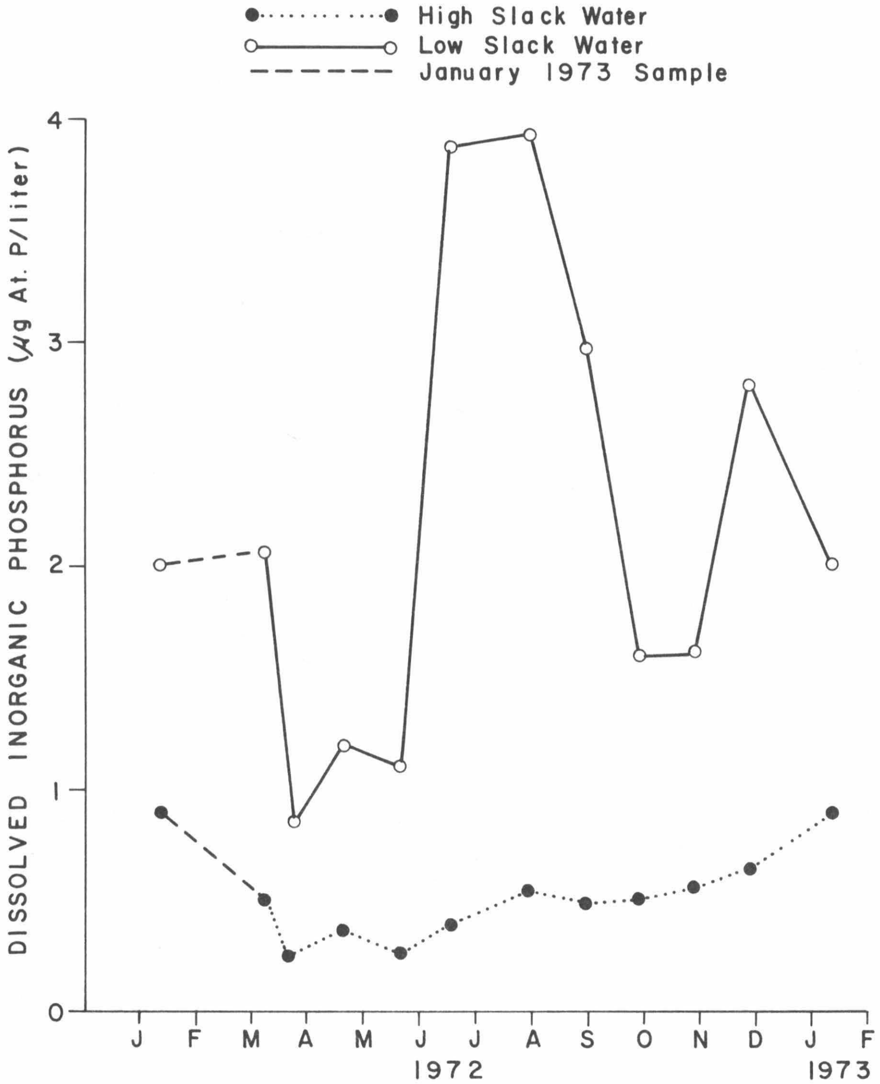


Figure 11

Variation in dissolved inorganic phosphorus concentration over Ware Creek marsh summer and winter tidal cycles.

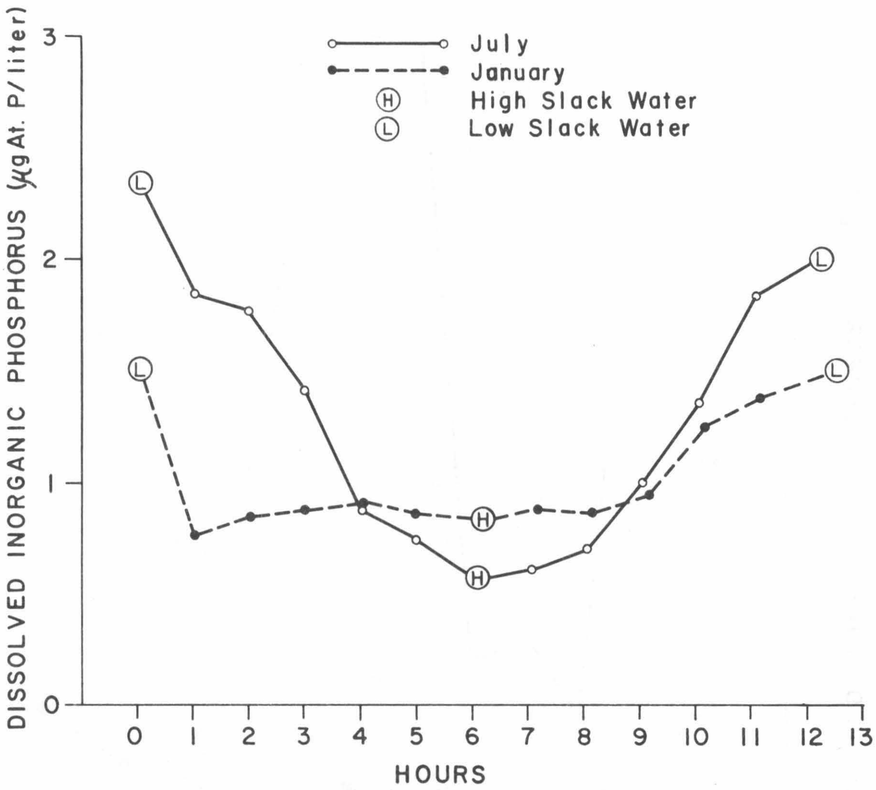


Figure 12

Variation in dissolved inorganic phosphorus concentration over Carter Creek marsh summer and winter tidal cycles.

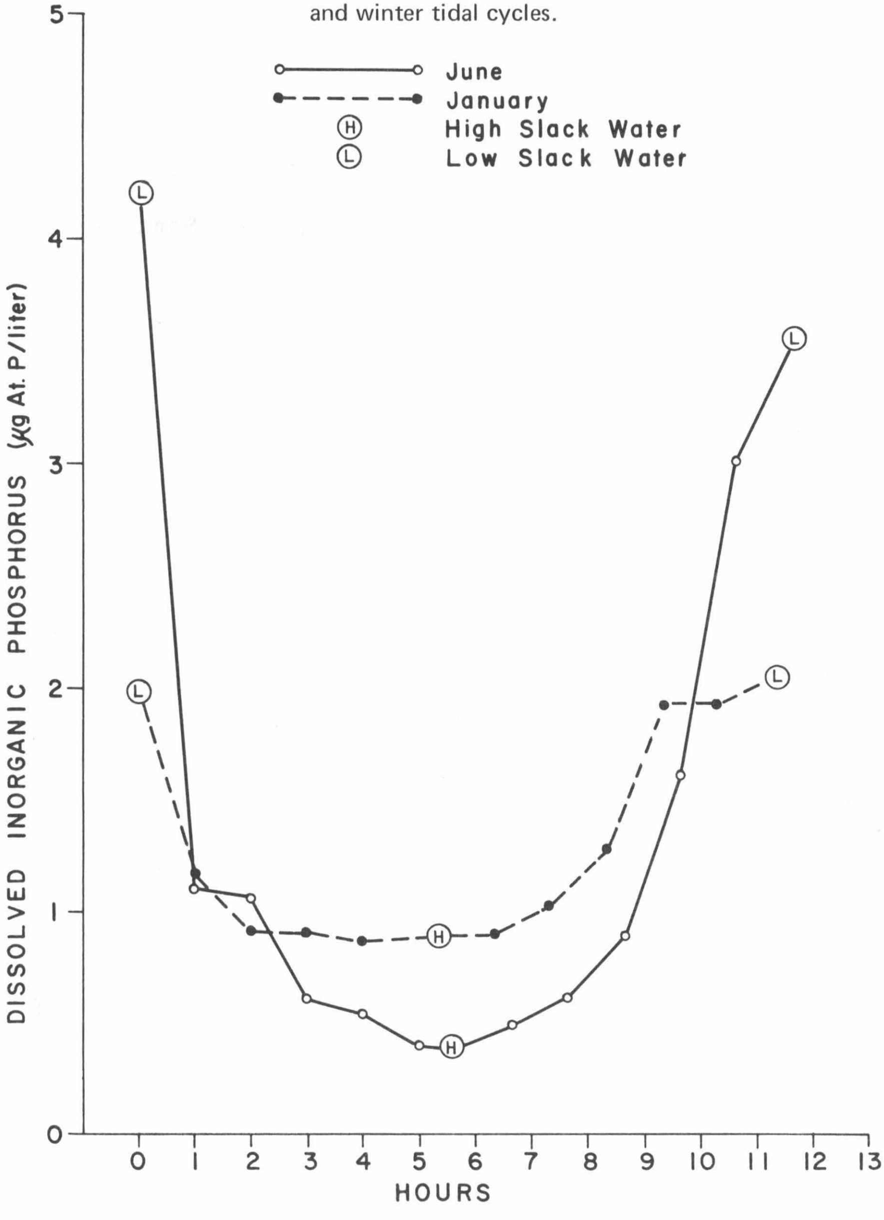


Figure 13

Annual variation in Ware Creek marsh high slack water and low slack water dissolved organic phosphorus concentration.

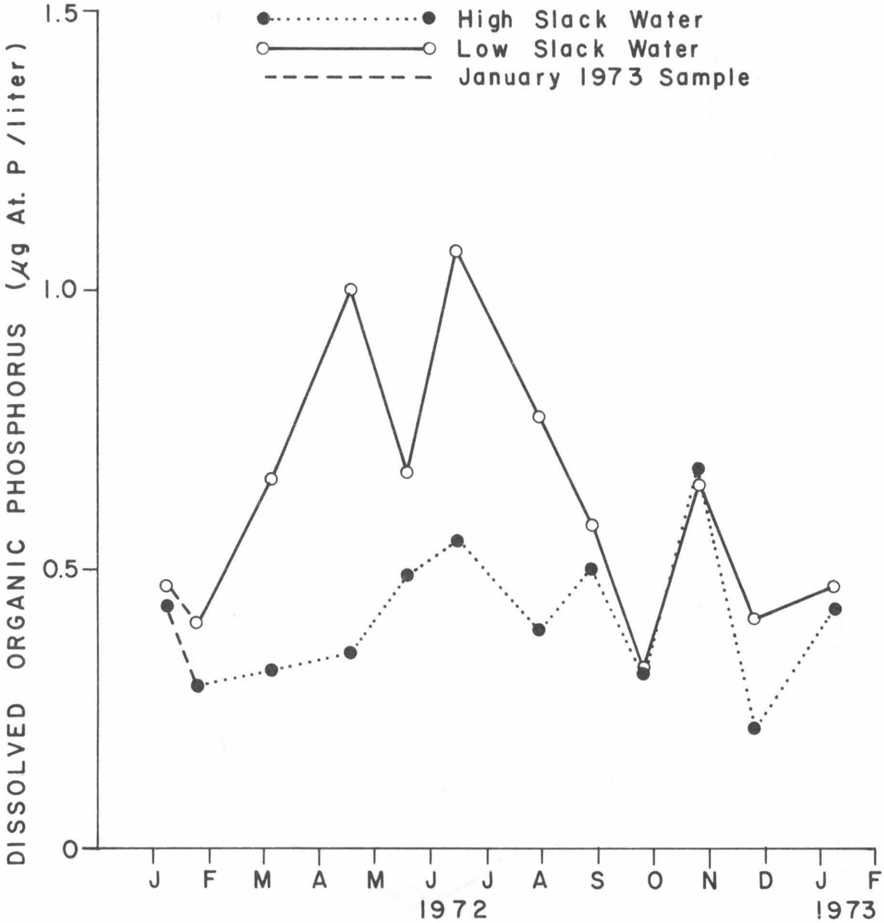


Figure 14

Annual variation in Carter Creek marsh slack water and low slack water dissolved organic phosphorus concentration.

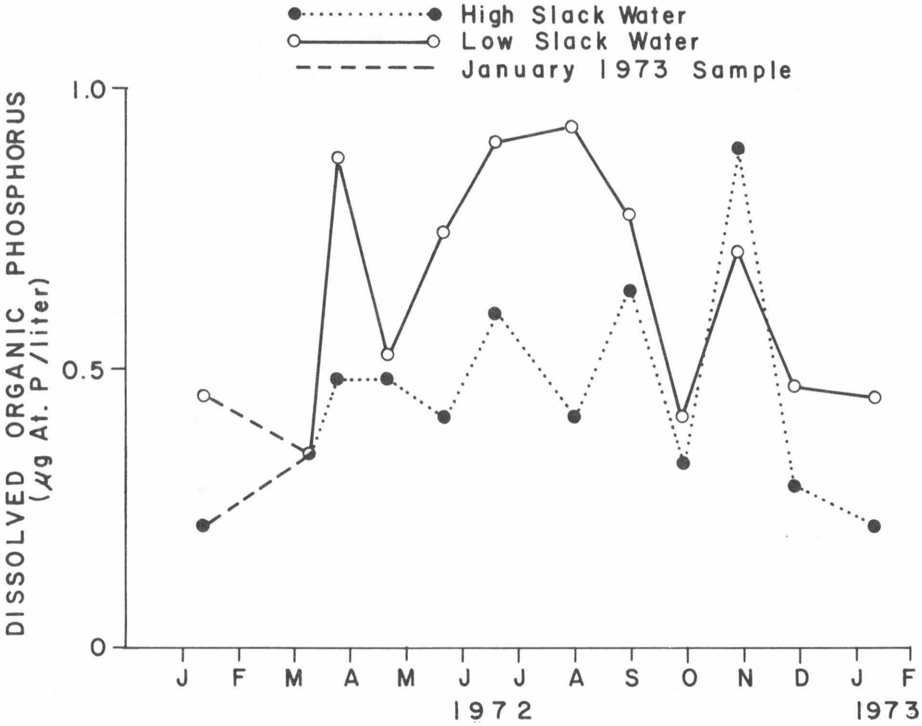


Figure 15

Variation in dissolved organic phosphorus concentration over Ware Creek marsh summer and winter tidal cycles.

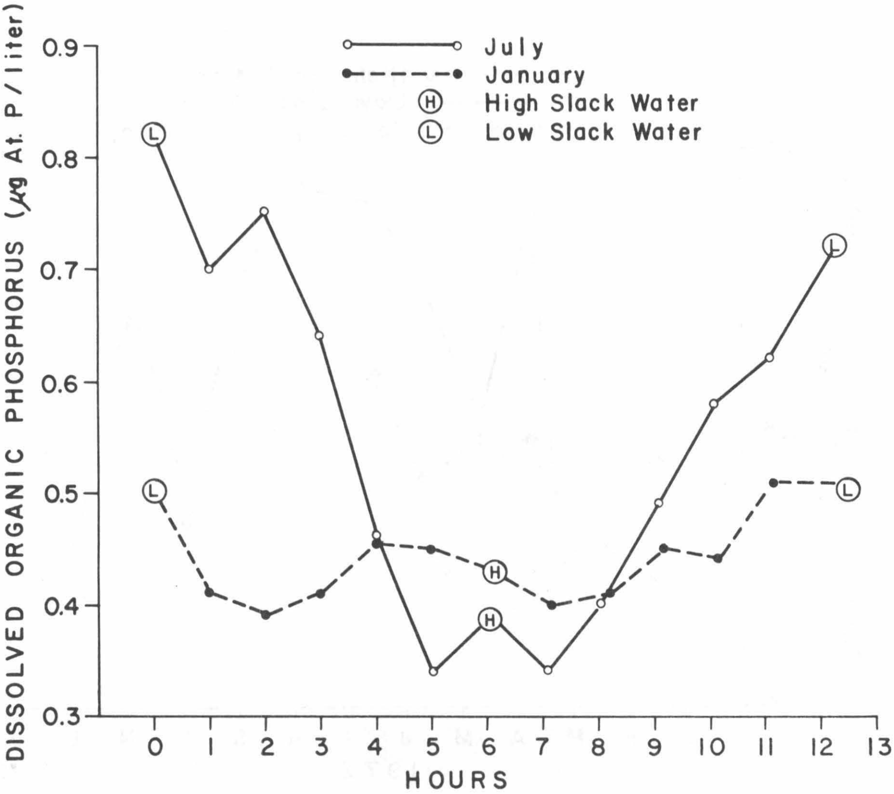


Figure 16

Variation in dissolved organic phosphorus concentration over Carter Creek marsh summer and winter tidal cycles.

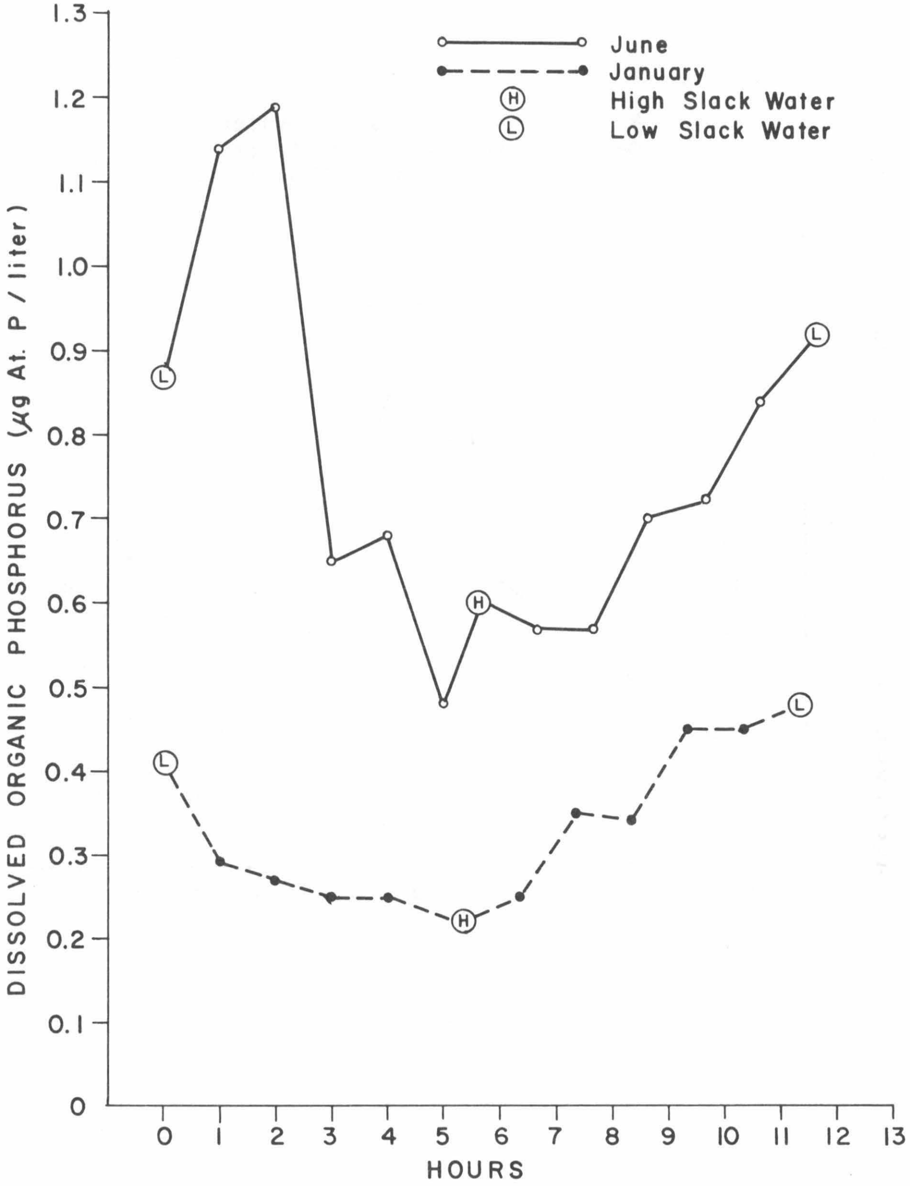


Figure 17

Annual variation in Ware Creek marsh high slack water and low slack water particulate phosphorus concentration.

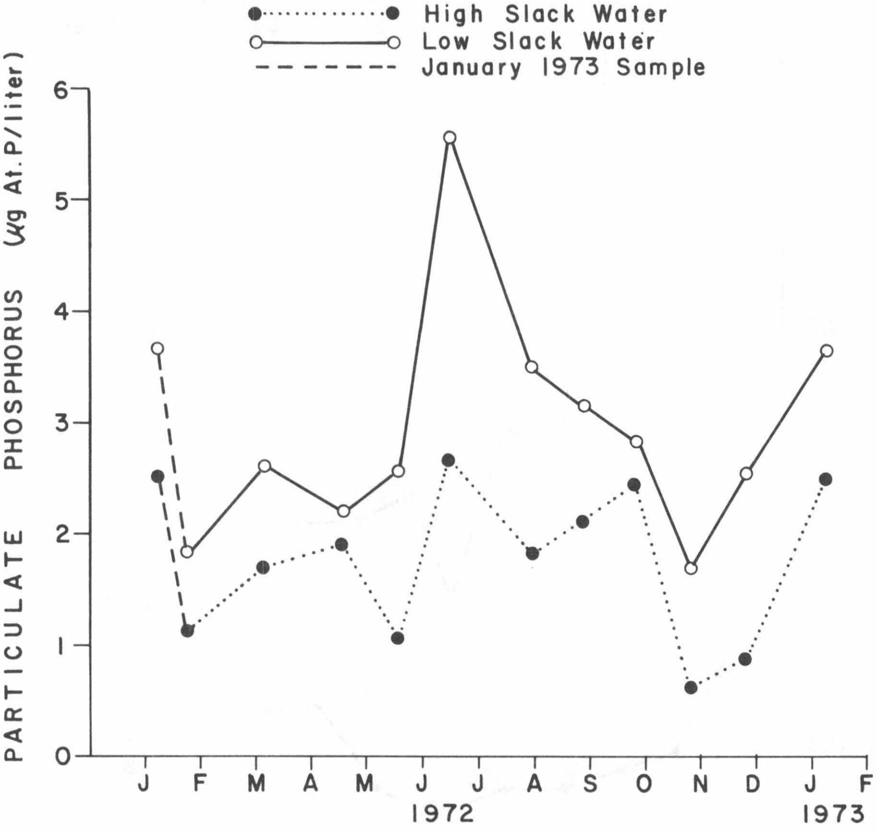


Figure 18

Annual variation in Carter Creek marsh high slack water and low slack water particulate phosphorus concentration.

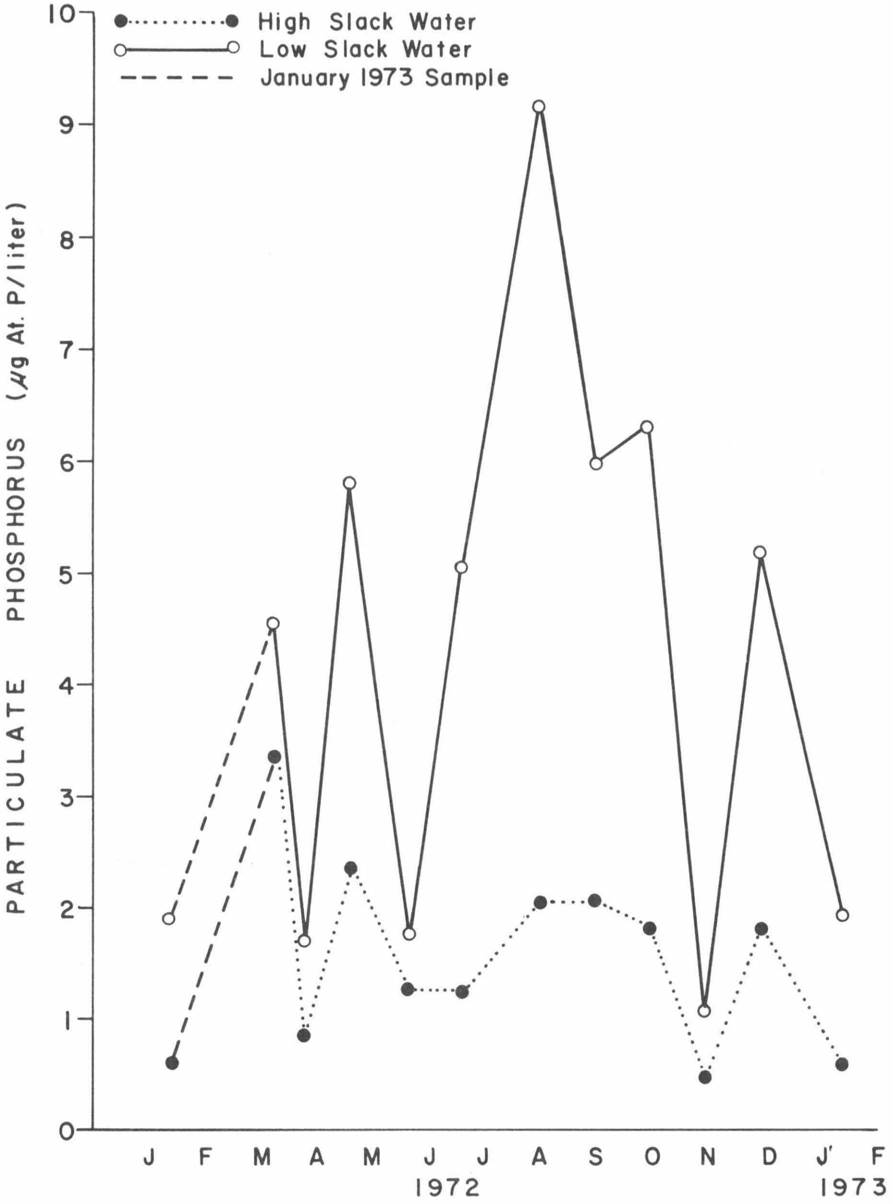


Figure 19

Variation in particulate phosphorus concentration over Ware Creek marsh summer and winter tidal cycles.

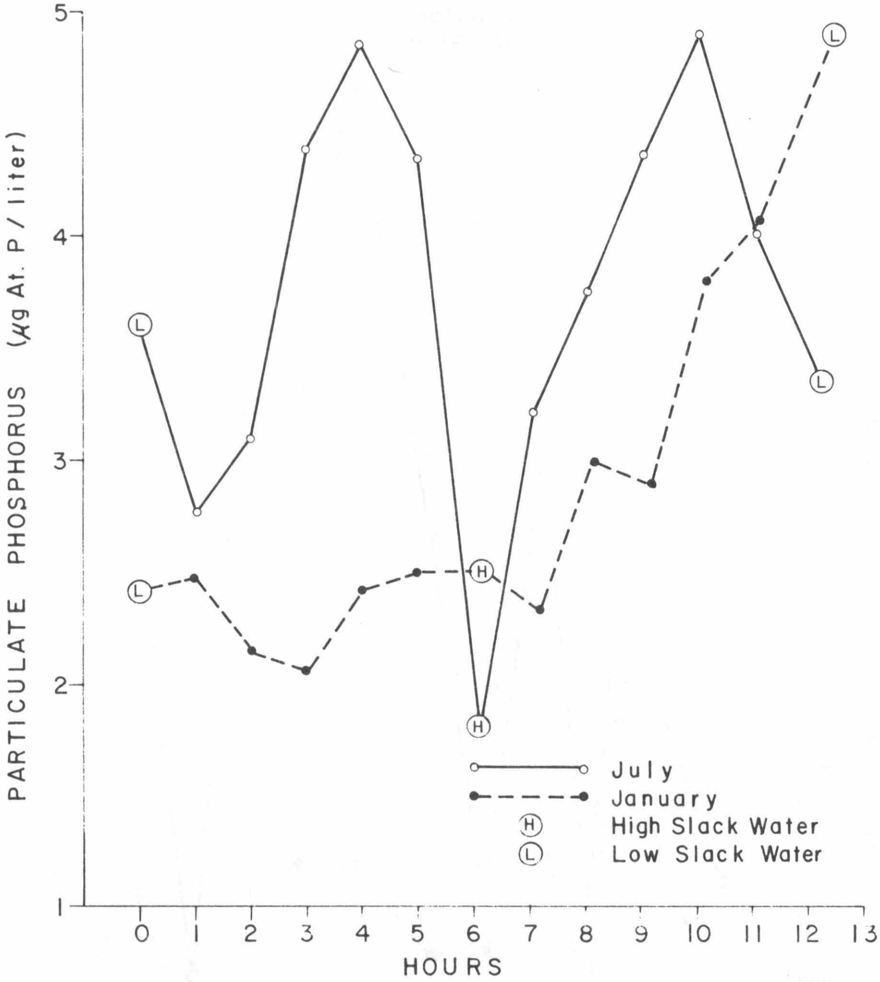


Figure 20

Variation in particulate phosphorus concentration over Carter Creek marsh summer and winter tidal cycles.

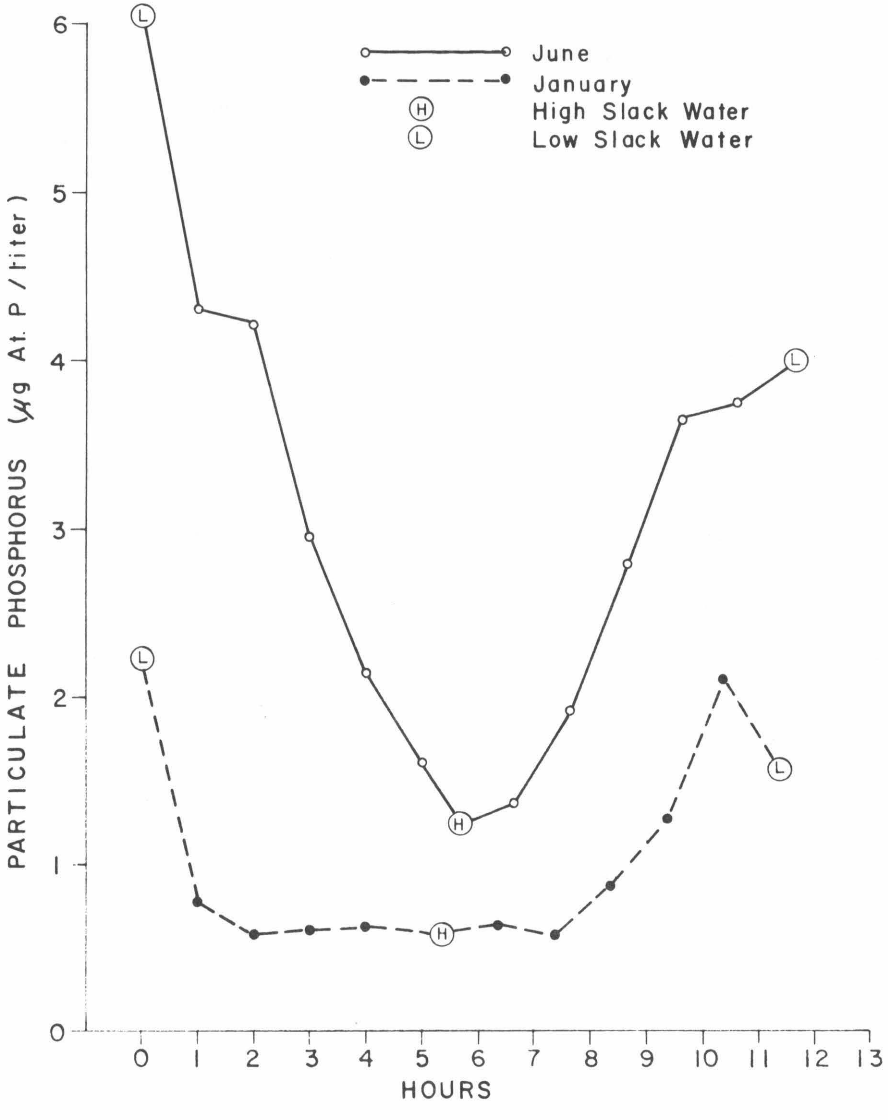


Figure 21

Annual variation in Ware Creek marsh high slack water and low slack water nitrate concentration.

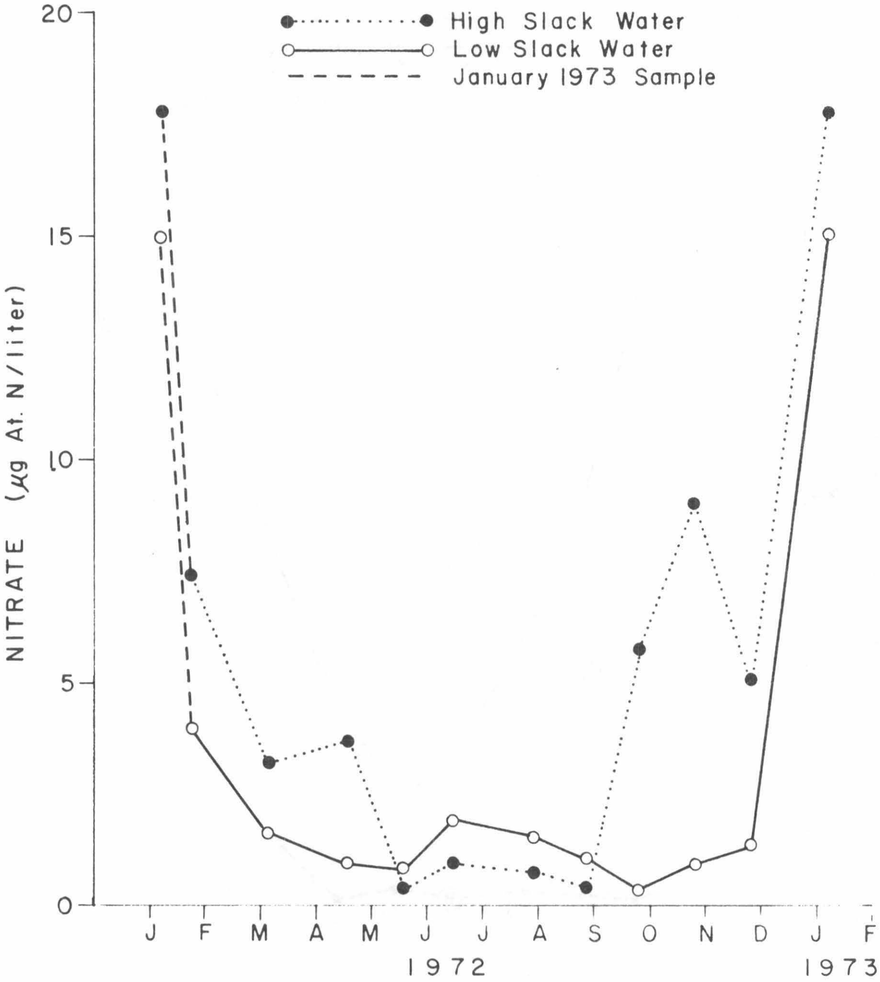


Figure 22

Annual variation in Carter Creek marsh high slack water and low slack water nitrate concentration.

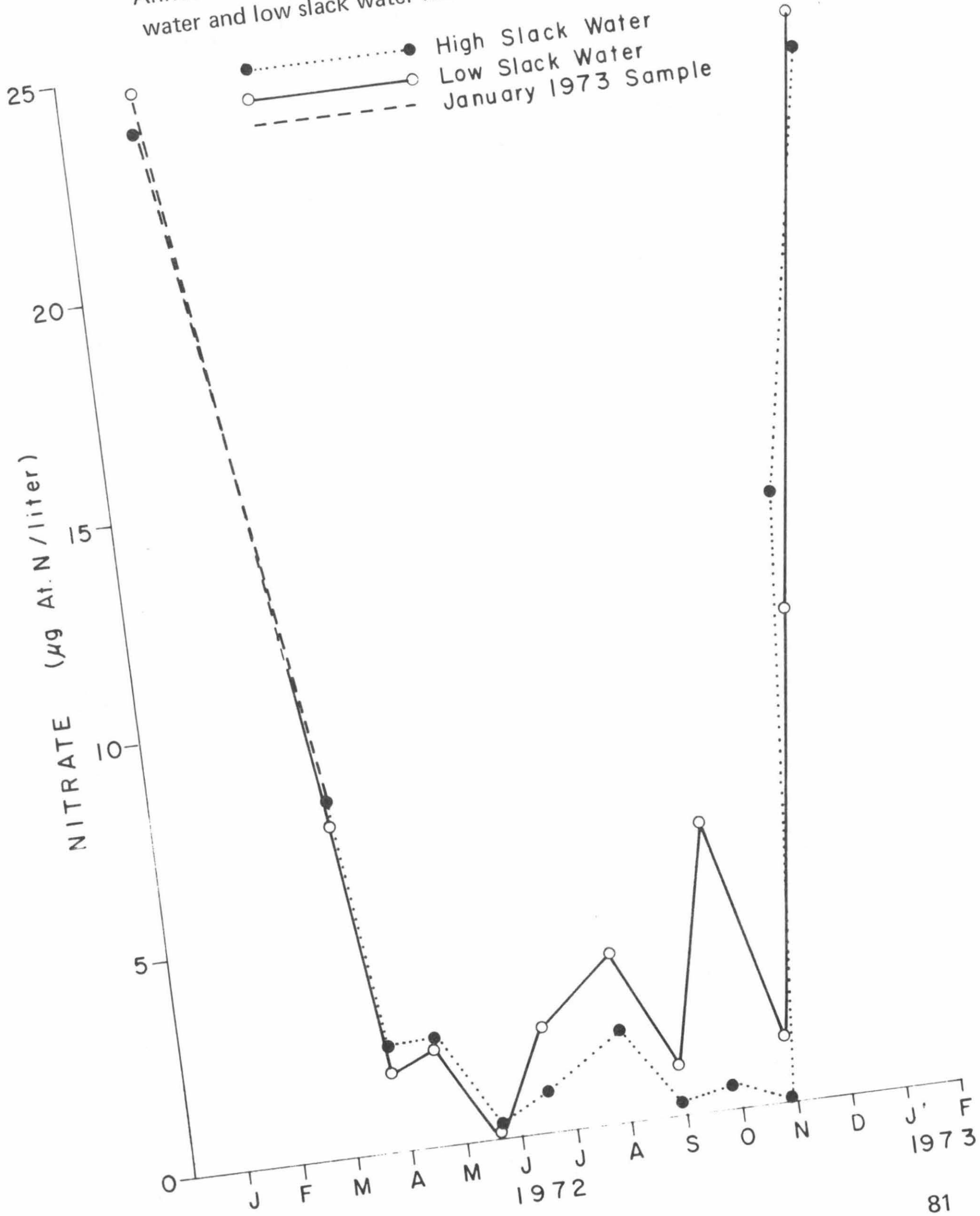


Figure 23

Variation in nitrate concentration over Ware Creek marsh summer and winter tidal cycles.

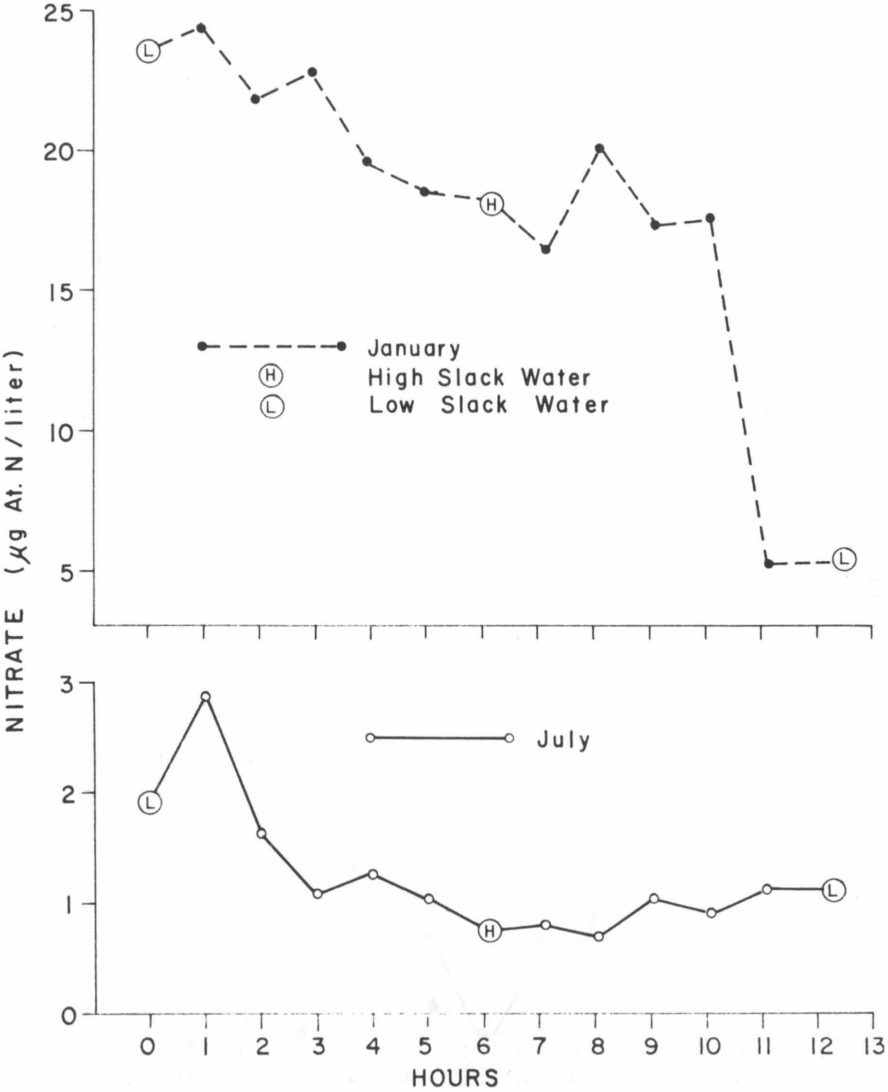


Figure 24

Variation in nitrate concentration over Carter Creek marsh summer and winter tidal cycles.

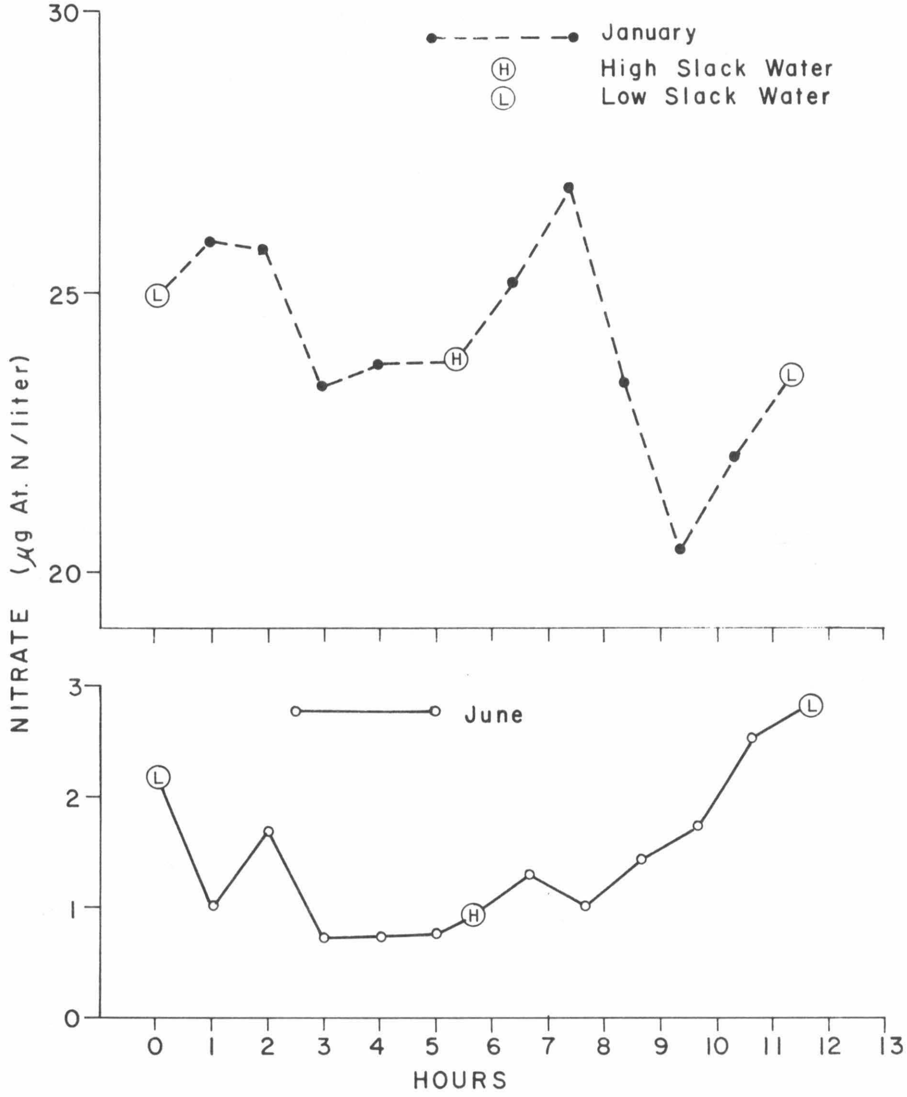


Figure 25

Annual variation in Ware Creek marsh high slack water and low slack water nitrate concentration.

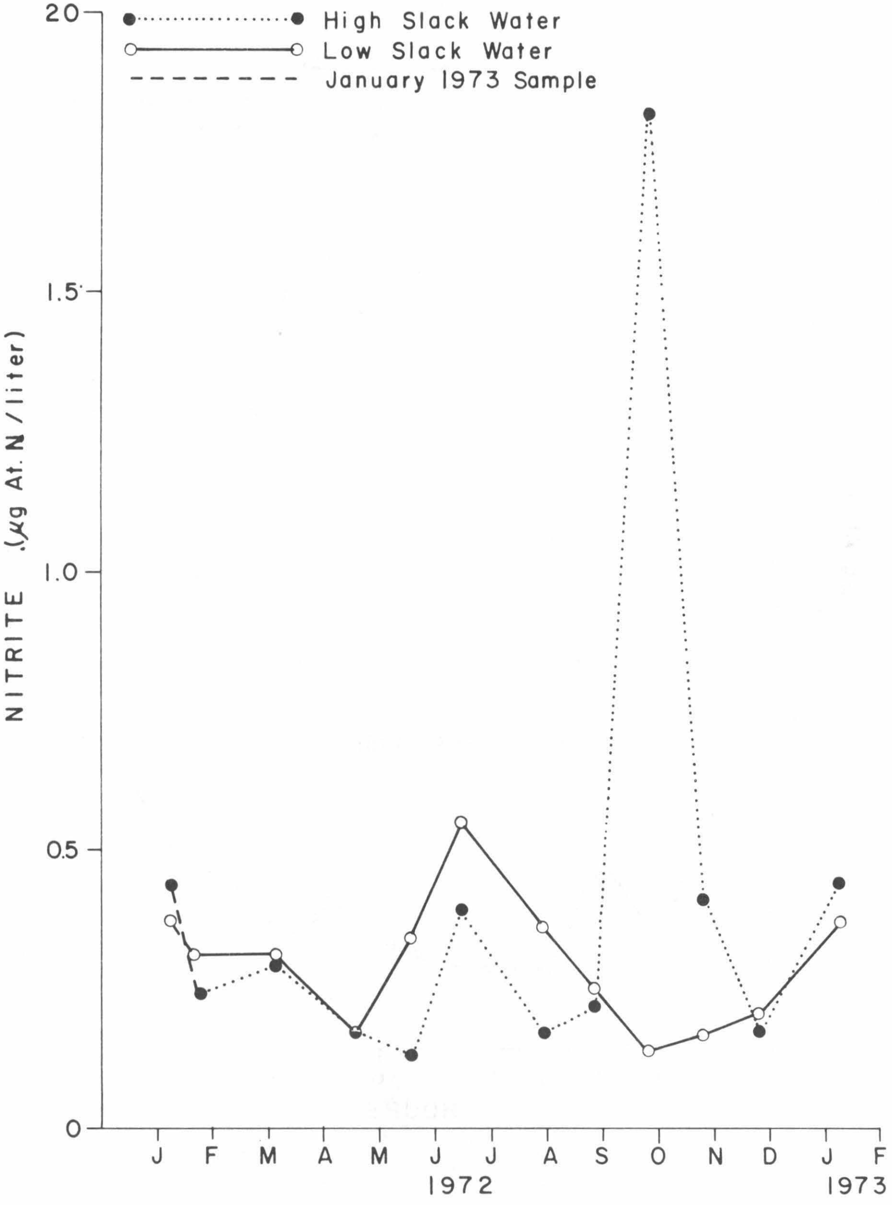


Figure 26

Annual variation in Carter Creek marsh high slack water and low slack water concentration.

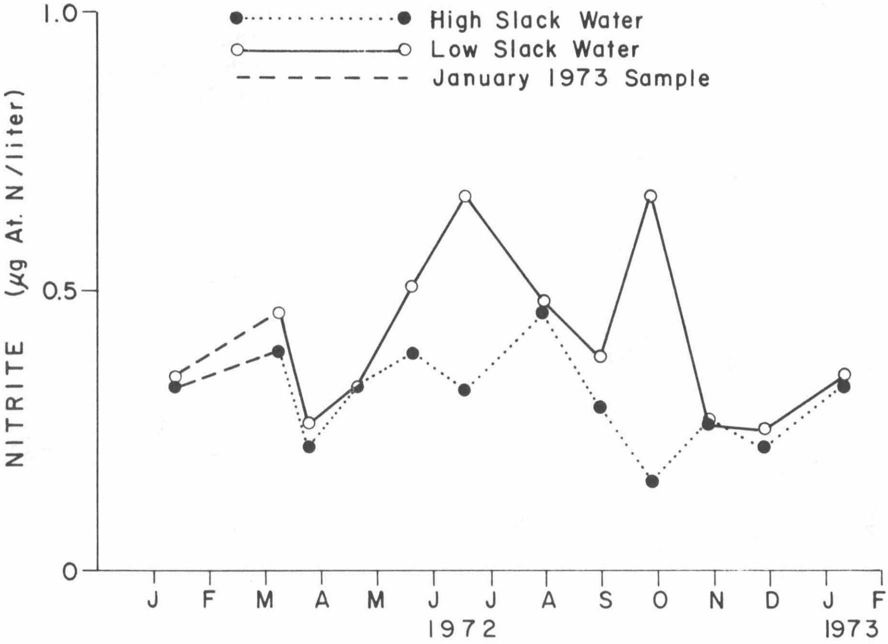


Figure 27

Variation in nitrite concentration over Ware Creek marsh summer and winter tidal cycles.

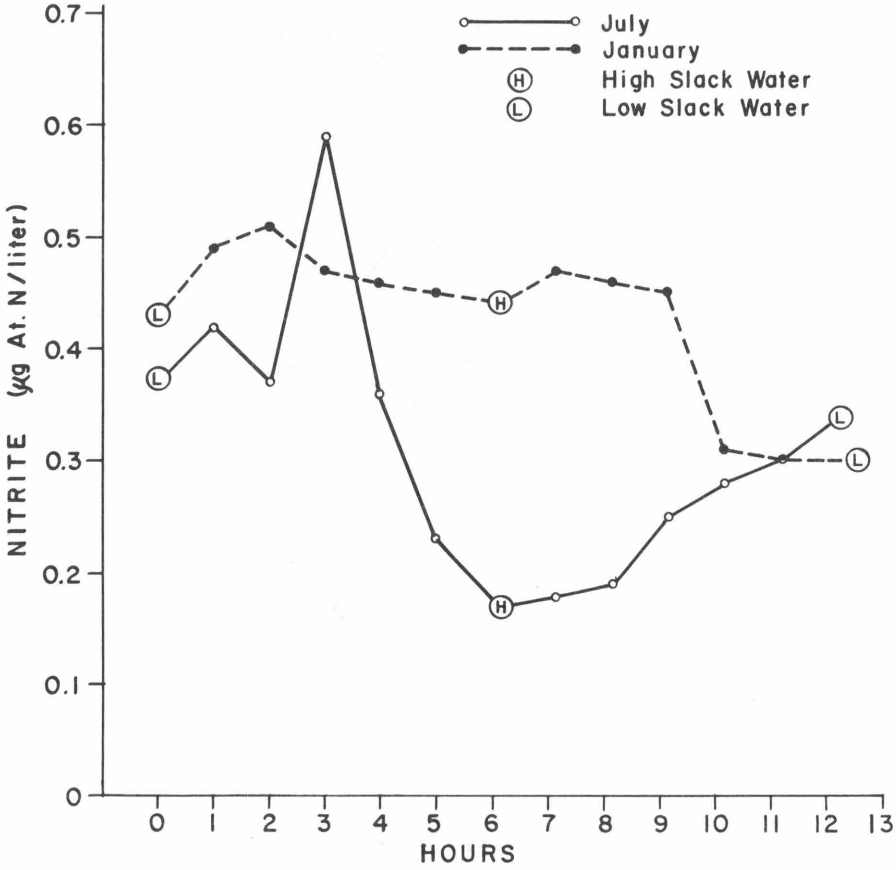


Figure 28

Variation in nitrite concentration over Carter Creek marsh summer and winter tidal cycles.

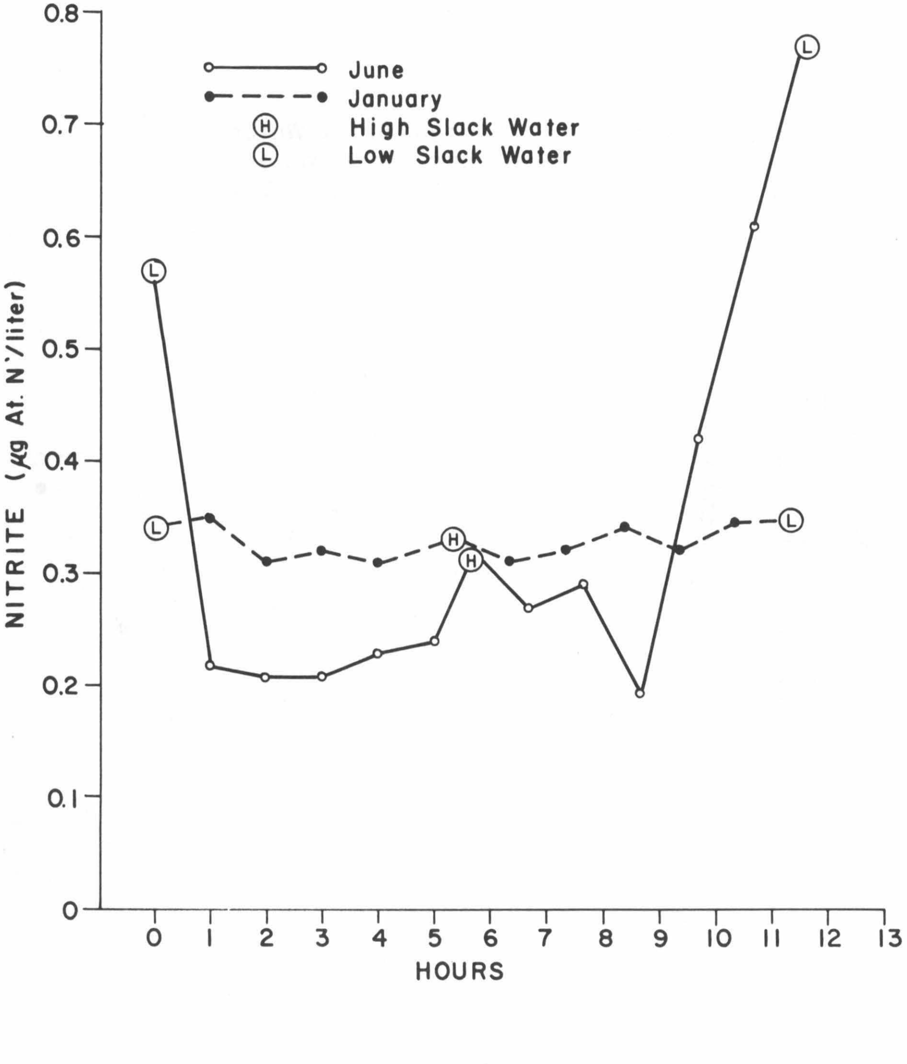


Figure 29

Annual variation in Ware Creek marsh high slack water and low slack water ammonia concentration.

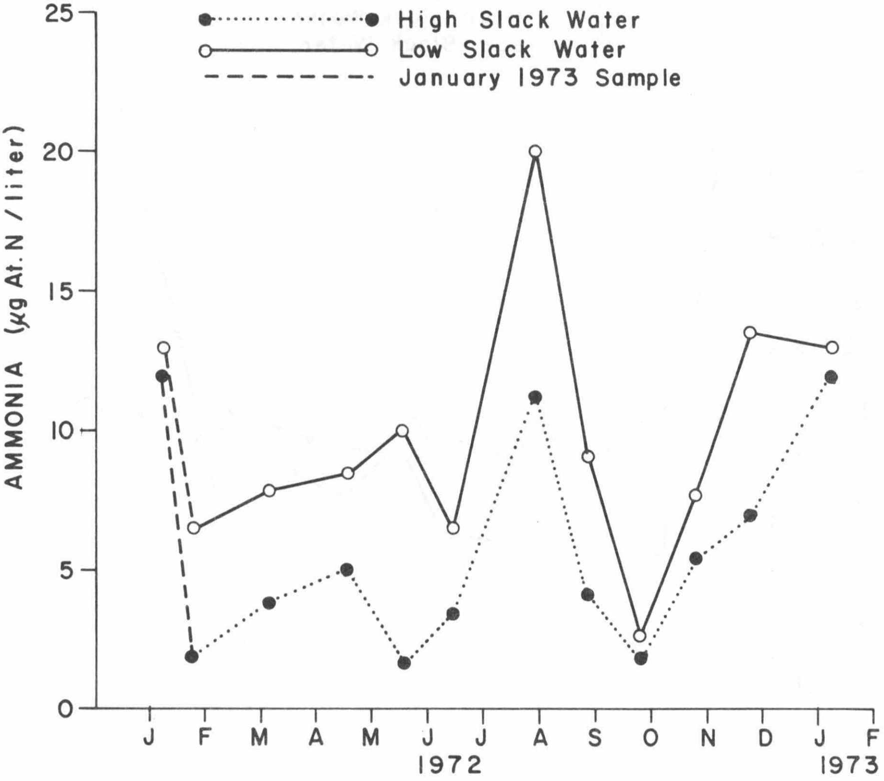


Figure 30

Annual variation in Carter Creek marsh high slack water and low slack water ammonia concentration.

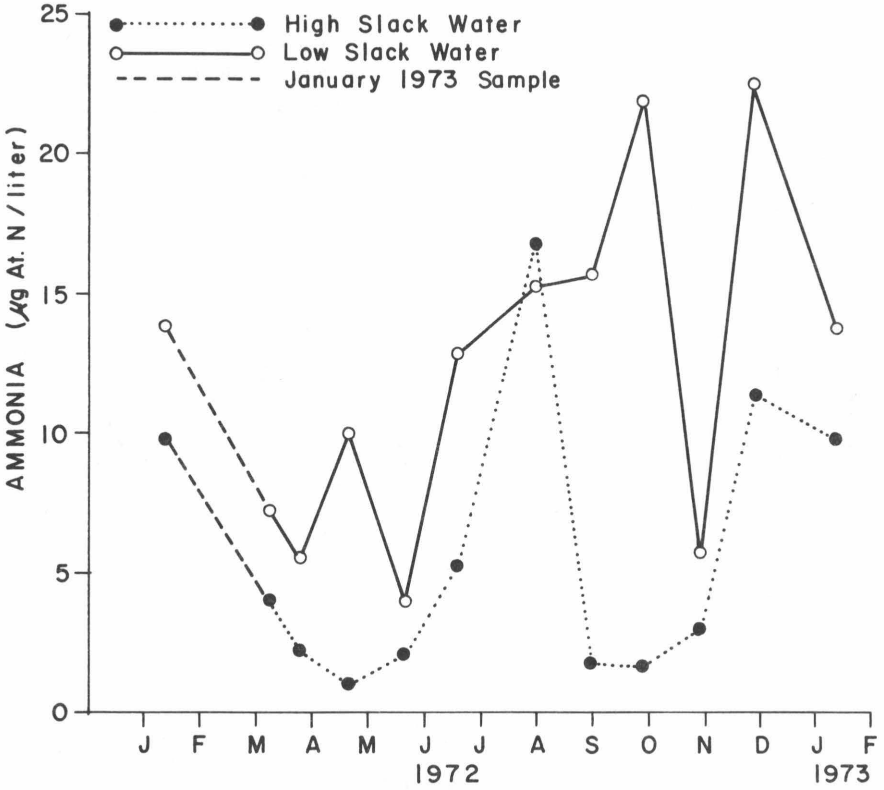


Figure 31

Variation in ammonia concentration over Ware Creek marsh summer and winter tidal cycles.

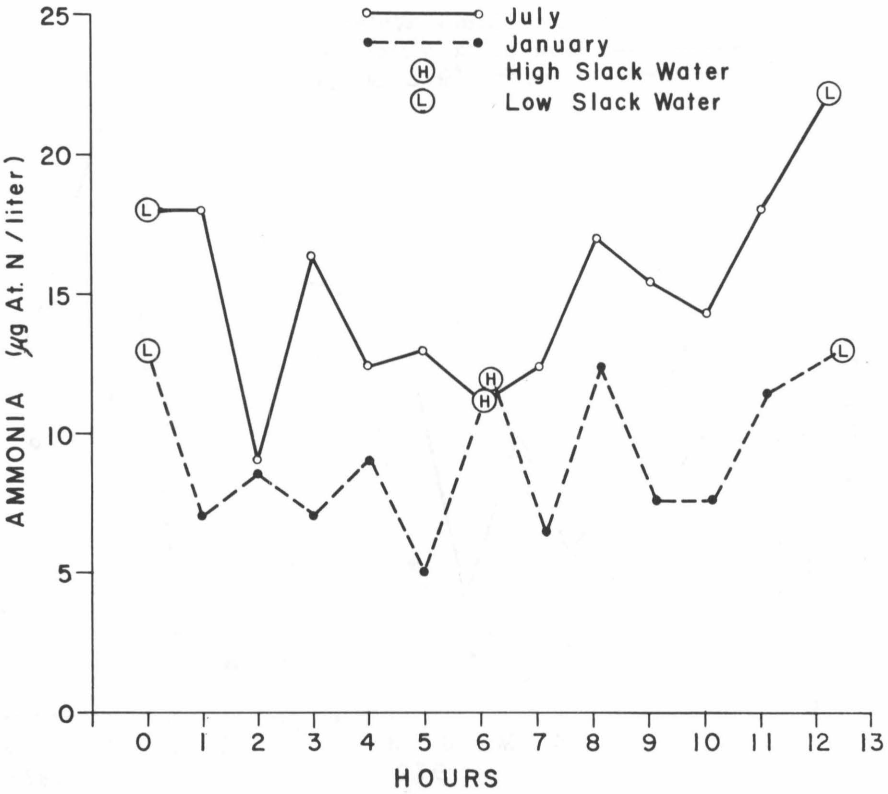


Figure 32

Variation in ammonia concentration over Carter Creek marsh summer and winter tidal cycles.

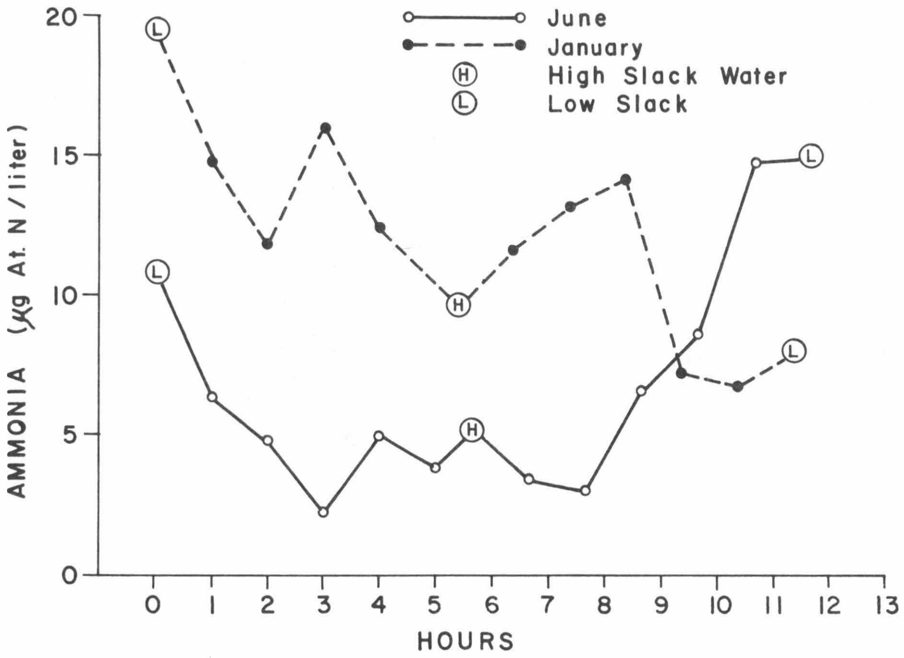
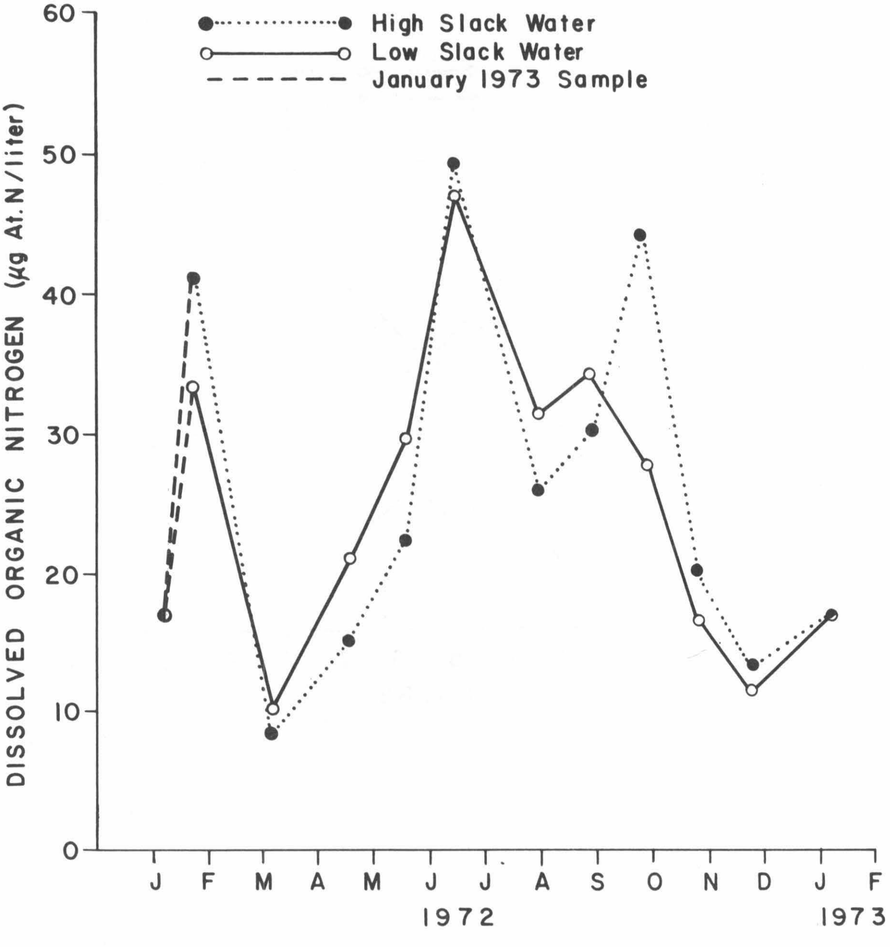


Figure 33

Annual variation in Ware Creek marsh high slack water and low slack water dissolved organic nitrogen concentration.



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Annual variation in Carter Creek marsh high slack water and low slack water dissolved organic nitrogen concentration.

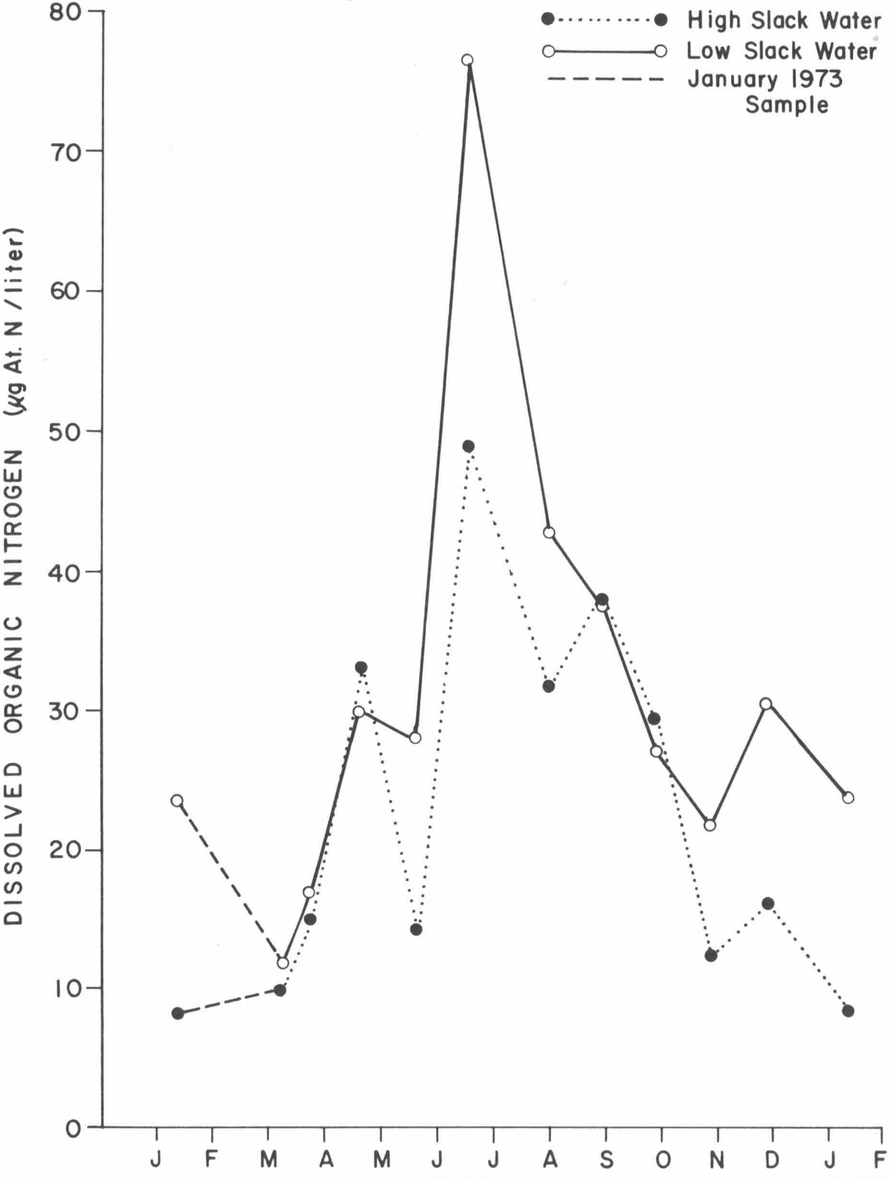


Figure 35

Variation in dissolved organic nitrogen concentration over Ware Creek marsh summer and winter tidal cycles.

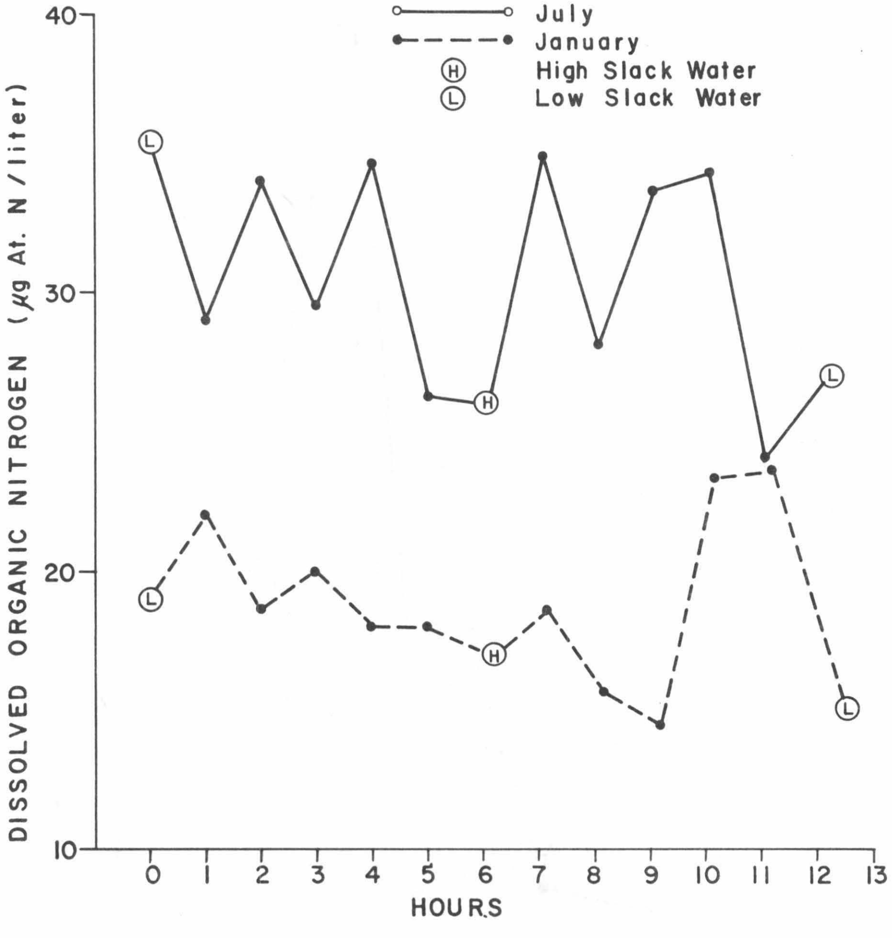


Figure 36

Variation in dissolved organic nitrogen concentration over Carter Creek marsh summer and winter tidal cycles.

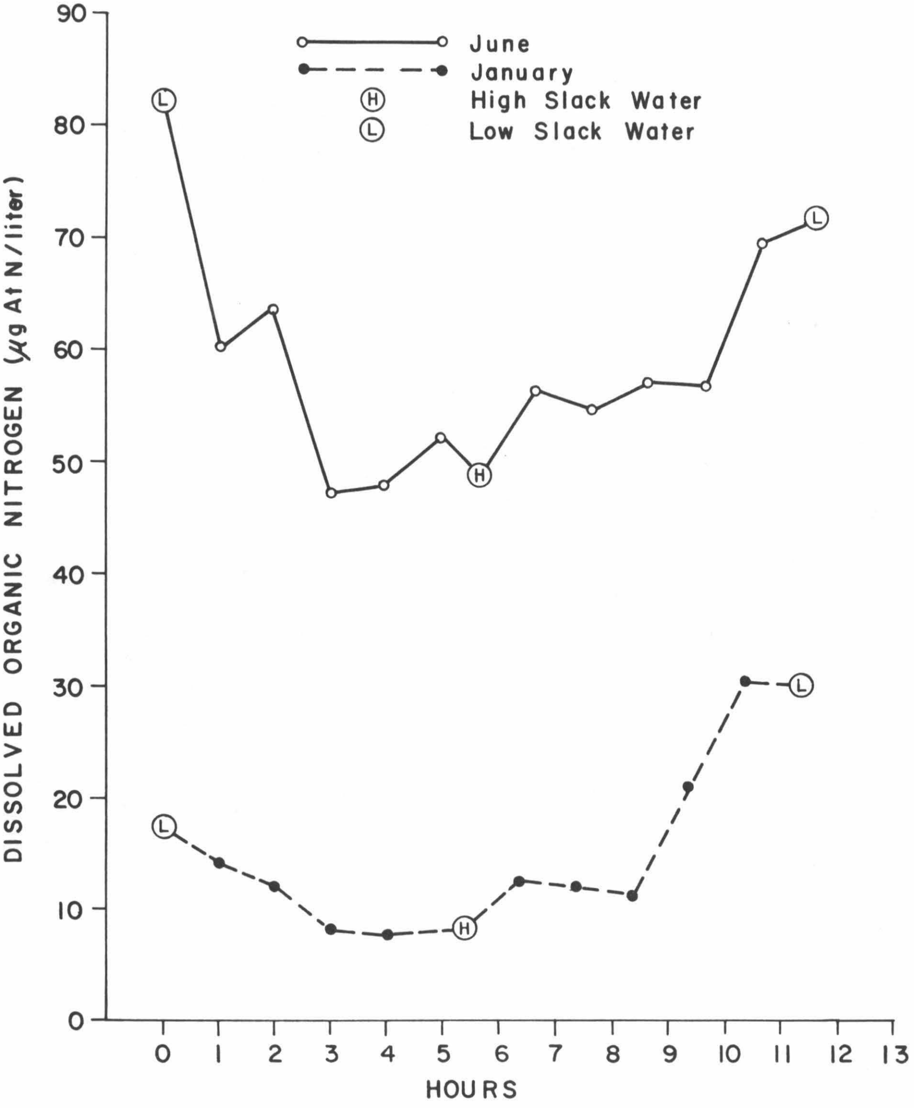


Figure 37

Annual variation in Ware Creek marsh high slack water and low slack water particulate nitrogen concentration.

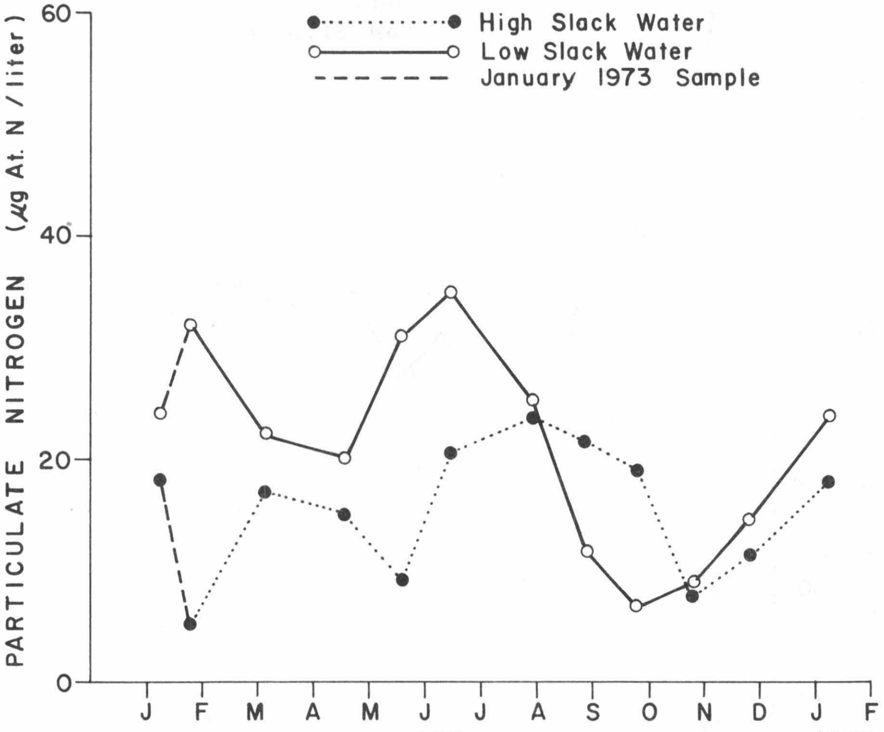


Figure 38

Annual variation in Carter Creek marsh high slack water and low slack water particulate nitrogen concentration.

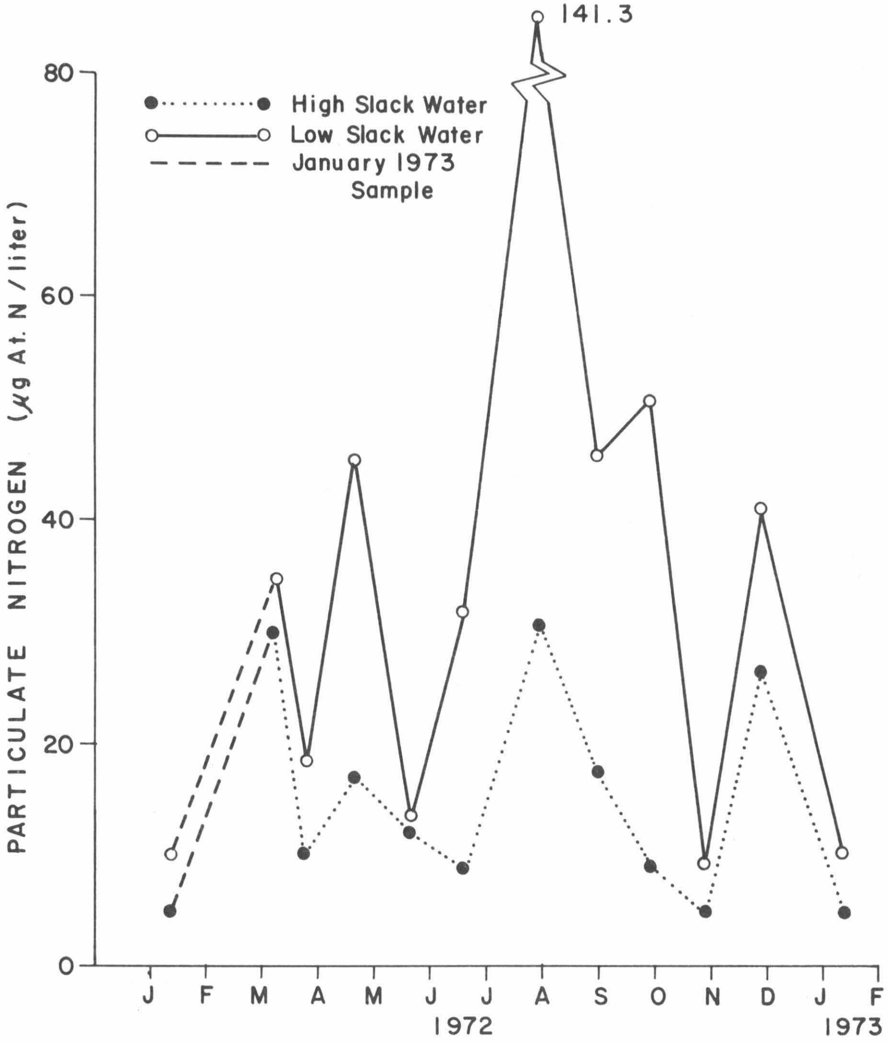


Figure 39

Variation in particulate nitrogen concentration over Ware Creek marsh summer and winter tidal cycles.

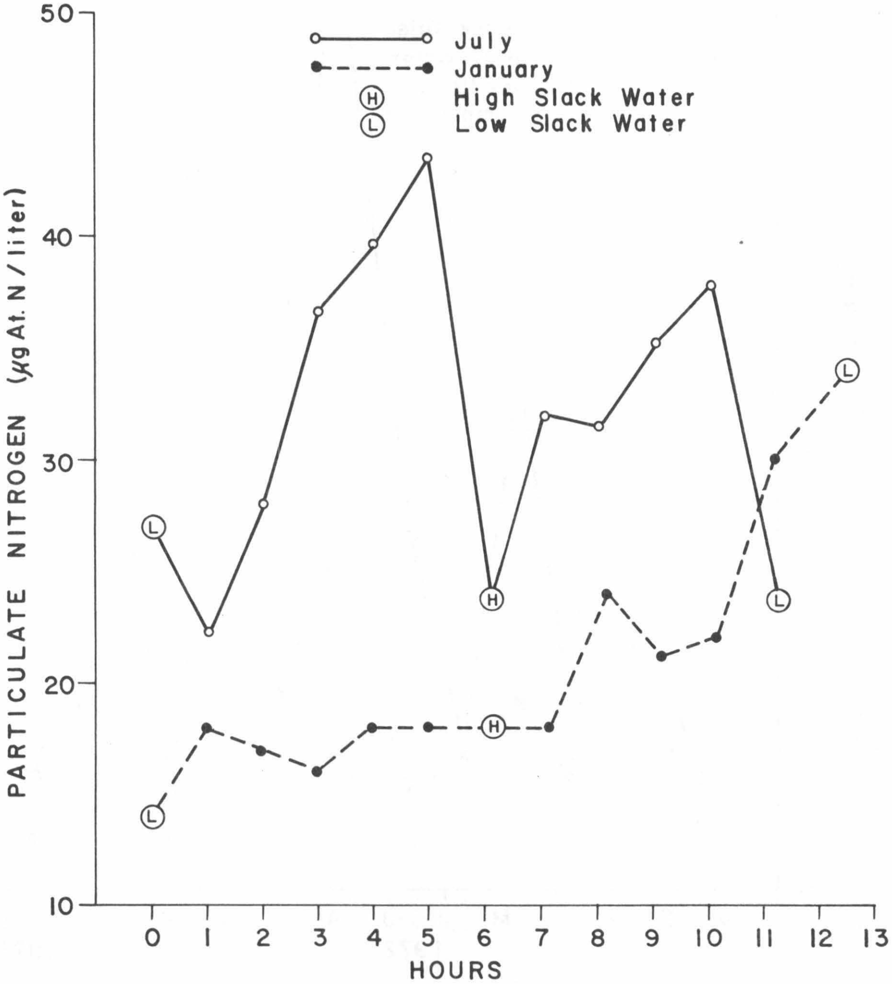


Figure 40

Variation in particulate nitrogen concentration over Carter Creek marsh summer and winter tidal cycles.

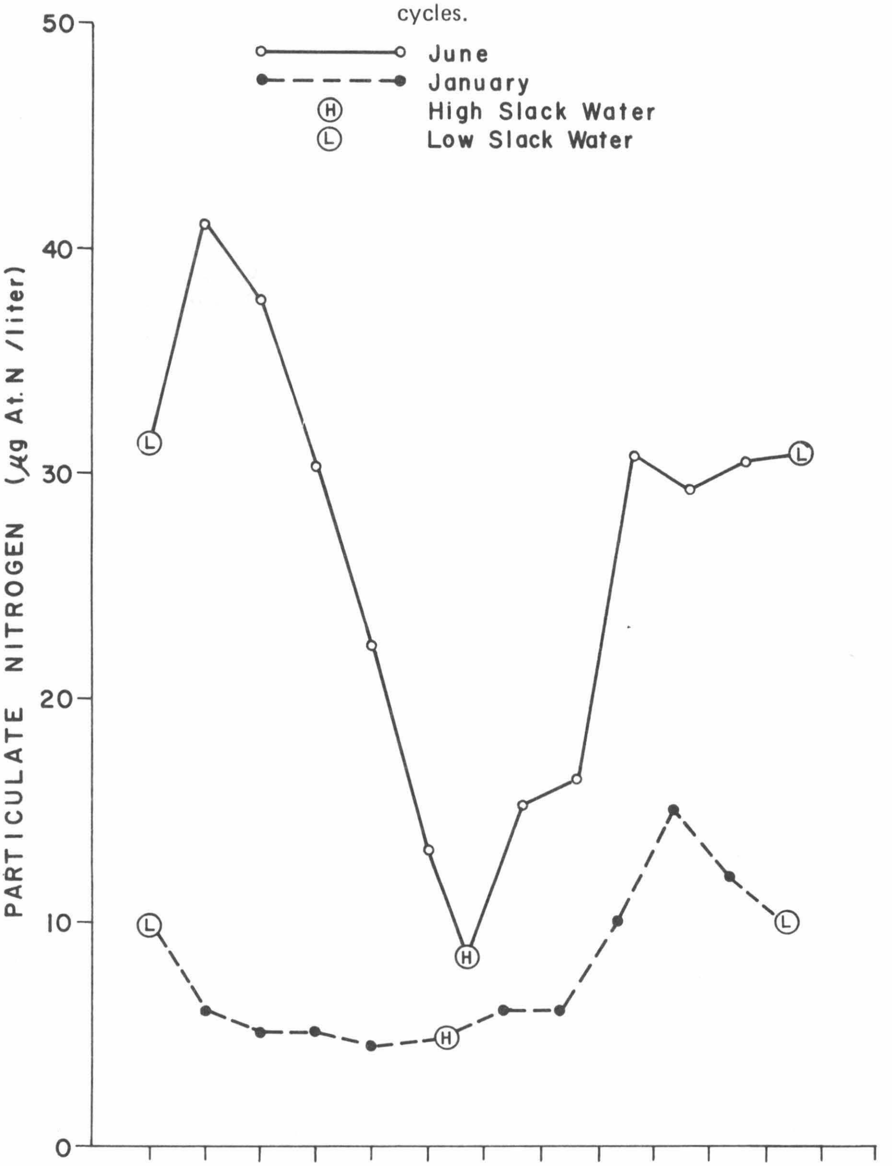


Figure 41

Annual variation in Ware Creek marsh high slack water and low slack water chlorophyll "a" concentration.

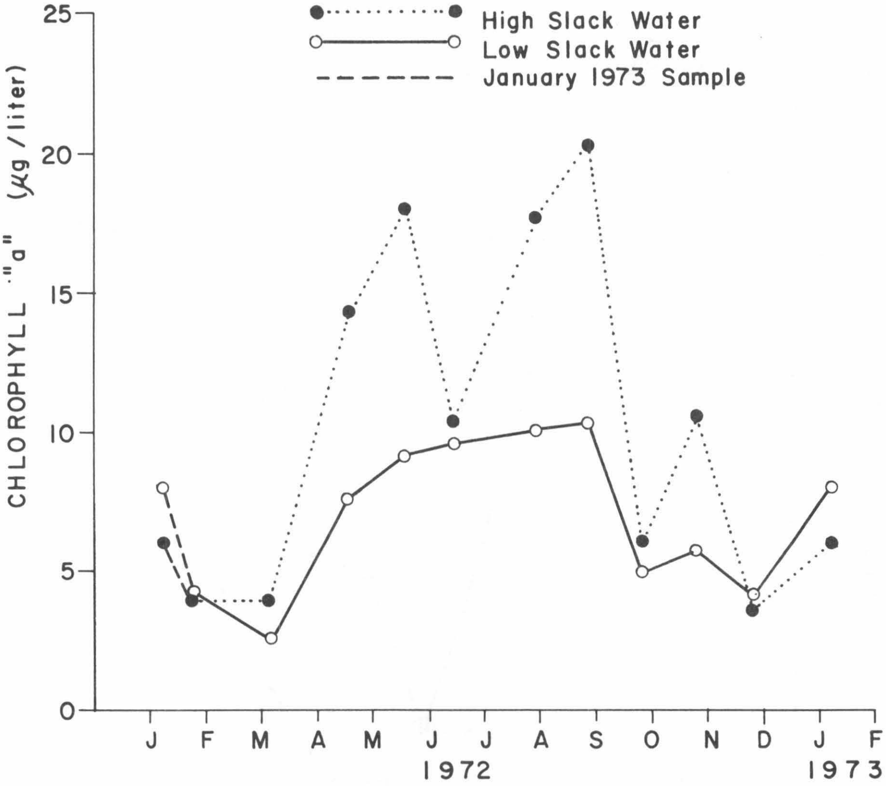


Figure 42

Annual variation in Carter Creek marsh high slack water and low slack water chlorophyll "a" concentration.

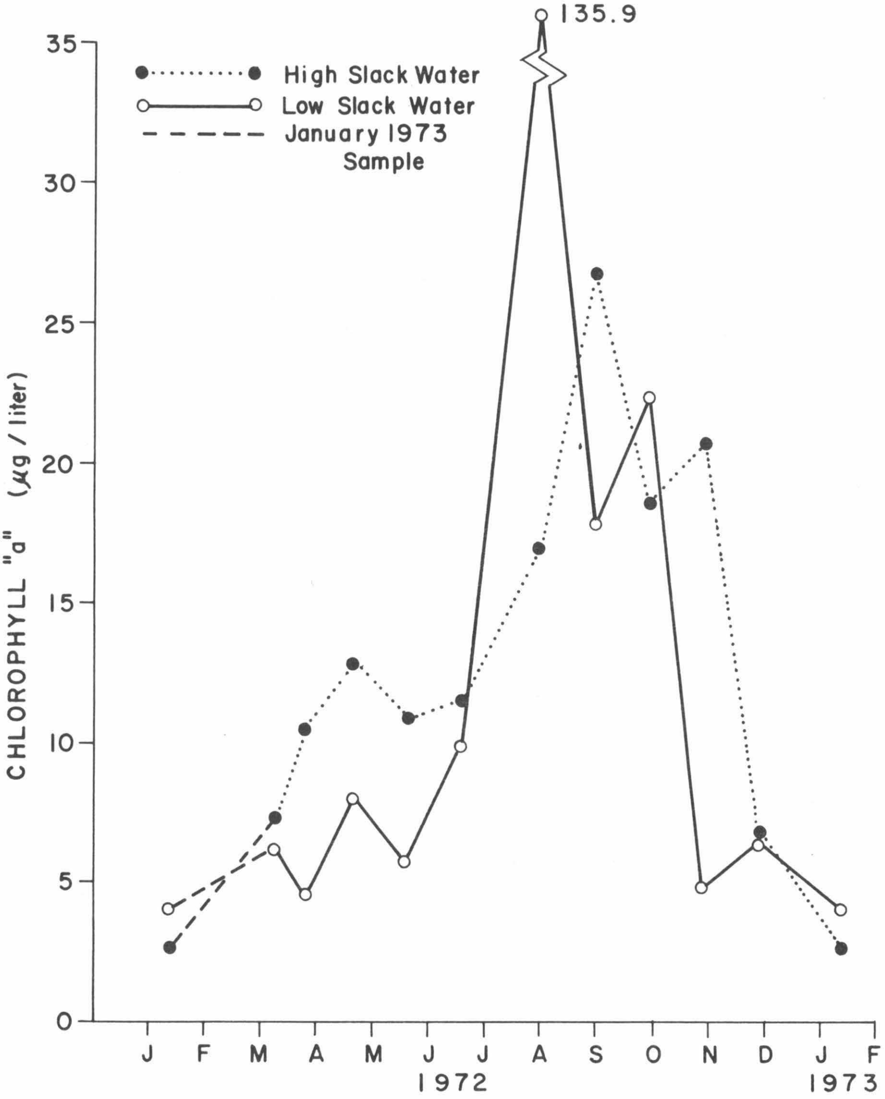


Figure 43

Annual variation in Ware Creek marsh high slack water and low slack water phytoplankton productivity.

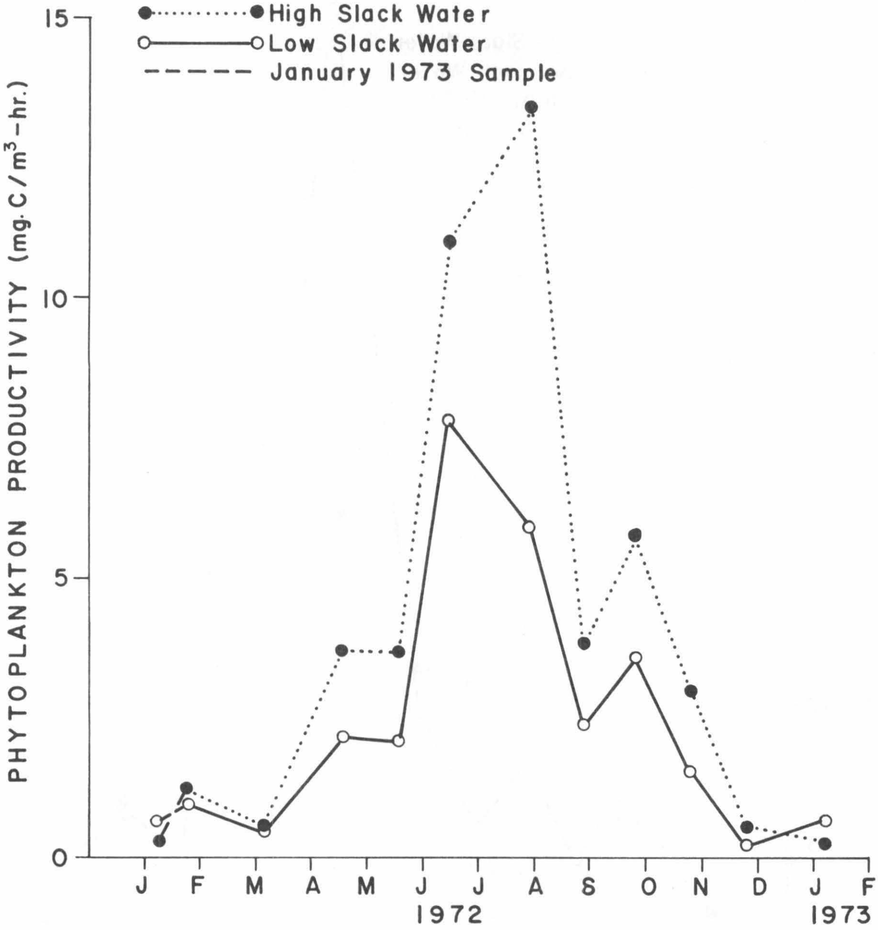


Figure 44

Annual variation in Carter Creek marsh high slack water and low slack water phytoplankton productivity.

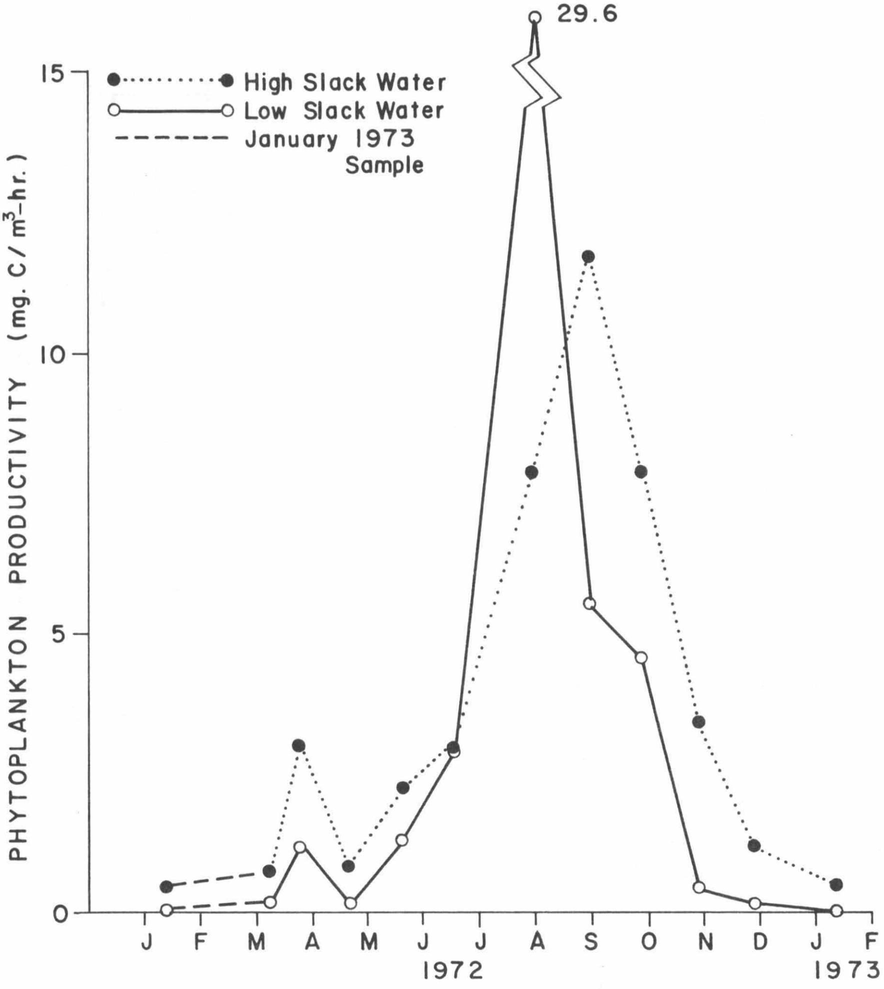


Figure 45

Seasonal changes in mean particulate organic carbon (POC) concentrations in Ware Creek and Carter Creek Marshes. Vertical lines represent range.

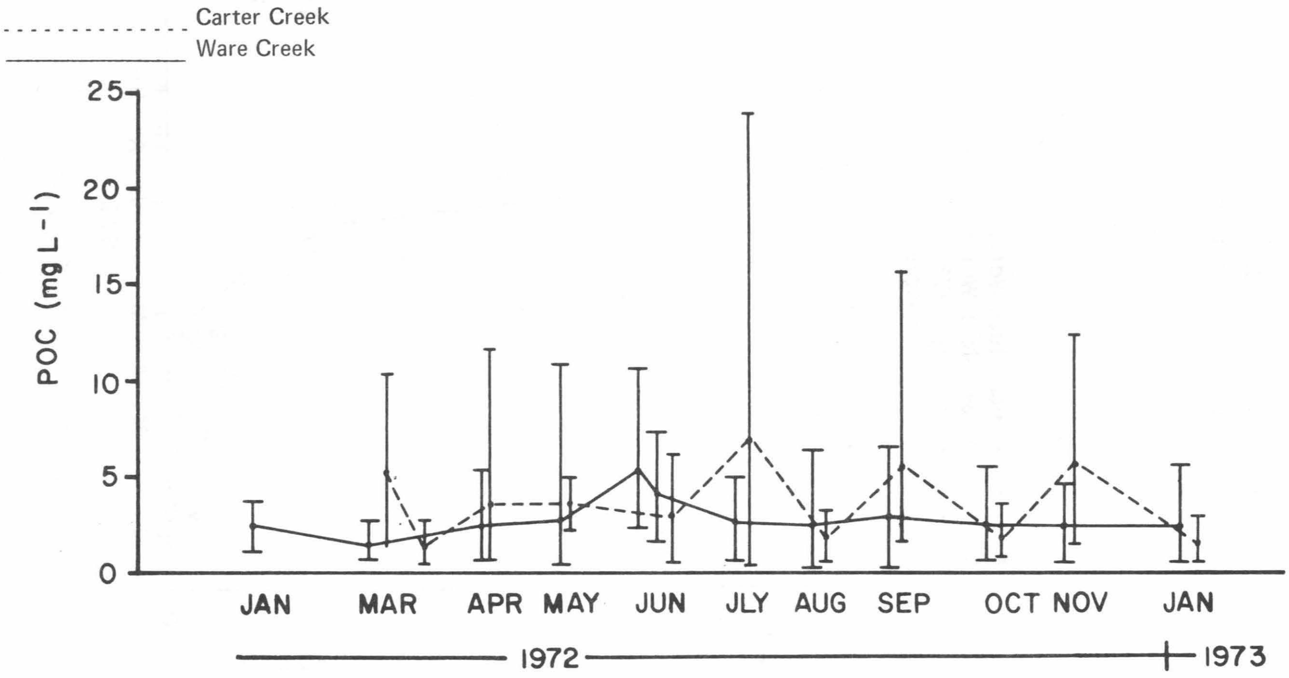


Figure 46

Seasonal changes in mean dissolved organic carbon (DOC) concentrations in Ware Creek and Carter Creek Marshes. Vertical lines represent range.

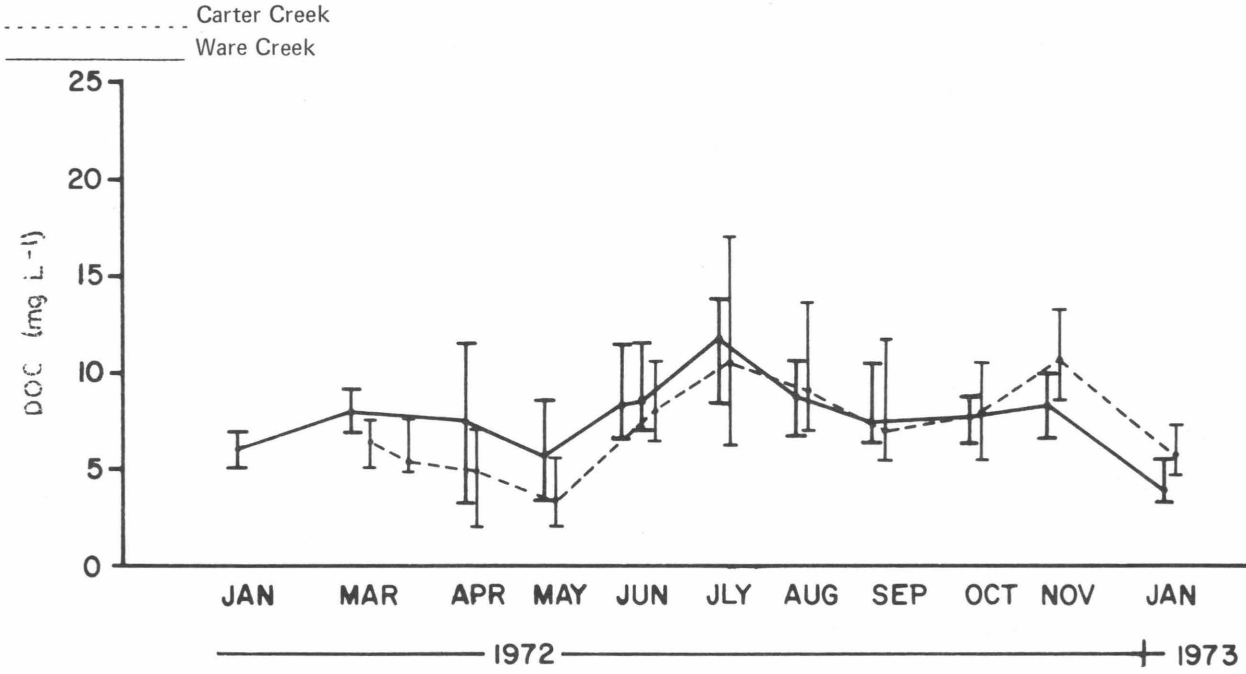


Figure 47

Seasonal changes in mean adenosine-tri-phosphate (ATP) concentrations in Ware Creek and Carter Creek marshes.

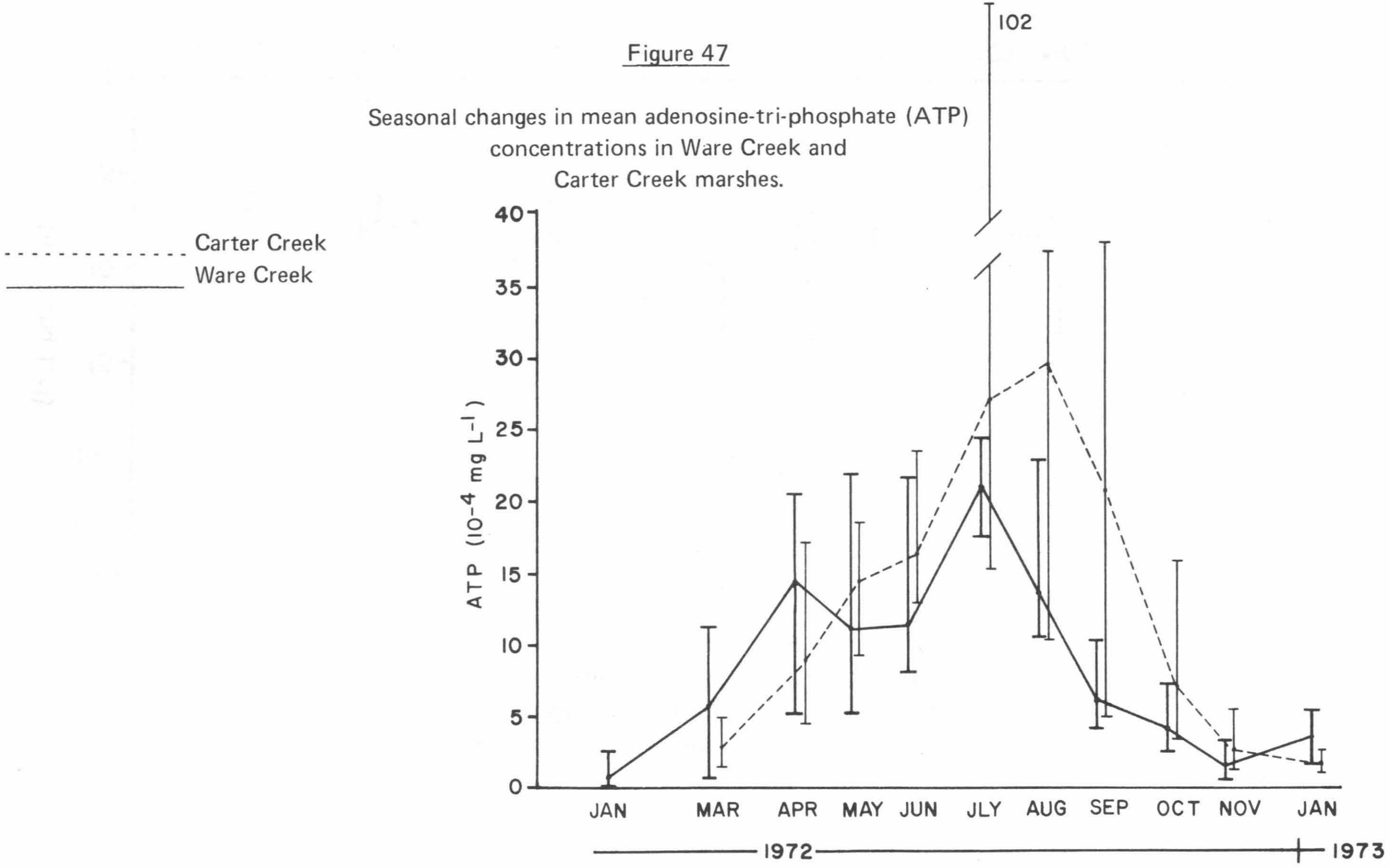


Figure 48

Seasonal changes in mean chlorophyll *a* (Chl. *a*) concentrations in Ware Creek and Carter Creek Marshes. Vertical lines represent range.

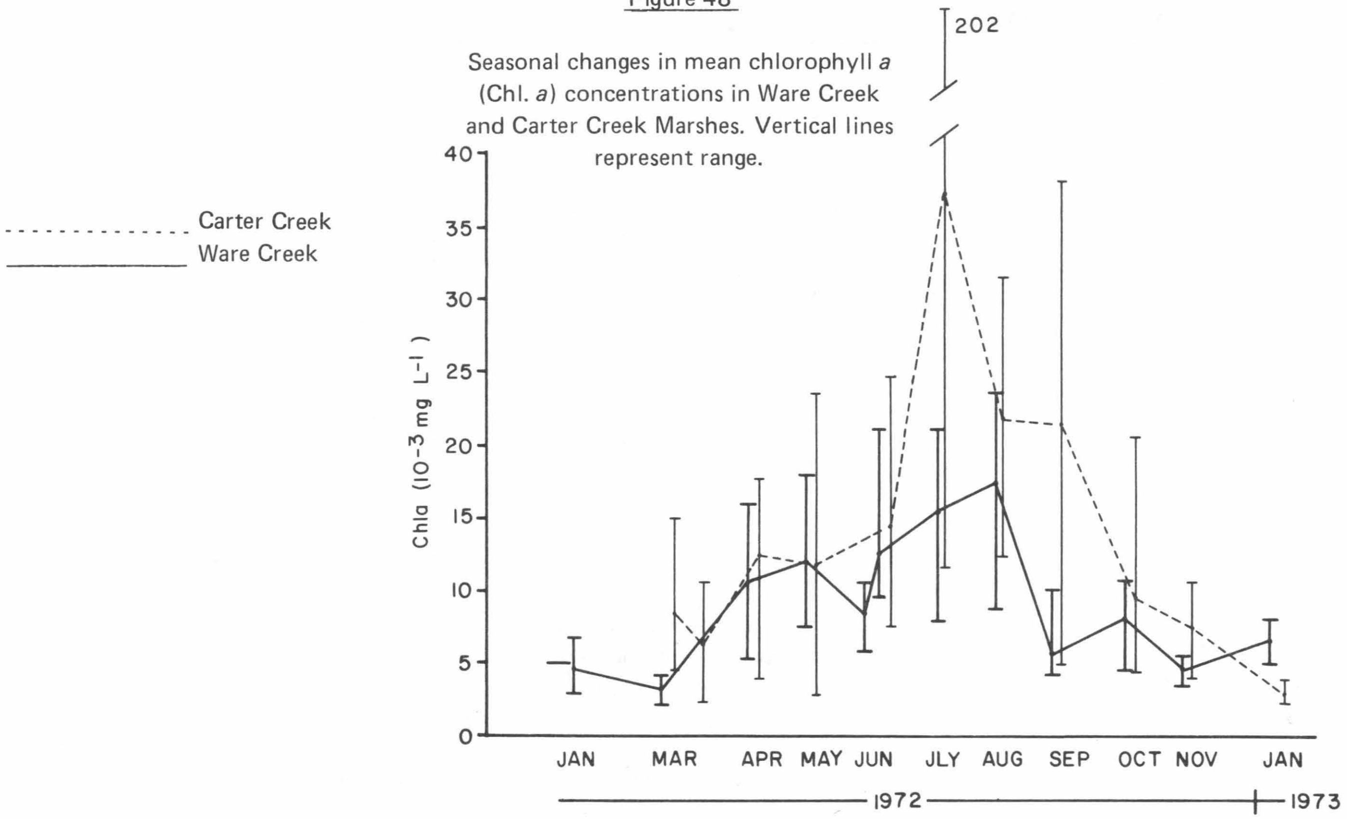
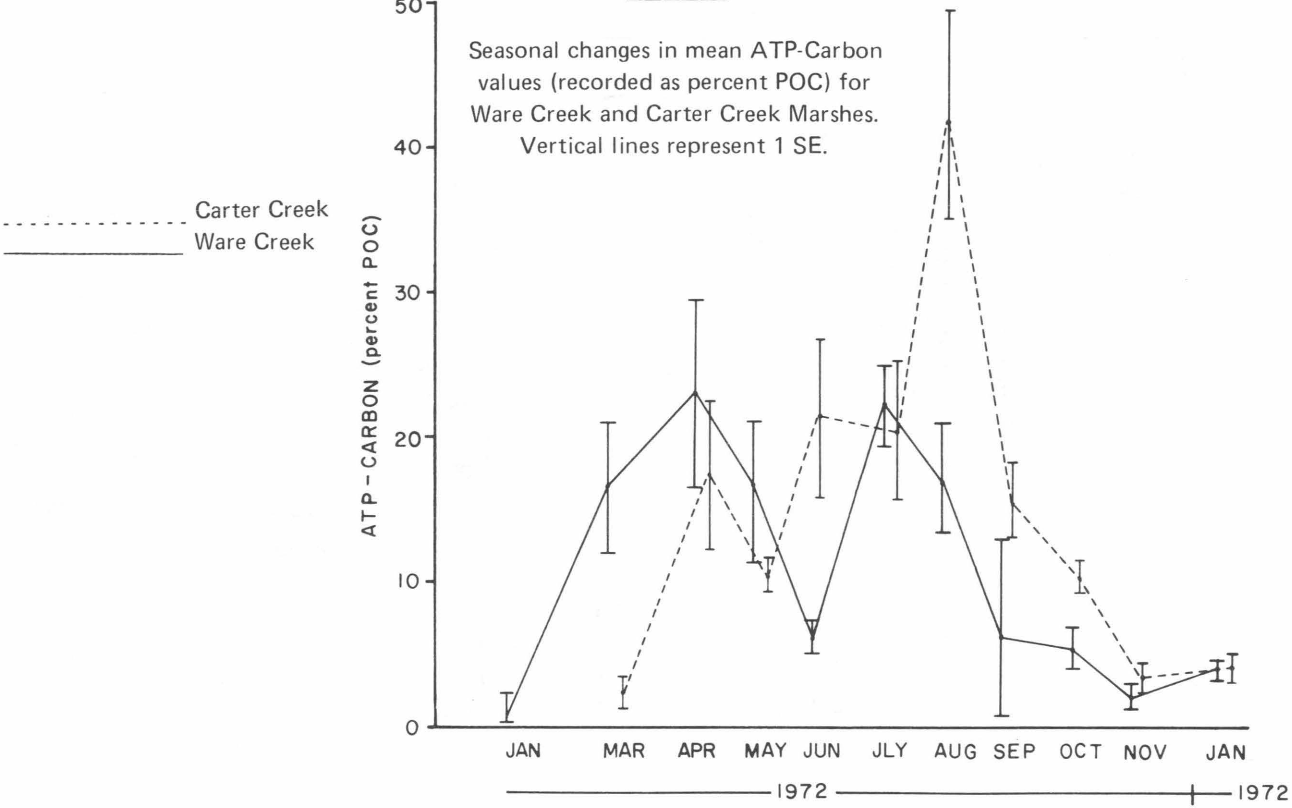


Figure 49



Seasonal changes in mean ATP-Carbon values (recorded as percent POC) for Ware Creek and Carter Creek Marshes. Vertical lines represent 1 SE.

Figure 50

Seasonal changes in mean detrital organic carbon concentrations in Ware Creek and Carter Creek Marshes. Vertical lines represent range.

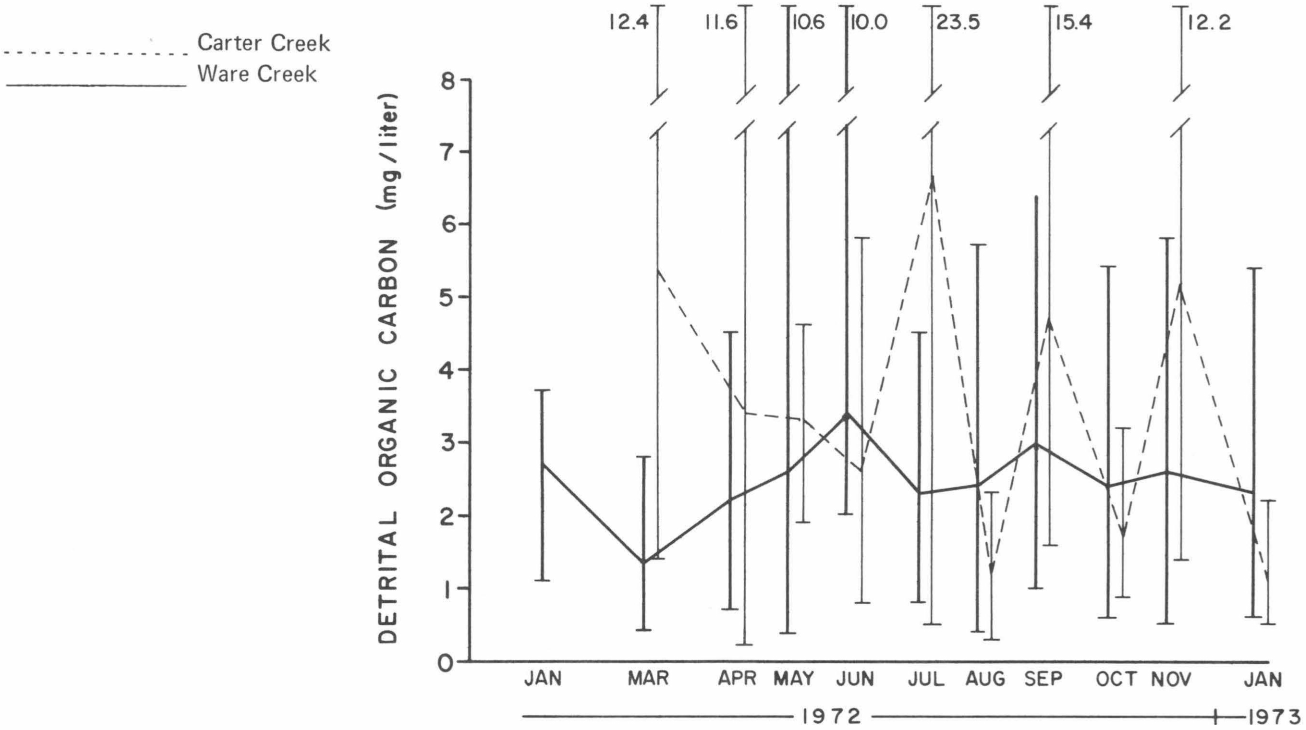


Figure 51

Seasonal changes in mean carbon: chlorophyll *a* ratios.

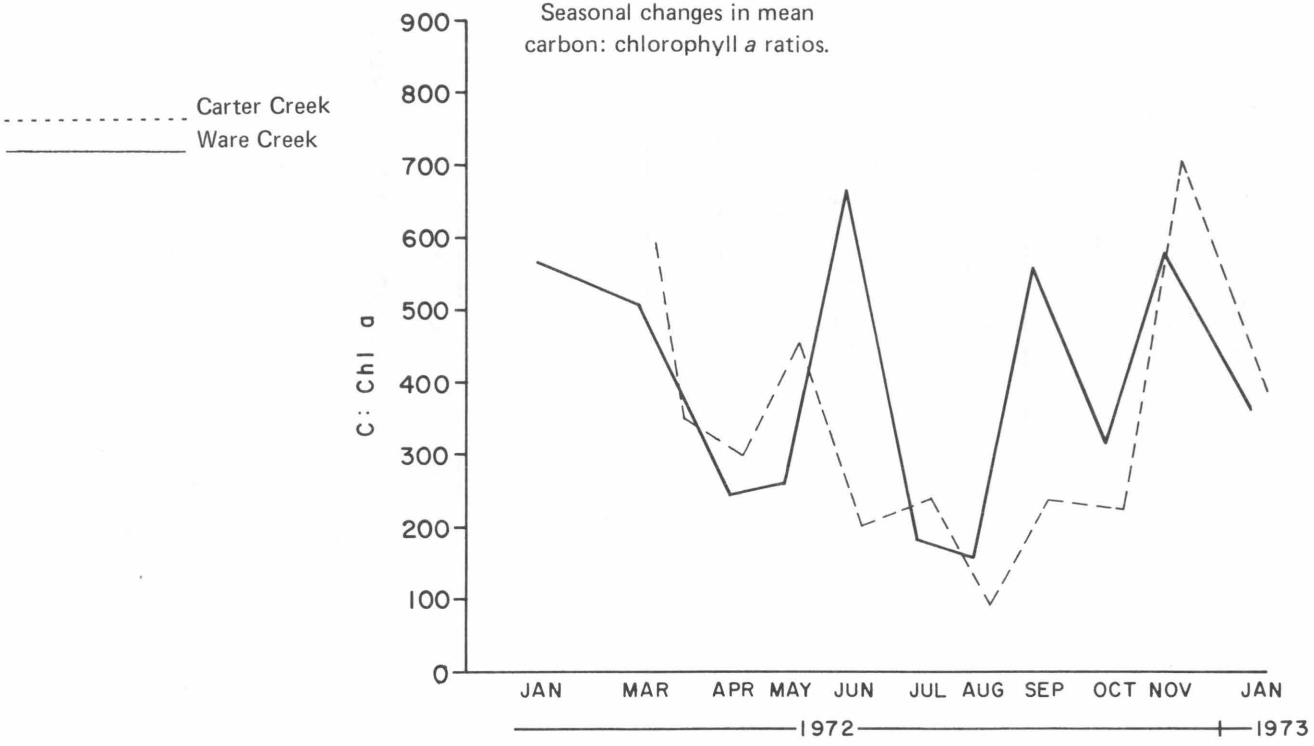
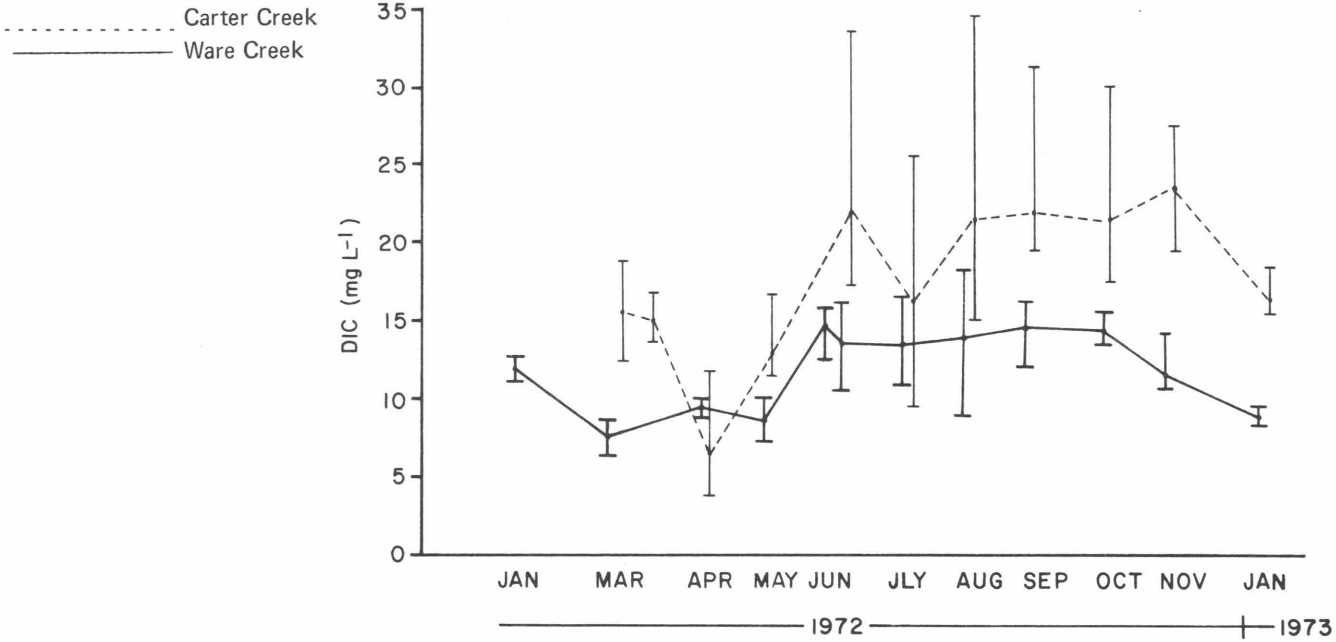


Figure 52

Seasonal changes in mean dissolved inorganic carbon (DIC) concentrations in Ware Creek and Carter Creek Marshes. Vertical lines represent range.



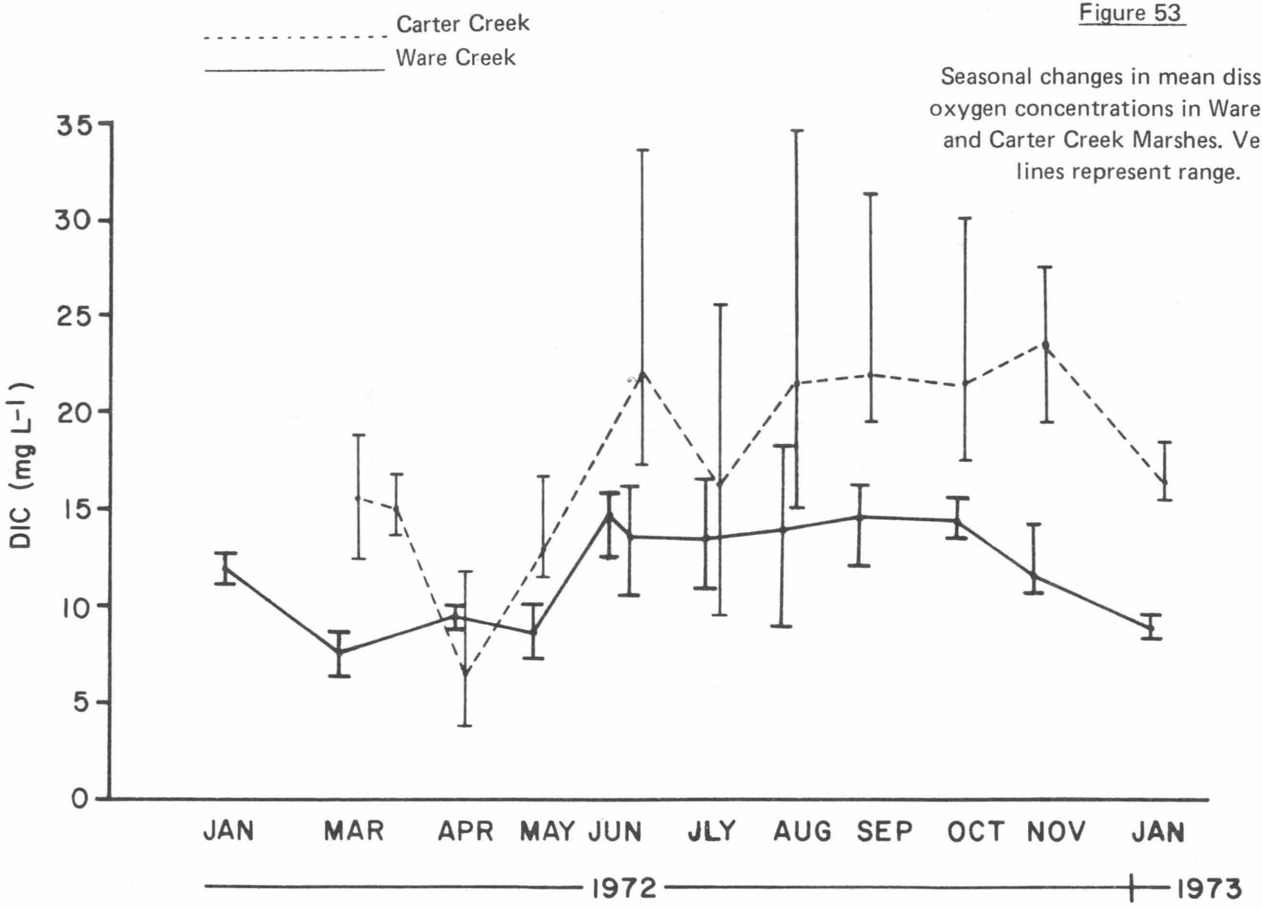


Figure 53

Seasonal changes in mean dissolved oxygen concentrations in Ware Creek and Carter Creek Marshes. Vertical lines represent range.

TABLES

Table 1

CORRELATION MATRIX OF NUTRIENT CONCENTRATIONS, SALINITY, WATER TEMPERATURE, TIDE HEIGHT, AND WATER FLOW IN WARE CREEK OVER THE YEAR

	DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN	Sal.	Temp.	Tide Ht.	Flow
DIP	1.000	0.598	0.275	-0.051	0.183	0.352	0.326	0.149	-0.419	0.228	-0.510	-0.334
DOP		1.000	0.259	-0.238	-0.068	0.127	0.408	0.006	-0.304	0.422	-0.411	-0.166
PP			1.000	-0.210	0.230	0.050	0.538	0.740	-0.019	0.439	-0.163	0.285
NO_3^-				1.000	0.212	0.093	-0.200	-0.152	-0.082	-0.594	-0.046	-0.201
NO_2^-					1.000	-0.162	0.320	0.238	0.403	0.073	0.173	0.057
NH_4^+						1.000	-0.215	0.030	-0.276	-0.079	-0.296	-0.128
DON							1.000	0.375	0.145	0.565	0.000	0.077
PN								1.000	0.105	0.266	0.005	0.336
Sal.									1.000	0.221	0.680	0.364
Temp.										1.000	0.120	0.259
Tide Ht.											1.000	0.555
Flow												1.000

Correlations are significant ($\alpha = 0.01$) for $-0.210 > r > 0.210$

Table 2

CORRELATION MATRIX OF NUTRIENT CONCENTRATIONS, SALINITY, WATER TEMPERATURE, TIDE HEIGHT, AND WATER FLOW IN CARTER CREEK OVER THE YEAR

	DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN	Sal.	Temp	Tide Ht.	Flow
DIP	1.000	0.272	0.422	0.209	0.422	0.482	0.327	0.437	-0.597	-0.038	-0.667	-0.391
DOP		1.000	-0.027	-0.459	-0.040	-0.188	0.462	0.038	0.026	0.344	-0.075	-0.086
PP			1.000	0.044	0.450	0.376	0.338	0.935	-0.381	0.262	-0.538	-0.201
NO_3^-				1.000	0.136	0.471	-0.316	0.015	-0.529	-0.769	-0.318	-0.270
NO_2^-					1.000	0.391	0.271	0.427	-0.420	0.164	-0.357	-0.244
NH_4^+						1.000	0.135	0.358	-0.521	-0.168	-0.380	-0.141
DON							1.000	0.274	-0.059	0.067	-0.137	-0.034
PN								1.000	-0.380	0.258	-0.459	-0.151
Sal.									1.000	0.398	0.705	0.448
Temp.										1.000	0.210	0.257
Tide Ht.											1.000	0.616
Flow												1.000

Correlations are significant ($\alpha = 0.01$) for $-0.210>r>0.210$

Table 3

WARE CREEK
TIDAL PHOSPHORUS TRANSPORT

Sampling Date	Tidal Prism m^3	Tidal Transport	DIP grams P	DOP grams P	PP grams P
1/23/72	19,600	Flood	+ 346	+ 198	+ 1,139
		Ebb	- 338	- 202	- 1,098
		Net	+ 8	- 4	+ 41
3/4/72	19,900	Flood	+ 378	+ 257	+ 1,059
		Ebb	- 518	- 267	- 867
		Net	- 140	- 10	+ 192
4/17/72	39,000	Flood	+ 384	+ 497	+ 3,378
		Ebb	- 420	- 587	- 4,209
		Net	- 36	- 90	- 831
5/17/72	39,400	Flood	+1,410	+ 723	+ 2,337
		Ebb	-1,495	- 775	- 2,598
		Net	- 85	- 52	- 261
6/14/72	24,500	Flood	+ 762	+ 585	+ 3,550
Day		Ebb	-1,007	- 789	3,617
		Net	- 245	- 204	- 67
6/15/72	34,300	Flood	+1,222	+ 749	+ 4,476
Night		Ebb	-1,347	- 715	- 5,679
		Net	- 125	+ 34	- 1,203
7/28/72	45,200	Flood	+1,657	+ 746	+ 5,606
		Ebb	-1,392	- 648	- 5,391
		Net	+ 265	+ 98	+ 215
8/26/72	43,700	Flood	+ 795	+ 704	+ 4,495
		Ebb	- 841	- 769	- 4,954
		Net	- 46	- 65	- 459
9/24/72	54,100	Flood	+1,102	+ 436	+10,717
		Ebb	- 792	- 412	- 6,773
		Net	+ 310	+ 24	+ 3,944
10/24/72	42,600	Flood	+ 748	+ 831	+ 3,377
		Ebb	- 590	- 926	- 2,659
		Net	+ 158	- 95	+ 718
11/24/72	39,100	Flood	+ 766	+ 393	+ 2,756
		Ebb	- 756	- 416	- 2,679
		Net	+ 10	- 23	+ 77
1/7/73	17,400	Flood	+ 461	+ 234	+ 1,271
		Ebb	- 518	- 230	- 1,583
		Net	- 57	+ 4	- 312

+ = input
- = output

Table 4

CARTER CREEK
TIDAL PHOSPHORUS TRANSPORT

Sampling Date	Tidal Prism m^3	Tidal Transport	DIP grams P	DOP grams P	PP grams P
3/7/72	4,100	Flood	+ 64	+ 47	+ 768
		Ebb	- 95	- 41	- 443
		Net	- 31	+ 6	+ 325
3/23/72	13,300	Flood	+ 125	+ 206	+ 436
		Ebb	- 135	- 228	- 384
		Net	- 10	- 22	+ 52
4/19/72	10,200	Flood	+ 128	+ 139	+ 1,411
		Ebb	- 120	- 157	- 933
		Net	8	- 18	+ 478
5/19/72	43,700	Flood	+ 707	+ 669	+ 2,498
		Ebb	- 832	- 811	- 2,272
		Net	- 125	- 142	+ 226
6/17/72	13,300	Flood	+ 250	+ 289	+ 1,054
		Ebb	- 373	- 262	- 911
		Net	- 123	+ 27	+ 143
7/31/72 Storm	43,700	Flood	+ 723	+ 449	+ 5,427
		Ebb	- 856	- 575	- 6,953
		Net	- 133	- 126	- 1,526
8/29/72	24,100	Flood	+ 455	+ 456	+ 2,228
		Ebb	- 553	- 467	- 1,653
		Net	- 98	- 11	+ 575
9/27/72	26,700	Flood	+ 493	+ 325	+ 2,201
		Ebb	- 610	- 319	- 2,559
		Net	- 117	+ 6	- 358
10/27/72	27,200	Flood	+ 405	+ 565	+ 242
		Ebb	- 491	- 587	- 401
		Net	- 86	- 22	- 159
11/27/72	4,300	Flood	+ 111	+ 47	+ 558
		Ebb	- 154	- 50	- 292
		Net	- 43	- 3	+ 266
1/11/73	8,800	Flood	+ 253	+ 70	+ 175
		Ebb	- 299	- 86	- 195
		Net	- 46	- 16	- 40

+ = input

- = output

Table 5

WARE CREEK
TIDAL NITROGEN TRANSPORT

Sampling Date	Tidal Prism m^3	Tidal Transport	NO_3^- grams N	NO_2^- grams N	NH_4^+ grams N	DON grams N	PN grams N
1/23/72	19,600	Flood	+1,992	+ 80	+ 940	+ 8,390	+ 6,679
		Ebb	-1,537	- 87	-1,148	- 9,661	- 7,328
		Net	+ 455	- 7	- 208	- 1,271	- 649
3/4/72	19,900	Flood	+ 728	+ 86	+1,186	+ 1,185	+ 4,096
		Ebb	- 589	- 80	-1,527	- 2,395	- 3,196
		Net	+ 139	+ 6	- 341	- 1,210	+ 900
4/17/72	39,000	Flood	+ 706	+ 94	+2,362	+13,048	+ 9,233
		Ebb	- 571	- 79	-5,148	- 9,451	-11,851
		Net	+ 135	+ 15	-2,786	+ 3,597	- 2,618
5/17/72	39,400	Flood	+1,011	+ 177	+ 961	+13,429	+ 7,820
		Ebb	- 525	- 149	-1,795	-16,325	-10,050
		Net	+ 486	+ 28	- 834	- 2,896	- 2,230
6/14/72 Day	24,500	Flood	+ 425	+ 142	+1,768	+18,775	+ 8,601
		Ebb	- 266	- 143	-2,028	-18,082	-10,373
		Net	+ 159	- 1	- 260	+ 693	- 1,772
6/15/72 Night	34,300	Flood	+ 394	+ 221	+3,231	+24,426	+12,029
		Ebb	- 329	- 263	-3,479	-24,408	-12,479
		Net	+ 65	- 42	- 248	+ 18	- 450

Sampling Date	Tidal Prism m^3	Tidal Transport	NO_3^- grams N	NO_2^- grams N	NH_4^+ grams N	DON grams N	PN grams N
7/28/72	45,200	Flood	+ 862	+ 240	+8,486	+19,299	+22,459
		Ebb	- 556	- 144	-9,510	-19,689	-19,681
		Net	+ 306	+ 96	-1,024	- 390	+ 2,778
8/26/72	43,700	Flood	+ 314	+ 116	+1,865	+18,511	+17,887
		Ebb	- 264	- 138	-3,974	-20,617	-16,199
		Net	+ 50	- 22	-2,109	- 2,106	+ 1,688
9/24/72	54,100	Flood	+2,340	+ 747	+1,659	+24,542	+36,719
		Ebb	-1,468	- 563	-1,359	-27,664	-32,580
		Net	+ 872	+ 184	+ 300	- 3,122	+ 4,139
10/24/72	42,600	Flood	+2,765	+ 180	+3,886	+11,959	+10,804
		Ebb	-1,916	- 175	-3,101	-11,873	- 9,090
		Net	+ 849	+ 5	+ 785	+ 86	+ 1,714
11/24/72	39,100	Flood	+2,559	+ 105	+5,917	+ 7,357	+ 9,323
		Ebb	-1,705	- 98	-5,048	- 7,422	-10,945
		Net	+ 854	+ 7	+ 869	- 65	- 1,622
1/7/73	17,400	Flood	+4,931	+ 113	+1,827	+ 4,532	+ 4,265
		Ebb	-4,148	- 105	-2,245	- 4,285	- 5,275
		Net	+ 783	+ 8	- 418	+ 247	- 1,010

+ = input

- = output

Table 6

CARTER CREEK
TIDAL NITROGEN TRANSPORT

Sampling Date	Tidal Prism m^3	Tidal Transport	NO_3^- grams N	NO_2^- grams N	NH_4^+ grams N	DON grams N	PN grams N
3/7/72	4,100	Flood	+ 516	+ 23	+ 244	+ 594	+ 3,494
		Ebb	- 435	- 25	- 244	- 810	- 2,187
		Net	+ 81	- 2	0	- 216	+ 1,307
3/23/72	13,300	Flood	+ 520	+ 49	+ 389	+ 2,618	+ 2,216
		Ebb	- 367	- 45	- 547	- 2,918	- 1,524
		Net	+ 153	+ 4	- 158	- 300	+ 692
4/19/72	10,200	Flood	+ 487	+ 46	+ 441	+ 4,009	+ 4,249
		Ebb	- 339	- 44	- 490	- 4,431	- 3,844
		Net	+ 148	+ 2	- 49	- 422	+ 405
5/19/72	43,700	Flood	+ 263	+ 167	+ 1,542	+11,148	+14,037
		Ebb	- 201	- 182	- 1,691	-14,044	-11,639
		Net	+ 62	- 15	- 149	- 2,896	+ 2,398
6/17/72	13,300	Flood	+ 166	+ 43	+ 764	+ 9,669	+ 4,488
		Ebb	- 250	- 57	- 1,025	-10,480	- 3,838
		Net	- 84	- 14	- 261	- 811	+ 650
7/31/72 Storm	43,700	Flood	+1,673	+ 250	+11,953	+18,351	+25,191
		Ebb	-1,653	- 239	- 7,734	-22,541	-30,112
		Net	+ 20	+ 11	+ 4,219	- 4,190	- 4,921

Sampling Date	Tidal Prism m^3	Tidal Transport	NO_3^- grams N	NO_2^- grams N	NH_4^+ grams N	DON grams N	PN grams N
8/29/72	24,100	Flood	+ 150	+ 100	+ 1,149	+12,247	+ 9,373
		Ebb	- 150	- 88	- 845	-11,706	- 7,336
		Net	0	+ 12	+ 304	+ 541	+ 2,037
9/27/72	26,700	Flood	+ 266	+ 72	+ 861	+ 6,246	+ 9,405
		Ebb	- 427	- 42	- 988	-12,022	- 8,173
		Net	- 161	+ 30	- 127	- 5,776	+ 1,232
10/27/72	27,200	Flood	+ 292	+ 88	+ 1,241	+ 5,077	+ 1,748
		Ebb	- 124	- 68	- 1,167	- 7,288	- 2,861
		Net	+ 168	+ 20	+ 74	- 2,211	- 1,113
11/27/72	4,300	Flood	+ 914	+ 16	+ 996	+ 1,217	+ 2,629
		Ebb	- 867	- 15	- 791	- 1,045	- 1,453
		Net	+ 47	+ 1	+ 205	+ 172	+ 1,176
1/11/73	8,800	Flood	+3,001	+ 39	+ 1,650	+ 1,213	+ 620
		Ebb	-3,036	- 40	- 1,507	- 1,520	- 923
		Net	- 35	- 1	+ 143	- 307	- 303

+ = input

- = output

Table 7

WARE CREEK
ANNUAL PHOSPHORUS BUDGET

	DIP grams P	DOP grams P	PP grams P
1/15/72 - 2/12/72	+ 381	- 183	+ 2,009
2/13 - 3/26	-14,037	- 992	+ 19,149
3/27 - 5/2	- 2,420	- 6,047	- 55,789
5/3 - 5/31	- 4,813	- 2,940	- 14,768
6/1 - 7/5	-21,196	-17,681	- 5,822
7/6 - 8/11	+17,554	+ 6,501	+ 14,252
8/12 - 9/10	- 2,623	- 3,765	- 26,472
9/11 - 10/8	+15,252	+ 1,189	+194,036
10/9 - 11/9	+ 9,052	- 5,431	+ 41,104
11/10 - 12/16	+ 634	- 1,493	+ 5,112
12/17/72 - 1/14/73	- 4,635	+ 330	- 25,530
1/15/72 - 1/14/73	- 6,851	-30,512	+147,281

1/15/72 - 1/14/73 DIP + DOP + PP = 109.918 grams P
+ = input
- = output

Table 8

CARTER CREEK
ANNUAL PHOSPHORUS BUDGET

	DIP grams P	DOP grams P	PP grams P
2/9/72 - 3/15/72	- 4,667	+ 877	+48,424
3/16 - 4/6	- 543	- 1,220	+ 2,832
4/7 - 5/4	+ 614	- 1,451	+37,811
5/5 - 6/3	- 5,513	- 6,324	+10,036
6/4 - 7/9	-11,429	+ 2,482	+13,305
7/10 - 8/14	- 6,834	- 6,423	-78,078
8/15 - 9/13	- 5,735	- 651	+33,536
9/14 - 10/12	- 6,398	+ 321	-19,532
10/13 - 11/12	- 4,745	- 1,212	- 8,754
11/13 - 12/20	- 7,756	- 499	+47,531
12/21/72 - 2/8/73	- 7,485	- 2,530	- 3,288
2/9/72 - 2/8/73	-60,491	-16,630	+83,823

2/9/72 - 2/8/73 DIP + DOP + PP = +6,702 grams P
+ = input
- = output

Table 9

WARE CREEK
ANNUAL NITROGEN BUDGET

	NO_3^- grams N	NO_2^- grams N	NH_4^+ grams N	DON grams N	PN grams N
1/15/72 - 2/12/72	+ 22,348	- 371	- 10,181	- 62,416	- 31,875
2/13 - 3/26	+ 13,825	+ 560	- 34,115	-120,942	+ 90,003
3/27 - 5/2	+ 9,086	+ 979	-187,387	+241,881	-176,042
5/3 - 5/31	+ 27,432	+ 1,557	- 47,054	-163,521	-125,895
6/1 - 7/5	+ 13,801	- 97	- 22,538	+ 59,980	-153,402
7/6 - 8/11	+ 20,236	+ 6,362	- 67,707	- 25,857	+183,803
8/12 - 9/10	+ 2,852	- 1,273	-121,402	-121,185	+ 97,151
9/11 - 10/8	+ 43,016	+ 9,044	+ 14,775	-153,588	+203,650
10/9 - 11/9	+ 48,555	+ 313	+ 44,940	+ 4,897	+ 98,288
11/10 - 12/16	+ 56,284	+ 453	+ 57,337	- 4,238	-107,001
12/17/72 - 1/14/73	+ 63,995	+ 664	- 34,222	+ 20,154	- 82,445
1/15/72 - 1/14/73	+321,420	+18,191	-407,554	-324,835	- 3,765

1/15/72 - 1/14/73 $NO_3 + NO_2 + NH_4 + DON + PN = -396,543$ grams N

+ = input

- = output

Table 10

CARTER CREEK
ANNUAL NITROGEN BUDGET

	NO_3^- grams N	NO_2^- grams N	NH_4^+ grams N	DON grams N	PN grams N
2/9/72 - 3/15/72	+12,061	- 230	+ 83	- 32,156	-194,793
3/16 - 4/6	+ 8,385	+ 230	- 8,669	- 16,434	+ 37,853
4/7 - 5/4	+11,771	+ 189	- 3,839	- 33,396	+ 32,061
5/5 - 6/3	+ 2,757	- 690	- 6,594	-128,464	+106,354
6/4 - 7/9	- 7,807	-1,343	-24,296	- 75,532	+ 60,478
7/10 - 8/14	+ 1,010	+ 559	- 2,840	-214,336	-251,738
8/15 - 9/13	- 32	+ 727	+17,744	+ 31,565	+118,859
9/14 - 10/12	- 8,791	+1,674	- 6,933	-315,577	+ 67,229
10/13 - 11/12	+ 9,233	+1,125	+ 4,061	-121,678	- 61,255
11/13 - 12/20	+ 8,406	+ 225	+36,627	+ 30,697	+210,127
12/21/72 - 2/8/73	- 5,802	- 69	+23,321	- 50,159	- 49,337
2/9/72 - 2/8/73	+31,191	+2,397	+28,665	-925,270	+465,424

2/9/72 - 2/8/73 $NO_3 + NO_2 + NH_4 + DON + PN = -397,593$ grams N

+ = input

- = output

Table 11

WARE CREEK FLOOD AND EBB TIDE SIMPLE AND PARTIAL CORRELATION COEFFICIENTS

Flood Tide Simple Correlation Coefficients

	Temp.	DIP	NO_3^-	NH_4^+
Prod./Chl.	0.571**	0.220	-0.348*	-0.182

Flood Tide Partial Correlation Coefficients, Temperature Held Constant

	DIP	NO_3^-	NH_4^+
Prod./Chl.	0.130	0.005	-0.048

Ebb Tide Simple Correlation Coefficients

	Temp.	DIP	NO_3^-	NH_4^+
Prod./Chl.	0.525**	0.271	-0.234	-0.118

Ebb Tide Partial Correlation Coefficients, Temperature Held Constant

	DIP	NO_3^-	NH_4^+
Prod./Chl.	0.173	0.087	-0.073

**Significant at the 1% level
*Significant at the 5% level

Table 12

CARTER CREEK FLOOD AND EBB TIDE SIMPLE AND PARTIAL CORRELATION COEFFICIENTS

Flood Tide Simple Correlation Coefficients

	Temp.	DIP	NO_3^-	NH_4^+
Prod./Chl.	0.581**	-0.165	-0.538**	-0.020

Flood Tide Partial Correlation Coefficients, Temperature Held Constant

	DIP	NO_3^-	NH_4^+
Prod./Chl.	0.108	-0.091	0.146

Ebb Tide Simple Correlation Coefficients

	Temp.	DIP	NO_3^-	NH_4^+
Prod./Chl.	0.651**	-0.156	-0.590**	-0.319

Ebb Tide Partial Correlation Coefficients, Temperature Held Constant,

	DIP	NO_3^-	NH_4^+
Prod./Chl.	-0.143	-0.159	-0.191

**Significant at the 1% level
*Significant at the 5% level

Table 13

WARE CREEK TIDAL TRANSPORT

Sampling Date	Water Transport (cu.m)	Tidal Transport	POC (kgC)	DOC (kgC)	ATP-C (10^{-1}kgC)	Chl. a (g)	DO (kgO_2)	DIC (kgC)
23 Jan 72	18732.0	Flood	+ 54.4	+ 108.5	+ 1.9	+ 102.3	+ 174.0	+ 224.1
		Ebb	- 44.0	- 116.7	- 4.8	- 83.1	- 163.0	- 223.1
		Net	+ 10.4	- 8.2	- 2.9	+ 19.2	+ 11.0	+ 1.0
4 Mar 72	20185.4	Flood	+ 20.1	+ 154.3	+ 20.2	+ 67.3	+ 163.2	+ 147.2
		Ebb	- 28.6	- 158.5	- 36.1	- 66.6	- 188.6	- 155.4
		Net	- 8.5	- 4.2	- 15.9	- 0.7	- 25.4	- 8.2
17 Apr 72	37714.1	Flood	+ 112.1	+ 217.0	+ 134.6	+ 409.3	+ 187.0	+ 355.9
		Ebb	+ 100.2	- 300.3	- 100.9	- 416.9	- 224.4	- 352.9
		Net	+ 11.9	- 83.3	+ 33.7	- 7.6	- 37.4	+ 3.0
17 May 72	38005.6	Flood	+ 63.4	+ 224.9	+ 90.1	+ 487.3	+ 196.4	+ 315.2
		Ebb	- 106.7	- 216.4	- 68.1	- 483.9	- 209.5	- 308.3
		Net	- 43.3	- 8.5	+ 22.0	+ 3.4	- 13.1	+ 6.9
14 Jun 72	24106.4	Flood	+ 133.1	+ 173.9	+ 59.7	+ 125.8	+ 135.8	+ 332.2
		Ebb	- 112.9	- 199.1	- 91.9	- 230.4	- 161.3	- 357.4
		Net	+ 20.2	- 25.2	- 32.2	- 104.6	- 25.5	- 25.2
15 Jun 72	33094.5	Flood	+ 135.1	+ 282.9		+ 389.7	+ 207.8	+ 478.1
		Ebb	- 137.1	- 262.6		- 394.6	- 127.4	- 435.1
		Net	- 2.0	+ 20.3		- 4.9	+ 80.4	+ 43.0

Sampling Date	Water Transport (cu.m)	Tidal Transport	POC (kgC)	DOC (kgC)	ATP-C (10^{-1}kgC)	Chl. *a* (g)	DO (kgO_2)	DIC (kgC)
28 Jul 72	45430.4	Flood	+ 160.3	+ 521.4	+ 226.2	+ 730.4	+ 185.6	+ 602.3
		Ebb	- 143.5	- 527.6	- 242.5	- 843.8	- 216.8	- 651.4
		Net	+ 16.8	- 6.2	- 16.3	- 113.4	- 31.2	- 49.1
26 Aug 72	42710.0	Flood	+ 121.7	+ 351.4	+ 137.6	+ 779.1	+ 179.0	+ 633.8
		Ebb	- 149.5	- 386.6	- 149.4	- 897.0	- 238.5	- 566.9
		Net	- 27.8	- 35.2	- 11.8	- 117.9	- 59.5	+ 66.9
24 Sep 72	51487.6	Flood	+ 171.1	+ 390.3	+ 78.9	+ 259.8	+ 285.2	+ 756.3
		Ebb	- 205.8	- 351.4	- 82.9	- 318.1	- 318.3	- 788.0
		Net	- 34.7	+ 38.9	- 4.0	- 58.3	- 33.1	- 31.7
24 Oct 72	41793.2	Flood	+ 149.9	+ 304.5	+ 44.4	+ 365.0	+ 287.1	+ 621.0
		Ebb	- 94.3	- 337.5	- 47.7	- 369.5	- 295.9	- 582.4
		Net	+ 55.6	- 33.0	- 3.3	- 4.5	- 8.8	+ 38.6
24 Nov 72	37758.0	Flood	+ 95.5	+ 298.5	+ 3.9	+ 164.2	+ 377.9	+ 443.4
		Ebb	- 135.5	- 331.9	- 22.1	- 184.4	- 414.7	- 433.5
		Net	- 40.0	- 33.4	- 13.2	- 20.2	- 36.8	+ 9.9
7 Jan 73	16603.7	Flood	+ 20.2	+ 64.9	+ 9.6	+ 98.8	+ 182.2	+ 145.1
		Ebb	- 46.4	- 64.3	- 12.1	- 97.3	- 205.1	- 144.8
		Net	- 26.2	+ 0.6	- 2.5	- 1.5	- 22.9	+ 0.3

Table 14

CARTER CREEK TIDAL TRANSPORT

Sampling Date	Water Transport (cu.m)	Tidal Transport	POC (kgC)	DOC (kgC)	ATP-C (10^{-1}kgC)	Chl. a (g)	DO (kgO_2)	DIC (kgC)
7 Mar 72	3083.4	Flood	+ 30.9	+ 16.8	+ 1.4	+ 39.6	+ 31.4	+ 41.2
		Ebb	- 11.2	- 17.7	- 3.0	- 20.6	- 29.0	- 43.4
		Net	+ 19.7	- 0.9	- 1.6	+ 19.0	+ 2.4	- 2.2
23 Mar 72	10840.7	Flood	+ 13.5	+ 54.3		+ 85.8	+ 91.9	+ 162.7
		Ebb	- 17.5	- 51.8	-	- 56.6	- 92.8	- 153.9
		Net	- 4.0	+ 2.5		+ 29.2	- 0.9	+ 8.8
19 Apr 72	10589.6	Flood	+ 23.7	+ 58.6	+ 18.9	+ 118.6	+ 73.5	+ 72.1
		Ebb	- 21.5	- 39.7	- 41.5	- 162.5	- 73.1	- 61.4
		Net	+ 1.8	+ 18.9	- 22.6	- 43.9	+ 0.4	+ 10.7
19 May 72	39893.2	Flood	+ 166.6	+ 122.2	+ 140.1	+ 577.2	+ 28.4	+ 504.0
		Ebb	- 146.6	- 112.7	- 141.7	- 694.9	- 26.7	- 492.9
		Net	+ 18.2	+ 9.5	- 1.6	- 117.7	+ 1.7	+ 11.1
17 Jun 72	12028.8	Flood	+ 29.3	+ 86.8	+ 40.8	+ 169.8	+ 75.3	+ 231.4
		Ebb	- 27.4	- 93.7	- 60.4	- 182.0	- 67.8	- 237.9
		Net	+ 1.9	- 6.9	- 19.6	- 12.2	+ 7.5	- 6.7
31 Jul 72	46718.4	Flood	+ 158.9	+ 405.7	+ 236.9	+ 652.6	+ 241.3	+ 807.1
		Ebb	- 404.6	- 429.5	- 303.8	-1009.1	- 261.9	- 644.9
		Net	- 245.7	- 23.8	- 66.9	- 356.4	- 20.6	+ 162.2

Sampling Date	Water Transport (cu.m)	Tidal Transport	POC (kgC)	DOC (kgC)	ATP-C (10^{-1}kgC)	Chl. a (g)	DO (kgO$_2$)	DIC (kgC)
29 Aug 72	25250.4	Flood	+ 46.0	+ 211.5	+ 229.4	+ 610.4	+ 148.0	+ 470.5
		Ebb	- 48.7	- 206.4	- 209.7	- 515.8	- 187.8	- 448.6
		Net	- 2.7	+ 5.1	+ 19.7	+ 94.6	- 39.8	+ 21.9
27 Sep 72	26678.2	Flood	+ 86.0	+ 166.4	+ 156.5	+ 525.3	+ 170.5	+ 549.6
		Ebb	- 120.8	- 164.8	- 184.2	- 531.7	- 191.0	- 559.6
		Net	- 37.5	+ 1.6	- 27.7	- 6.4	- 20.5	- 10.0
27 Oct 72	27537.3	Flood	+ 37.1	+ 196.8	+ 45.3	+ 240.2	+ 205.3	+ 549.9
		Ebb	- 72.8	- 218.4	- 69.8	- 364.5	- 238.8	- 507.8
		Net	- 35.7	- 20.0	- 24.5	- 124.3	- 33.5	+ 42.1
27 Nov 72	3364.4	Flood	+ 14.2	+ 30.3	+ 2.4	+ 299.6	+ 32.4	+ 77.0
		Ebb	- 9.5	- 36.0	- 3.6	- 199.1	- 31.5	- 73.6
		Net	+ 4.7	- 5.7	- 1.2	+ 100.5	+ 0.9	+ 3.4
11 Jan 73	10466.2	Flood	+ 7.7	+ 56.0	+ 3.8	+ 29.6	+ 89.9	+ 172.3
		Ebb	- 10.6	- 59.9	- 4.0	- 28.6	- 95.2	- 167.4
		Net	- 2.9	- 3.9	- 0.2	+ 1.0	- 5.3	+ 4.9

Table 15

WARE CREEK MARSH ANNUAL NET CARBON TRANSPORT

Time Period	POC (kgC)	DOC (kgC)	ATP-C (kgC)
15 Jan 72 to 12 Feb 72	+ 575.6	- 453.9	- 16.3
13 Feb 72 to 26 Mar 72	- 853.6	- 421.8	-159.9
27 Mar 72 to 2 May 72	+ 799.4	-5595.4	+226.7
3 May 72 to 31 May 72	-2407.5	+ 472.6	+122.2
1 Jun 72 to 5 Jul 72	+ 779.3	- 205.8	-270.8
6 Jul 72 to 11 Aug 72	+1082.1	- 399.3	-104.7
12 Aug 72 to 10 Sep 72	-1556.9	-1971.2	- 66.6
11 Sep 72 to 8 Oct 72	-1680.0	+1883.3	- 19.2
9 Oct 72 to 9 Nov 72	+3140.1	-1862.2	- 18.6
10 Nov 72 to 16 Dec 72	-2652.1	-2652.1	- 87.4
17 Dec 72 to 15 Jan 73	-2172.1	+ 49.6	- 20.7
Annual Net Transport	-4945.7	-11156.2	-415.4

+ into marsh

- out of marsh

Table 16

CARTER CREEK MARSH ANNUAL NET CARBON TRANSPORT

Time Period	POC (kgC)	DOC (kgC)	ATP-C (kgC)
9 Feb 72 to 15 Mar 72	+ 3243.6	- 148.2	- 30.4(1)
16 Mar 72 to 6 Apr 72	- 341.0	+ 156.1	- 243.0(2)
7 Apr 72 to 4 May 72	+ 168.2	+1444.9	
5 May 72 to 3 Jun 72	+ 922.0	+ 438.0	- 7.4
4 Jun 72 to 9 Jul 72	+ 189.4	- 688.0	- 195.7
10 Jul 72 to 14 Aug 72	-12297.3	-1191.2	- 334.7
15 Aug 72 to 13 Sep 72	- 156.2	+ 295.0	+ 114.3
14 Sep 72 to 12 Oct 72	- 1933.2	+ 88.9	- 154.3
13 Oct 72 to 12 Nov 72	- 1967.0	-1190.2	- 135.1
13 Nov 72 to 20 Dec 72	+ 934.6	-1178.8	- 25.3
21 Dec 72 to 8 Feb 73	- 417.6	- 561.6	- 3.7
Annual Net Transport	-11654.6	-2535.1	-1014.8

+ into marsh

- out of marsh

(1) - Time interval 9 Feb 72 to 25 Mar 72

(2) - Time interval 26 Mar 72 to 4 May 72

Table 17

PERCENT NET ANGIOSPERM PRODUCTION EXPORTED FROM WARE AND CARTER CREEK MARSHES

<u>Ware Creek</u>

Net Angiosperm Production (dry weight)[1]

79604.5 kg

Percent exported as:

POC = 12.4

DOC = 28.0

ATP-C = 0.5

<u>Carter Creek</u>

Net Angiosperm Production (dry weight)[2]

57177.6 kg

Percent exported as:

POC = 40.7

DOC = 8.9

ATP-C = 1.8

[1,2] Based on productivity figures of Mendelssohn (1973)
Ware = 562 g/m^2, Carter = 572 g/m^2

APPENDIX – A

Table A1

WARE CREEK 1/23/72

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
12.25	0	0.78	0.40	1.70	4.99	0.28	8.0	30.0	47.0
12.67	+ 155								
12.92	+ 319								
13.25	+ 879	0.65	0.39	1.88	7.68	0.32	4.0	27.0	21.0
13.58	+1,143								
14.05	+1,278								
14.25	+1,332	0.63	0.41	1.91	7.27	0.30	4.0	29.0	28.0
14.70	+1,976								
14.92	+2,037								
15.25	+1,136	0.55	0.29	1.96	7.02	0.28	3.0	30.0	30.0
15.58	+1,213								
15.92	+1,216								
16.75	+1,252	0.49	0.24	1.95	7.13	0.27	3.0	31.0	25.0
16.58	+1,215								
16.92	+ 999								
17.25	+ 716	0.51	0.27	1.44	7.37	0.29	3.0	39.0	8.0
17.58	0	0.51	0.29	1.12	7.41	0.24	2.0	41.0	5.0
17.92	- 807								
18.25	-1,090								
18.58	-1,095	0.48	0.30	1.42	6.97	0.29	6.0	34.0	26.0
19.00	-1,257								
19.25	-1,239								
19.58	-1,236	0.51	0.30	1.85	5.95	0.32	4.0	33.0	29.0
19.92	-1,283								
20.25	-1,237								
20.58	-1,147	0.55	0.33	1.92	5.73	0.34	4.0	32.0	31.0
20.92	-1,023								
21.25	- 983								
21.58	- 869	0.62	0.39	2.27	4.67	0.33	3.0	41.0	32.0
21.92	- 701								
22.25	- 625								
22.58	- 530	0.69	0.39	1.96	3.23	0.34	4.0	36.0	20.0
22.92	- 398								
23.25	- 291								
23.58	- 153								
23.75	0	0.82	0.40	1.94	2.92	0.34	5.0	37.0	17.0

Table A2

WARE CREEK 3/4/72

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
09.00	0	1.00	0.60	4.22	1.59	0.28	8.0	4.0	26.0
09.33	+ 177								
09.67	+ 410								
10.00	+ 544	0.57	0.45	1.12	3.44	0.32	6.0	3.0	14.0
10.33	+ 583								
10.67	+ 627								
11.00	+ 921	0.54	0.45	1.31	2.70	0.28	3.6	3.4	13.0
11.33	+ 977								
11.67	+1,051								
12.00	+1,245	0.59	0.45	1.63	2.44	0.31	4.0	5.0	13.0
12.33	+1,385								
12.67	+1,525								
13.00	+1,490	0.65	0.41	2.02	2.35	0.32	4.6	4.4	15.0
13.33	+1,443								
13.67	+1,216								
14.00	+ 880	0.69	0.31	1.89	2.65	0.31	3.4	4.6	18.0
14.33	0	0.50	0.32	1.69	3.19	0.29	3.8	8.2	17.0
14.67	- 902	0.61	0.35	1.70	2.90	0.29	4.0	8.0	15.0
15.00	-1,222								
15.33	-1,453	0.68	0.40	1.73	2.31	0.29	4.4	7.6	11.0
15.67	-1,586								
16.00	-1,738								
16.33	-1,689	0.77	0.45	1.48	2.31	0.28	5.2	9.8	11.0
16.67	-1,607								
17.00	-1,660								
17.33	-1,488	0.83	0.44	1.42	1.86	0.29	6.2	9.8	10.0
17.67	-1,257								
18.00	-1,099								
18.33	- 925	1.09	0.47	0.76	1.76	0.30	6.4	7.6	11.0
18.67	- 673								
19.00	- 526								
19.33	- 377	1.37	0.47	1.12	1.40	0.28	7.2	5.8	16.0
19.67	- 242								
20.00	- 52								
20.33	0	1.40	0.72	0.98	1.65	0.33	7.8	3.8	18.0

Table A3

WARE CREEK 4/17/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l) DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
09.62	0	0.70	1.18	2.10	0.96	0.17	6.0	22.0	20.0
09.95	+1,010								
10.28	+ 644								
10.62	+ 838	0.42	0.62	2.00	0.64	0.22	3.0	24.0	16.0
10.95	+1,335								
11.28	+1,609								
11.62	+1,800	0.37	0.43	2.64	0.61	0.15	7.0	25.0	16.0
11.95	+1,990								
12.28	+2,210								
12.62	+2,360	0.29	0.31	3.00	0.89	0.15	4.0	20.0	20.0
12.95	+2,477								
13.28	+2,463								
13.62	+2,502	0.25	0.37	2.68	1.22	0.18	6.0	24.0	14.0
13.95	+2,532								
14.28	+2,246								
14.62	+1,944	0.31	0.43	3.56	2.73	0.17	1.0	29.0	18.0
14.95	+1,367								
15.28	+ 493								
15.50	0	0.37	0.35	1.90	3.70	0.17	5.0	15.0	15.0
15.83	-1,771								
16.17	-2,229								
16.50	-2,415	0.26	0.40	2.64	1.80	0.15	2.0	15.0	18.0
16.83	-2,574								
17.17	-2,735								
17.50	-2,707	0.26	0.46	3.90	0.83	0.14	12.0	17.0	23.0
17.83	-2,842								
18.17	-2,768								
18.50	-2,721	0.31	0.51	3.88	0.55	0.14	11.0	20.0	24.0
18.83	-2,550								
19.17	-2,397								
19.50	-2,157	0.43	0.52	4.01	0.49	0.15	14.0	17.0	23.0
19.83	-1,773								
20.17	-1,439								
20.50	-1,076	0.65	0.65	3.36	0.56	0.13	9.0	18.0	22.0
20.83	- 683								
21.17	- 215								
21.33	0	1.01	0.81	2.28	0.89	0.17	11.0	20.0	20.0

Table A4

WARE CREEK 5/17/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
11.25	0	2.02	0.65	3.33	0.87	0.29	3.0	33.0	25.0
11.58	+ 492								
11.92	+ 715								
12.25	+ 872	1.64	0.63	1.90	2.96	0.48	2.0	28.0	15.0
12.58	+1,091								
12.92	+1,346								
13.25	+1,757	1.68	0.72	1.80	2.54	0.43	2.2	30.8	14.0
13.58	+2,021								
13.92	+2,213								
14.25	+2,540	1.47	0.68	2.32	2.19	0.39	2.0	29.0	14.0
14.58	+2,727								
14.92	+2,777								
15.25	+2,823	1.09	0.56	2.13	1.45	0.29	1.4	18.6	16.0
15.58	+2,829								
15.92	+2,703								
16.25	+2,268	0.35	0.42	1.23	0.98	0.13	1.4	19.6	12.0
16.58	+1,701								
16.92	+ 348								
17.00	0	0.26	0.49	1.05	0.33	0.13	1.6	22.4	9.0
17.33	-1,712								
17.67	-2,374								
18.00	-2,641	0.53	0.57	1.83	0.58	0.19	2.0	28.0	16.0
18.33	-2,938								
18.67	-2,855								
19.00	-2,770	1.08	0.72	2.07	1.05	0.28	2.4	32.6	15.0
19.33	-2,576								
19.67	-2,656								
20.00	-2,409	1.53	0.61	2.25	1.61	0.30	2.4	33.6	18.0
20.33	-2,256								
20.67	-2,098								
21.00	-1,742	1.78	0.67	2.88	0.84	0.34	1.8	26.2	29.0
21.33	-1,542								
21.67	-1,502								
22.00	- 940	2.24	0.66	2.23	0.72	0.33	12.0	28.0	17.0
22.33	- 773								
22.67	- 377								
22.92	0	2.43	0.69	1.75	0.82	0.38	17.0	26.0	37.0

Table A5

WARE CREEK 6/14/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
10.33	0	2.04	0.82	6.99	2.90	0.55	4.8	45.0	47.0
10.67	+ 263								
11.00	+ 620								
11.33	+ 800	1.36	0.85	4.67	1.72	0.46	8.6	55.4	23.0
11.67	+ 973								
12.00	+1,156								
12.33	+1,227	1.10	0.79	5.31	1.02	0.38	6.2	51.2	24.0
12.67	+1,479								
13.00	+1,626								
13.33	+1,779	1.06	0.77	5.42	1.31	0.43	5.4	58.0	29.0
13.67	+1,972								
14.00	+2,013								
14.33	+2,029	0.82	0.76	3.92	1.18	0.40	3.0	55.0	22.0
14.67	+1,673								
15.00	+1,417								
15.33	0	0.60	0.55	2.67	0.90	0.39	3.4	49.4	20.6
15.67	-1,369								
16.00	-1,784								
16.33	-1,989	0.73	0.70	3.46	1.00	0.32	6.0	43.6	26.0
16.67	-2,033								
17.00	-1,945								
17.33	-1,981	1.16	1.10	5.06	0.72	0.42	6.6	56.6	30.0
17.67	-1,718								
18.00	-1,524								
18.33	-1,662	1.60	1.30	5.80	0.47	0.45	6.8	56.0	36.0
18.67	-1,290								
19.00	-1,066								
19.33	- 811	2.15	1.26	6.10	0.49	0.47	4.0	58.0	32.0
19.67	- 654								
20.00	- 554								
20.33	- 505	2.39	1.40	6.04	1.32	0.55	6.2	54.0	36.0
20.67	- 354								
21.00	- 206								
21.33	- 110	2.95	1.27	6.52	1.12	0.60	6.2	61.6	35.0
21.67	0	1.88	1.31	4.08	0.82	0.55	8.2	49.0	23.0

Table A6

WARE CREEK 6/14-15/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
21.67	0	1.88	1.31	4.08	0.82	0.55	8.2	49.0	23.0
22.00	+ 409								
22.33	+ 640								
22.67	+ 756	1.43	0.99	3.85	1.17	0.52	6.2	49.8	24.0
23.00	+ 923								
23.33	+1,098								
23.67	+1,196	1.60	0.80	4.88	0.73	0.34	7.0	52.2	24.0
24.00	+1,414								
00.33	+1,714								
00.67	+1,760	1.45	0.76	4.79	0.70	0.33	5.6	52.2	32.0
01.00	+2,159								
01.33	+2,433								
01.67	+2,346	1.07	0.75	4.38	0.94	0.57	8.2	52.8	26.0
02.00	+2,316								
02.33	+2,350								
02.67	+2,307	0.88	0.60	4.08	0.86	0.50	7.2	58.8	23.0
03.00	+2,129								
03.33	+1,870								
03.67	+ 742	0.49	0.30	2.29	0.41	0.45	3.4	43.4	13.6
03.92	0	0.48	0.41	2.03	0.34	0.48	5.2	39.8	12.0
04.25	-1,502								
04.58	-1,831								
04.92	-2,277	0.69	0.49	3.23	0.54	0.61	5.6	45.6	17.4
05.25	-2,186								
05.58	-2,514								
05.92	-2,424	0.99	0.60	5.29	0.88	0.61	9.6	40.0	19.4
06.25	-2,440								
06.58	-2,118								
06.92	-2,116	1.28	0.73	6.34	0.52	0.61	8.2	57.8	36.0
07.25	-1,799								
07.58	-1,502								
07.92	-1,353	1.95	0.86	6.42	0.85	0.26	6.6	65.2	33.0
08.25	-1,209								
08.58	- 962								
08.92	- 789	2.52	0.98	7.29	0.81	0.66	5.4	60.2	35.0
09.25	- 612								
09.58	- 498								
09.92	- 249								
10.17	0	2.88	1.03	7.70	0.95	0.71	5.2	57.8	46.8

Table A7

WARE CREEK 7/28/72

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
08.75	0	2.35	0.82	3.62	1.90	0.37	18.0	35.4	27.0
09.08	+ 543								
09.42	+ 830								
09.75	+ 971	1.85	0.70	2.77	2.88	0.42	18.0	29.0	22.2
10.08	+1,180								
10.42	+1,490								
10.75	+1,862	1.77	0.75	3.11	1.61	0.37	9.0	34.0	28.0
11.08	+2,112								
11.42	+2,450								
11.75	+2,710	1.41	0.64	4.40	1.09	0.59	16.4	29.4	36.6
12.08	+2,938								
12.42	+2,717								
12.75	+3,162	0.87	0.46	4.82	1.26	0.36	12.4	34.6	39.6
13.08	+3,142								
13.42	+2,838								
13.75	+2,741	0.74	0.34	4.33	1.02	0.23	13.0	26.2	43.6
14.08	+2,151								
14.42	+1,658								
14.75	+ 351								
14.83	0	0.57	0.39	1.81	0.74	0.17	11.2	26.0	23.8
15.17	-1,992								
15.50	-2,376								
15.83	-2,959	0.66	0.34	3.21	0.78	0.18	12.4	34.8	26.0
16.17	-3,058								
16.50	-3,055								
16.83	-3,419	0.71	0.40	3.75	0.68	0.19	17.0	28.0	32.0
17.17	-3,255								
17.50	-3,039								
17.83	-2,834	1.00	0.49	4.35	1.03	0.25	15.4	33.6	31.2
18.17	-2,612								
18.50	-2,345								
18.83	-2,147	1.36	0.58	4.90	0.89	0.28	14.2	34.2	35.2
19.17	-1,791								
19.50	-1,573								
19.83	-1,317	1.84	0.62	3.99	1.25	0.30	18.0	24.0	38.0
20.17	- 928								
20.50	- 496								
21.00	0	2.01	0.72	3.35	1.21	0.34	22.2	27.0	23.8

Table A8

WARE CREEK 8/26/72

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
08.00	0	1.09	0.54	3.42	1.00	0.19	9.6	34.4	8.0
08.33	+ 393								
08.67	+ 557								
09.00	+ 557	0.64	0.54	2.27	0.57	0.18	2.0	30.0	12.0
09.33	+ 782								
09.67	+ 990								
10.00	+1,315	0.62	0.52	2.74	0.55	0.19	1.8	35.2	10.6
10.33	+1,620								
10.67	+1,966								
11.00	+2,138	0.51	0.57	3.18	0.67	0.20	1.6	32.4	34.6
11.33	+2,456								
11.67	+2,774								
12.00	+2,837	0.51	0.54	3.64	0.46	0.19	2.2	32.8	30.6
12.33	+2,956								
12.67	+2,457								
13.00	+2,534	0.64	0.47	3.92	0.44	0.17	2.2	26.8	42.4
13.33	+2,619								
13.67	+2,287								
14.00	+1,372	0.70	0.48	2.84	0.44	0.21	10.8	23.2	22.0
14.33	+ 352								
14.50	0	0.80	0.50	2.11	0.43	0.23	4.1	30.2	21.6
14.83	-2,304								
15.17	-2,613								
15.50	-3,167	0.62	0.55	2.79	0.38	0.21	6.6	29.4	20.0
15.83	-3,284								
16.17	-3,269								
16.50	-3,332	0.56	0.58	3.75	0.43	0.23	3.2	34.8	37.0
16.83	-3,393								
17.17	-3,187								
17.50	-3,147	0.56	0.54	4.01	0.47	0.22	10.4	37.2	21.0
17.83	-2,690								
18.17	-2,347								
18.50	-1,978	0.59	0.60	4.86	0.39	0.23	6.0	34.2	29.8
18.83	-1,625								
19.17	-1,233								
19.50	-1,014	0.82	0.65	3.93	0.48	0.25	7.2	34.4	26.6
19.83	- 676								
20.17	- 339								
20.66	0	1.25	0.62	2.86	1.01	0.30	8.6	33.8	15.6

Table A9

WARE CREEK 9/24/72

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
08.00	0	0.81	0.27	3.42	0.40	0.07	2.6	27.4	7.2
08.33	+ 884								
08.67	+ 984								
09.00	+1,144	0.73	0.34	3.59	0.96	0.18	1.4	29.6	11.0
09.33	+1,581								
09.67	+1,871								
10.00	+2,268	0.58	0.39	7.76	0.74	0.11	1.8	28.2	56.0
10.33	+2,429								
10.67	+2,965								
11.00	+3,185	0.43	0.24	8.79	1.50	0.36	1.8	30.8	62.4
11.33	+3,378								
11.67	+3,287								
12.00	+3,300	0.71	0.21	6.67	4.76	1.64	2.6	32.4	60.0
12.33	+3,117								
12.67	+2,829								
13.00	+2,677	0.80	0.21	5.39	5.19	1.80	2.8	35.2	48.0
13.33	+2,365								
13.67	+1,914								
14.00	+1,181	0.85	0.20	3.25	5.46	1.83	2.6	41.4	18.0
14.33	0	0.84	0.31	2.45	5.75	1.82	1.8	44.2	19.0
14.67	-2,285								
15.00	-2,557								
15.33	-2,749	0.66	0.28	2.68	4.01	1.44	1.6	38.4	26.0
15.67	-3,317								
16.00	-3,303								
16.33	-3,134	0.49	0.19	4.15	2.82	1.05	1.2	38.8	25.0
16.67	-2,904								
17.00	-3,122								
17.33	-3,067	0.36	0.25	4.14	1.24	0.52	1.4	36.6	59.0
17.67	-3,112								
18.00	-2,960								
18.33	-2,791	0.36	0.23	5.45	0.46	0.29	2.8	34.6	74.6
18.67	-2,961								
19.00	-2,601								
19.33	-2,328	0.38	0.25	4.39	0.30	0.19	1.8	32.2	42.0
19.67	-2,003								
20.00	-1,627								
20.33	-1,160	0.44	0.28	3.83	0.41	0.22	2.4	33.6	30.0
20.67	- 403								
20.92	0	0.64	0.35	2.23	0.26	0.20	2.6	27.8	6.6

Table A10

WARE CREEK 10/24/72

Time	Flow (1/sec)	Nutrient Concentrations							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
08.00	0	0.69	0.60	2.21	1.28	0.23	10.0	12.0	10.0
08.33	+ 323								
08.67	+ 445								
09.00	+ 594	0.45	0.77	1.20	1.02	0.20	7.6	17.4	6.0
09.33	+ 730								
09.67	+1,063								
10.00	+1,449	0.42	0.57	2.84	1.01	0.21	8.2	13.8	16.0
10.33	+1,616								
10.67	+1,791								
11.00	+2,228	0.42	0.53	3.12	2.05	0.27	5.0	22.4	19.6
11.33	+2,483								
11.67	+2,651								
12.00	+2,933	0.43	0.76	3.24	3.25	0.28	5.4	20.6	31.0
12.33	+2,712								
12.67	+2,574								
13.00	+2,486	0.78	0.65	2.18	8.50	0.38	7.2	21.8	12.0
13.33	+2,452								
13.67	+2,338								
14.00	+1,811	0.82	0.48	1.70	8.94	0.38	7.6	19.8	14.6
14.33	+ 841								
14.63	0	0.85	0.68	0.61	9.03	0.41	5.4	20.0	7.6
15.00	-1,992								
15.33	-2,663								
15.67	-3,065	0.61	0.84	0.80	6.45	0.35	6.0	22.4	7.6
16.00	-3,030								
16.33	-2,609								
16.67	-2,507	0.41	0.81	1.71	3.71	0.35	8.2	15.8	14.6
17.00	-2,594								
17.33	-2,611								
17.67	-2,212	0.30	0.57	2.74	1.43	0.25	4.0	21.6	17.4
18.00	-2,371								
18.33	-2,126								
18.67	-1,897	0.32	0.63	2.89	0.42	0.31	1.0	22.2	20.0
19.00	-1,714								
19.33	-1,431								
19.67	-1,472	0.37	0.52	3.28	0.39	0.14	5.0	17.4	25.4
20.00	-1,284								
20.33	- 907								
20.67	- 507	0.44	0.75	2.29	0.38	0.09	6.6	18.2	16.8
21.25	0	0.61	0.69	1.50	0.53	0.10	5.4	21.0	8.0

Table A11

WARE CREEK 11/24/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
08.67	0	1.08	0.37	2.42	1.36	0.16	15.0	15.0	12.4
09.00	+ 346								
09.33	+ 375								
09.67	+ 453	0.86	0.40	1.89	9.20	0.29	13.6	10.4	13.4
10.00	+ 573								
10.33	+ 903								
10.67	+1,207	0.83	0.39	2.06	6.52	0.25	14.6	9.4	22.4
11.00	+1,628								
11.33	+1,799								
11.67	+2,088	0.75	0.43	2.80	3.76	0.21	13.0	11.2	23.2
12.00	+2,212								
12.33	+2,329								
12.67	+2,443	0.61	0.29	3.04	2.76	0.19	10.8	13.6	20.2
13.00	+2,698								
13.33	+2,576								
13.67	+2,440	0.48	0.25	1.79	5.01	0.14	7.0	17.4	10.6
14.00	+2,294								
14.33	+1,921								
14.67	+1,264	0.45	0.26	1.11	5.24	0.16	9.0	14.8	9.2
15.00	+ 134								
15.13	0	0.45	0.21	0.88	5.10	0.17	7.0	13.2	11.2
15.50	-1,692								
15.83	-2,053								
16.17	-2,251	0.45	0.28	1.21	4.26	0.13	9.8	11.4	11.2
16.50	-2,476								
16.83	-2,683								
17.17	-2,701	0.48	0.35	1.87	3.01	0.15	6.4	16.2	17.2
17.50	-2,842								
17.83	-2,691								
18.17	-2,475	0.64	0.34	2.58	2.49	0.19	8.2	15.0	24.4
18.50	-2,522								
18.83	-2,327								
19.17	-1,962	0.79	0.36	2.99	2.88	0.22	12.0	10.4	26.4
19.50	-1,779								
19.83	-1,568								
20.17	-1,189	0.85	0.47	3.07	2.42	0.24	13.0	12.0	24.0
20.50	- 948								
20.83	- 673								
21.17	- 326	1.21	0.41	3.29	1.64	0.23	10.2	18.4	31.0
21.50	- 119								
21.75	0	1.50	0.42	2.65	1.33	0.26	12.6	7.8	17.2

Table A12

WARE CREEK 1/7/73

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
07.67	0	1.50	0.43	2.42	23.55	0.43	13.0	19.0	14.0
08.00	+ 111								
08.33	+ 210								
08.67	+ 339	0.76	0.41	2.35	24.39	0.49	7.0	22.0	18.0
09.00	+ 364								
09.33	+ 485								
09.67	+ 405	0.85	0.39	2.15	21.83	0.51	8.6	18.6	17.0
10.00	+ 527								
10.33	+ 494								
10.67	+ 514	0.87	0.41	2.05	22.81	0.47	7.0	20.0	16.0
11.00	+ 693								
11.33	+1,063								
11.67	+1,127	0.88	0.46	2.42	19.51	0.46	9.0	18.0	18.0
12.00	+1,321								
12.33	+1,368								
12.67	+1,174	0.86	0.45	2.50	18.55	0.45	5.0	18.0	18.0
13.00	+1,082								
13.33	+ 758								
13.67	+ 232								
13.83	0	0.84	0.43	2.51	18.06	0.44	12.0	17.0	18.0
14.17	-1,067								
14.50	-1,352								
14.83	-1,525	0.87	0.40	2.32	16.37	0.47	6.4	18.6	18.0
15.17	-1,719								
15.50	-1,559								
15.83	-1,624	0.86	0.41	3.00	20.04	0.46	12.4	15.6	24.0
16.17	-1,423								
16.50	-1,285								
16.83	-1,128	0.95	0.45	2.89	17.28	0.45	7.6	14.4	21.2
17.17	- 901								
17.50	- 700								
17.83	- 589	1.24	0.44	3.79	17.55	0.31	7.6	23.4	22.0
18.17	- 526								
18.50	- 399								
18.83	- 298	1.38	0.51	4.07	6.16	0.30	11.4	23.6	30.0
19.17	- 222								
19.50	- 171								
19.83	- 111								
20.17	0	1.50	0.50	4.90	6.44	0.30	13.0	15.0	34.0

Table A13

CARTER CREEK 3/7/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
10.50	0	2.03	0.43	3.78	9.33	0.40	7.0	9.0	30.0
11.25	+ 40								
11.50	+ 57	0.59	0.41	5.58	18.63	0.46	5.6	12.4	47.0
12.50	+ 205	0.49	0.41	9.48	8.78	0.39	5.0	11.0	87.0
12.75	+ 260								
13.50	+ 548	0.48	0.33	7.05	8.64	0.40	4.0	10.0	78.0
14.50	+ 567								
14.67	0	0.50	0.35	0.35	8.14	0.39	4.0	10.0	30.0
14.83	- 181								
15.25	- 358								
15.50	- 447								
15.67	- 509	0.48	0.29	1.83	7.36	0.42	3.6	12.4	28.0
16.00	- 225								
16.17	- 284								
16.33	- 374								
16.67	- 167	0.61	0.39	4.14	7.36	0.43	4.4	16.6	42.0
17.17	- 216								
17.33	- 138								
17.67	- 80	1.62	0.25	6.29	7.63	0.43	5.6	16.4	59.0
18.00	- 30								
18.67	- 19	2.09	0.41	5.24	7.99	0.49	5.6	18.4	48.0
19.25	- 19								
19.67	- 11	1.87	0.31	7.00	7.85	0.50	5.4	18.6	64.0
20.17	- 14								
20.67	- 13	1.72	0.17	9.17	6.85	0.52	4.8	16.2	88.0
21.67	- 9	1.78	0.24	7.38	6.13	0.54	5.8	15.2	71.0
22.67	0	2.10	0.27	5.37	5.88	0.51	7.4	14.6	40.0

Table A14

CARTER CREEK 3/23/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
10.83	0	0.78	0.70	2.50	1.84	0.26	5.0	21.0	16.0
11.17	+ 84								
11.50	+ 228								
11.83	+ 316	0.38	0.48	1.66	3.82	0.28	3.6	15.4	8.0
12.17	+ 262								
12.50	+ 75								
12.83	+ 37	0.41	0.51	1.00	4.22	0.26	3.0	14.0	7.0
13.17	+ 458								
13.50	+ 398								
13.83	+ 402	0.33	0.49	1.38	3.69	0.29	2.0	13.0	13.0
14.17	+1,233								
14.50	+ 829								
14.72	+ 82	0.27	0.50	1.05	3.06	0.26	2.0	15.0	10.0
14.88	+ 172								
15.17	+ 721								
15.50	+ 263								
15.83	+1,745	0.33	0.52	0.93	2.12	0.26	1.6	12.4	14.0
16.17	+ 610								
16.50	+ 954								
16.83	+ 136	0.26	0.50	0.80	2.42	0.28	1.6	12.4	12.0
17.25	+ 112								
17.30	+1,517	0.25	0.49	0.91	2.31	0.25	2.2	15.8	12.0
17.75	+ 358								
17.83	0	0.24	0.48	0.80	2.42	0.22	2.2	15.0	10.0
17.92	- 480	0.22	0.62	1.36	1.90	0.28	2.6	15.4	8.0
18.25	-1,533								
18.58	- 454								
18.92	- 807	0.29	0.59	0.84	1.84	0.28	3.0	15.0	7.0
19.25	-1,257								
19.58	- 709								
19.92	- 985	0.26	0.50	0.82	1.89	0.26	3.0	16.0	7.0
20.25	- 843								
20.58	- 695								
20.92	- 457	0.53	0.55	0.82	2.14	0.11	3.4	16.6	8.0
21.25	- 150								
21.58	- 60								
21.92	- 121	0.93	0.47	0.94	1.93	0.07	3.6	15.4	8.0
22.25	- 188								
22.58	- 67								
22.92	0	0.90	1.06	0.86	1.73	0.25	6.0	13.0	21.0

Table A15

CARTER CREEK 4/19/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
09.00	0	1.15	0.53	2.48	2.12	0.24	10.0	22.0	19.0
09.33	+								
09.67	+ 50								
10.00	+ 176	0.50	0.42	7.96	1.98	0.26	11.0	26.0	56.0
10.33	+ 243								
10.67	+ 341								
11.00	+ 436	0.43	0.47	5.88	3.28	0.30	4.0	33.0	41.0
11.33	+ 504								
11.67	+ 636								
12.00	+ 797	0.43	0.41	4.91	4.67	0.36	4.0	28.0	30.0
12.33	+ 900								
12.67	+1,045								
13.00	+ 761	0.37	0.45	3.27	2.87	0.31	1.0	28.0	23.0
13.33	+ 751								
13.67	+ 499								
14.00	+ 488	0.35	0.43	2.88	2.70	0.31	1.0	23.0	19.0
14.33	0	0.36	0.48	2.36	2.46	0.33	1.0	33.0	17.0
14.67	- 350								
15.00	- 947								
15.33	- 855	0.30	0.46	2.12	2.32	0.31	2.0	31.0	12.0
15.67	- 877								
16.00	-1,011								
16.33	-1,005	0.32	0.48	2.22	2.54	0.31	2.0	30.0	25.0
16.67	- 946								
17.00	- 793								
17.33	- 920	0.31	0.53	2.44	2.32	0.27	6.0	30.0	28.0
17.67	- 482								
18.00	- 384								
18.33	- 254	0.66	0.58	5.40	1.94	0.29	6.0	34.0	45.0
18.67	- 203								
19.00	- 114								
19.33	- 81	1.25	0.45	13.12	2.45	0.41	6.0	33.0	118.0
19.67	- 46								
20.00	- 34								
20.33	- 29	1.30	0.46	14.23	2.40	0.42	10.0	39.0	111.0
20.67	0	1.24	0.50	9.06	2.38	0.42	10.0	38.0	72.0

Table A16

CARTER CREEK 5/19/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
10.00	0	0.98	0.70	2.27	0.20	0.50	4.8	34.2	11.0
10.33	+ 251								
10.67	+ 407								
11.00	+ 354	0.88	0.82	1.95	0.40	0.30	3.2	22.8	31.0
11.33	+ 632								
11.67	+ 370								
12.00	+ 730	0.71	0.72	2.01	0.45	0.25	2.8	21.2	34.0
12.33	+1,016								
12.67	+1,466								
13.00	+1,265	0.67	0.64	2.03	0.41	0.24	2.6	18.4	32.0
13.33	+1,405								
13.67	+2,370								
14.00	+2,882	0.73	0.57	2.31	0.37	0.25	3.6	26.4	30.0
14.33	+4,160								
14.67	+4,926								
15.00	+3,365	0.43	0.39	1.76	0.29	0.27	2.0	14.0	22.0
15.33	+4,361								
15.67	+5,055								
16.00	+2,662	0.30	0.39	1.42	0.71	0.30	2.0	15.0	11.0
16.33	+1,908								
16.67	+1,015								
17.00	0	0.26	0.41	1.27	0.34	0.39	2.0	14.0	12.0
17.33	-2,109								
17.67	-3,342								
18.00	-2,778	0.63	0.57	2.02	0.29	0.29	2.0	21.0	21.0
18.33	-3,586								
18.67	-4,026								
19.00	-4,235	0.65	0.62	1.56	0.41	0.25	3.0	26.2	16.0
19.33	-2,775								
19.67	-2,207								
20.00	-1,864	0.58	0.66	1.63	0.31	0.30	3.6	25.6	21.0
20.33	- 893								
20.67	- 929								
21.00	- 958	0.72	0.67	1.69	0.25	0.32	3.4	23.8	27.0
21.33	- 439								
21.67	- 434								
22.00	- 552	0.75	0.62	1.31	0.17	0.39	3.2	22.0	23.0
22.33	- 328								
22.67	- 322								
23.00	0	1.21	0.78	1.19	0.16	0.52	2.8	21.2	16.0

Table A17

CARTER CREEK 6/17/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
10.00	0	4.20	0.87	6.05	2.17	0.57	10.8	82.2	31.4
10.33	+ 111								
10.67	+ 104								
11.00	+ 176	1.11	1.14	4.29	0.99	0.22	6.4	60.2	41.2
11.33	+ 362								
11.67	+ 446								
12.00	+ 422	1.06	1.19	4.22	1.68	0.21	4.8	66.4	38.0
12.33	+ 624								
12.67	+1,012								
13.00	+ 908	0.60	0.65	2.95	0.72	0.21	2.2	47.2	30.4
13.33	+1,014								
13.67	+1,057								
14.00	+1,145	0.54	0.68	2.14	0.72	0.23	5.0	48.0	22.2
14.33	+1,410								
14.67	+1,265								
15.00	+1,342	0.38	0.48	1.60	0.73	0.24	3.8	52.4	13.2
15.33	+1,153								
15.67	0	0.38	0.60	1.23	0.93	0.32	5.2	48.8	8.6
16.00	- 867								
16.33	- 749								
16.67	- 772	0.49	0.57	1.37	1.27	0.27	3.4	56.4	15.2
17.00	-1,222								
17.33	-1,238								
17.67	- 467	0.66	0.57	1.91	0.99	0.29	3.0	54.6	16.4
18.00	- 460								
18.33	- 443								
18.67	- 740	0.89	0.70	2.79	1.43	0.19	6.6	57.0	30.8
19.00	- 707								
19.33	- 419								
19.67	- 461	1.61	0.72	3.65	1.70	0.42	8.6	56.8	28.6
20.00	- 351								
20.73	- 236								
20.67	- 151	3.02	0.84	3.74	2.50	0.61	14.8	69.6	30.6
21.00	- 98								
21.33	- 46								
21.67	0	3.56	0.92	4.01	2.80	0.77	15.0	71.4	32.0

Table A18

CARTER CREEK 7/31/72

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
08.67	0	5.06	1.04	11.57	1.90	0.38	16.2	31.8	174.6
09.00	+ 533								
09.33	+ 694								
09.67	+ 684	1.09	0.47	5.27	2.81	0.32	19.8	33.8	38.6
10.00	+ 980								
10.33	+ 955								
10.67	+1,105	0.68	0.36	3.64	2.84	0.42	23.4	33.2	28.2
11.00	+1,088								
11.33	+1,779								
11.67	+2,477	0.42	0.30	2.14	2.78	0.44	18.2	32.8	24.0
12.00	+2,324								
12.33	+2,083								
12.67	+4,507	0.38	0.28	1.96	2.36	0.45	23.0	26.8	26.0
13.00	+3,543								
13.33	+2,766								
13.67	+1,029	0.30	0.23	1.57	2.21	0.47	23.0	24.2	24.0
14.00	0	0.53	0.41	2.05	2.08	0.46	16.8	31.6	31.8
14.33	- 508								
14.67	-2,283								
15.00	-2,622	0.35	0.36	1.82	2.05	0.45	16.8	32.4	25.2
15.33	-3,469								
15.67	-2,692								
16.00	-3,308	0.46	0.37	1.43	1.56	0.34	11.4	37.0	21.8
16.33	-2,269								
16.67	-1,976								
17.00	-2,140	0.45	0.30	6.61	2.16	0.42	8.2	45.0	53.0
17.33	-2,730								
17.58	0								
17.90	+7,087								
17.94	0								
18.00	-6,814	0.67	0.41	7.89	3.41	0.33	14.8	30.0	75.2
18.33	-2,604								
18.67	-1,086								
19.00	- 830	1.63	0.60	11.23	5.58	0.44	12.4	51.8	92.6
19.33	- 508								
19.67	- 264								
20.00	- 169	2.01	0.73	13.71	6.14	0.56	16.8	51.6	130.0
20.33	- 42								
20.67	- 157								
21.00	- 128								
21.28	0	2.79	0.82	6.82	6.11	0.58	14.4	53.4	108.0

Table A19

CARTER CREEK 8/29/72

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
08.33	0	3.33	0.69	6.44	1.34	0.34	18.6	39.4	46.0
08.67	+ 110								
09.00	+ 199								
09.33	+ 230	1.25	0.64	4.98	0.91	0.29	10.0	44.0	38.4
09.67	+ 418								
10.00	+ 619								
10.33	+ 847	0.90	0.66	4.44	0.55	0.38	3.8	45.2	38.0
10.67	+1,024								
11.00	+1,024								
11.33	+1,380	0.69	0.69	3.53	0.53	0.30	3.8	44.2	33.0
11.67	+1,549								
12.00	+1,792								
12.33	+2,488	0.52	0.59	2.58	0.41	0.30	2.6	33.4	22.6
12.67	+4,265								
13.00	+3,427								
13.33	+1,612	0.42	0.55	2.10	0.29	0.25	2.8	29.2	25.0
13.67	0	0.48	0.64	2.05	0.28	0.29	1.8	37.8	17.4
14.00	- 292								
14.33	-1,409								
14.67	-3,530	0.43	0.63	1.85	0.52	0.15	2.4	30.8	21.8
15.00	-3,223								
15.33	-2,004								
15.67	-1,859	0.67	0.63	2.15	0.34	0.33	2.2	35.8	19.8
16.00	-1,643								
16.33	- 574								
16.67	- 883	0.85	0.60	2.31	0.35	0.30	1.6	38.4	23.0
17.08	- 563								
17.33	- 707								
17.67	- 731	1.23	0.58	3.05	0.52	0.35	3.8	38.4	22.8
18.00	- 475								
18.33	- 457								
18.67	- 331	2.22	0.68	3.23	0.65	0.36	4.2	37.8	30.0
19.00	- 206								
19.33	- 83								
19.67	- 32	2.69	0.69	4.67	0.79	0.44	9.6	37.8	29.2
20.00	0	2.60	0.65	5.48	0.63	0.42	12.8	35.6	45.4

Table A20

CARTER CREEK 9/27/72

Time	Flow (l/sec)	Nutrient Concentrations (ug at/l)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
07.83	0	1.68	0.36	4.05	1.37	0.47	22.6	15.4	44.0
08.25	+ 64								
08.50	+ 107								
08.83	+ 229	0.84	0.33	4.64	0.78	0.31	6.8	21.2	36.4
09.17	+ 336								
09.50	+ 417								
09.83	+ 852	0.65	0.40	4.90	0.98	0.33	3.4	19.6	39.0
10.17	+1,181								
10.50	+1,223								
10.83	+1,256	0.83	0.52	3.34	0.81	0.30	2.4	20.6	26.0
11.17	+1,035								
11.50	+2,086								
11.83	+2,291	0.55	0.38	2.16	0.70	0.13	2.0	17.0	23.8
12.17	+2,491								
12.50	+2,821								
12.83	+2,934	0.48	0.38	1.93	0.59	0.14	1.8	10.2	23.0
13.17	+1,982								
13.67	0	0.50	0.33	1.81	0.55	0.16	1.6	29.4	9.0
14.00	-1,873								
14.33	-2,509								
14.67	-2,840	0.60	0.40	2.09	1.22	0.06	2.8	29.2	14.0
15.00	-2,961								
15.33	-2,122								
15.67	-1,717	0.70	0.40	2.57	0.15	0.07	1.0	33.0	18.0
16.00	-1,336								
16.33	-1,306								
16.67	-1,074	0.85	0.41	2.90	0.33	0.11	1.2	33.8	24.0
17.00	- 959								
17.33	- 821								
17.67	- 684	1.01	0.31	2.10	0.43	0.14	2.6	35.4	12.0
18.00	- 458								
18.33	- 613								
18.67	- 398	1.32	0.37	11.24	5.82	0.38	9.0	38.0	84.0
19.00	- 213								
19.33	- 184								
19.67	- 137	1.07	0.42	19.52	11.35	0.39	19.0	46.0	150.0
20.00	- 77								
20.33	- 38								
20.50	0	1.49	0.46	8.56	11.88	0.87	21.4	38.6	57.6

Table A21

CARTER CREEK 10/27/72

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
08.00	0	1.80	0.68	1.55	2.20	0.28	8.0	23.6	10.4
08.42	+ 35								
08.67	+ 50								
09.00	+ 229	1.05	0.71	0.62	1.76	0.23	7.0	18.6	5.0
09.33	+ 324								
09.67	+ 354								
10.00	+ 639	0.69	0.55	0.43	1.34	0.27	5.4	13.4	5.2
10.33	+ 515								
10.67	+ 738								
11.00	+1,130	0.54	0.60	0.32	1.41	0.27	4.4	11.2	5.5
11.33	+1,350								
11.67	+1,406								
12.00	+1,826	0.60	0.71	0.18	1.00	0.26	2.6	16.0	3.4
12.33	+2,329								
12.67	+3,492								
13.00	+3,669	0.43	0.71	0.33	0.49	0.20	3.4	12.6	5.0
13.33	+3,224								
13.67	+2,097								
14.00	+1,128	0.40	0.64	0.19	0.14	0.22	1.4	13.4	5.2
14.33	0	0.55	0.90	0.45	0.07	0.27	3.0	12.2	4.8
14.67	- 911								
15.00	-2,545								
15.33	-2,355	0.49	0.77	0.40	0.24	0.17	1.2	17.0	5.8
15.67	-2,596								
16.00	-1,549								
16.33	-2,114	0.51	0.66	0.54	0.28	0.16	5.0	19.8	8.2
16.67	-1,662								
17.00	-1,011								
17.33	-1,079	0.63	0.57	0.67	0.44	0.19	3.0	22.6	11.4
17.67	- 873								
18.00	- 833								
18.33	- 619	0.78	0.63	0.37	0.61	0.17	3.8	21.6	8.3
18.67	- 692								
19.00	- 236								
19.33	- 283	1.16	0.61	0.39	0.67	0.19	3.0	25.2	4.8
19.67	- 187								
20.00	- 115								
20.33	0	1.42	0.86	0.52	0.72	0.23	3.4	19.6	8.0

Table A22

CARTER CREEK 11/27/72

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
10.33	0	2.40	0.52	5.81	11.04	0.21	22.5	43.8	43.4
10.67	+ 57								
11.00	+ 88								
11.33	+ 214	1.07	0.53	7.90	16.11	0.31	26.0	33.0	66.0
11.67	+ 274								
12.00	+ 179								
12.33	+ 154	0.94	0.40	6.32	16.39	0.30	17.2	17.0	62.6
12.67	+ 436								
13.00	+ 557								
13.33	+ 345	0.74	0.28	3.05	14.97	0.25	16.6	16.6	40.0
13.67	+ 158								
14.00	+ 565								
14.33	+ 161	0.72	0.31	2.02	13.66	0.24	10.8	20.0	22.2
14.67	+ 601								
15.00	0	0.64	0.29	1.82	13.86	0.22	11.4	16.0	26.6
15.33	- 82								
15.67	- 120								
16.00	- 316	0.69	0.24	1.44	13.91	0.21	8.2	15.8	28.8
16.33	- 569								
16.67	- 315								
17.00	- 290	0.77	0.33	1.46	15.88	0.24	14.8	15.6	15.6
17.33	- 456								
17.67	- 181								
18.00	- 195	1.63	0.50	1.65	13.54	0.26	14.6	19.4	18.0
18.33	- 259								
18.67	- 313								
19.00	- 128	2.09	0.53	5.75	12.92	0.30	16.0	19.8	40.0
19.33	- 54								
19.67	- 21								
20.00	- 10	2.20	0.51	4.96	13.01	0.27	16.0	21.6	39.4
20.33	- 8								
20.67	- 5								
21.00	- 5	2.57	0.50	3.71	12.17	0.26	16.0	21.0	37.0
21.33	- 1								
21.67	- 1								
22.00	- 0	2.80	0.48	6.75	11.36	0.27	21.2	18.0	51.8
22.33	- 0								
22.67	0	3.23	0.42	4.61	11.28	0.29	22.6	17.2	39.2

Table A23

CARTER CREEK 1/11/73

Time	Flow (1/sec)	Nutrient Concentrations (ug at/1)							
		DIP	DOP	PP	NO_3^-	NO_2^-	NH_4^+	DON	PN
09.00	0	1.97	0.41	2.22	24.89	0.34	19.6	17.4	10.0
09.33	+ 96								
09.67	+ 230								
10.00	+ 472	1.16	0.29	0.76	25.91	0.35	14.8	14.2	6.0
10.33	+ 288								
10.67	+ 460								
11.00	+ 805	0.91	0.27	0.56	25.75	0.31	11.8	12.2	5.0
11.33	+ 714								
11.67	+ 446								
12.00	+ 914	0.90	0.25	0.59	23.28	0.32	16.0	8.0	5.0
12.33	+ 948								
12.67	+ 92								
13.00	+ 869	0.86	0.25	0.61	23.68	0.31	12.4	7.6	4.4
13.33	+ 753								
13.67	+ 186								
14.00	+ 199								
14.33	0	0.89	0.22	0.58	23.78	0.33	9.8	8.2	4.8
14.67	- 646								
15.00	- 472								
15.33	- 818	0.90	0.25	0.63	25.15	0.31	11.6	12.4	6.0
15.67	- 627								
16.00	- 737								
16.33	- 816	1.01	0.35	0.57	26.86	0.32	13.2	11.8	6.0
16.67	- 706								
17.00	- 662								
17.33	- 561	1.28	0.34	0.86	23.39	0.34	15.0	11.0	10.0
17.67	- 407								
18.00	- 222								
18.33	- 145	1.93	0.45	1.27	20.39	0.32	7.2	20.8	15.0
18.67	- 97								
19.00	- 43								
19.33	- 24	1.92	0.45	2.09	22.07	0.34	6.8	30.2	12.0
19.67	- 12								
20.00	- 9								
20.33	0	2.04	0.48	1.58	23.55	0.35	8.0	30.0	10.0

APPENDIX – B

Table B1

WARE CREEK 1/23/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
1215	0	3.0	7.0	1.6	11.5	5.3	1.4	8.9	+8.0
1315	+ 879	3.7	5.8	0.4	11.2	6.7	1.1	8.8	+8.0
1415	+1333	3.5	6.0	0.2	12.0	5.9	1.6	9.0	+8.0
1515	+1136	2.2	5.8	0.7	12.2	5.3	3.1	9.1	+8.0
1615	+1253	2.5	5.8	0.4	12.2	4.8	5.3	9.1	+7.5
1715	+ 716	2.5	5.3	0.3	12.2	5.1	7.3	9.3	+7.0
1735	0	2.4	5.1	0.3	12.4	3.9	7.4	10.0	+7.0
1835	-1095	1.2	5.8	0.9	12.2	4.1	6.0	9.7	+7.5
1935	-1236	1.1	6.4	0.6	12.6	4.0	3.9	9.2	+8.0
2035	-1147	3.5	7.0	1.1	11.5	4.6	2.4	9.0	+8.0
2135	- 869	3.3	6.2	1.4	11.3	4.7	1.8	8.5	+7.5
2235	- 530	3.5	5.5	1.7	11.5	5.1	1.4	8.6	+7.5
2345	0	2.7	6.3	2.5	11.2	3.0	1.0	8.5	+8.0

Table B2

WARE CREEK 3/4/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt.	DO mg/1	H_2O Temp. Deg. C
0900	0	2.8	8.8	1.1	7.4	2.7	0.4	8.2	+ 6.0
1000	+ 544	0.4	8.6	0.9	7.0	3.4	0.2	8.3	+ 9.0
1100	+ 921	0.7	8.0	5.5	6.3	2.9	0.3	8.3	+10.0
1200	+1245	0.4	7.6	4.4	7.4	3.7	0.4	8.4	+10.5
1300	+1490	1.5	7.4	4.5	7.2	2.9	0.6	8.3	+11.0
1400	+ 880	1.8	7.0	3.0	8.7	4.1	0.9	6.7	+12.0
1420	0	1.2	7.3	6.0	7.9	3.9	1.0	4.2	+12.0
1520	+1453	1.2	7.5	6.6	8.2	3.2	0.7	8.8	+12.0
1620	+1689	0.8	8.0	8.7	7.7	3.7	0.5	9.4	+12.0
1720	+1488	1.2	7.5	6.0	7.4	3.2	0.4	9.8	+11.5
1820	+ 925	2.9	8.3	7.3	7.4	3.2	0.4	9.8	+11.0
1920	+ 377	2.0	9.2	8.7	7.1	2.2	0.4	9.6	+10.5
2020	0	2.3	8.3	11.3	7.4	2.2	0.4	7.4	+10.5

Table B3

WARE CREEK 4/17/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0937	0	2.2	7.6	18.6	9.9	9.3	2.0	5.3	+19.0
1037	+ 912	4.9	3.3	15.9	9.9	8.5	1.4	5.5	+20.5
1137	+1800	1.7	7.6	9.8	9.9	9.0	2.0	5.4	+21.0
1237	+2361	5.3	3.3	15.9	9.5	10.7	3.0	3.3	+21.0
1337	+2502	1.1	7.6	14.8	8.9	9.3	5.0	5.5	+21.0
1437	+1944	2.7	6.0	14.8	9.4	16.0	8.0	5.6	+19.0
1530	0	0.5	7.6	18.6	9.4	14.3	8.3	5.4	+20.0
1630	-2415	1.6	7.1	12.8	9.4	9.5	6.5	5.5	+21.0
1730	-2707	2.7	7.6	5.2	9.4	11.9	4.1	5.6	+21.0
1830	-2721	2.9	8.1	10.6	9.4	11.9	2.9	5.9	+22.0
1930	-2157	4.0	8.6	10.4	9.4	10.9	2.7	6.6	+21.5
2030	-1076	1.5	9.7	20.6	8.9	10.0	2.0	6.8	+21.0
2120	0	1.5	11.5	20.2	9.4	6.3	1.7	6.7	+20.0

Table B4

WARE CREEK 5/17/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
1115	0	10.9	3.3	10.8	9.9	10.9	0.4	4.6	+21.0
1215	+ 872	2.8	4.9	5.2	8.3	10.0	0.2	5.1	+22.5
1315	+1757	2.2	7.1	5.8	8.3	10.0	0.3	5.0	+22.0
1415	+2540	1.5	6.7	8.9	8.3	10.7	0.6	5.2	+22.5
1515	+2823	1.2	6.5	9.9	8.3	13.4	1.9	4.4	+22.5
1615	+2268	1.5	3.8	14.6	8.3	18.0	5.9	6.3	+23.0
1700	0	1.1	4.2	19.5	7.9	18.0	6.3	6.5	+24.0
1800	-2641	3.2	3.8	6.1	7.2	17.2	4.3	6.2	+23.5
1900	-2770	1.5	6.0	3.8	8.3	12.4	1.8	5.5	+23.5
2000	-2409	3.6	6.5	6.8	8.3	11.4	0.8	5.3	+23.5
2100	-1742	2.4	6.5	8.7	8.3	9.7	0.6	4.9	+23.0
2200	- 940	4.4	7.3	16.6	9.4	8.5	0.5	5.0	+23.0
2255	0	1.1	8.6	27.0	9.4	7.5	0.5	4.6	+22.0

Table B5

WARE CREEK 6/14/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_20 Temp. Deg. C
1020	0	7.1	8.9	16.2	14.6	9.6	0.5	4.4	+21.4
1120	+ 800	10.4	6.8	14.5	13.0	7.8	0.4	5.1	+23.0
1220	+1227	6.6	6.8	10.6	14.6	5.9	0.7	5.4	+23.0
1320	+1779	6.1	8.3	8.5	15.2	5.9	1.0	5.7	+23.5
1420	+2029	2.5	6.7	8.1	12.5	8.1	2.1	5.8	+24.0
1520	0	2.3	6.1	13.1	12.5	10.4	5.4	6.6	+24.2
1620	-1989	3.8	7.9	21.8	14.1	10.0	2.1	7.9	+25.5
1720	-1981	4.5	8.3	14.2	15.2	9.3	1.2	6.7	+26.7
1820	-1662	5.5	7.8	7.0	15.7	10.7	1.0	6.4	+26.3
1920	- 811	6.0	8.9	4.6	14.6	8.1	0.6	5.9	+26.5
2020	- 505	4.9	10.1	11.0	14.6	7.6	0.5	4.7	+26.5
2120	- 110	4.9	10.6	11.3	14.6	8.9	0.6	3.2	+26.0
2140	0	5.6	10.5	9.0	15.6	9.6	0.2	6.3	+25.0

Table B6

WARE CREEK 6/14/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
2240	+ 756	3.5	7.6	5.0	11.0	10.5	0.3	6.4	+24.0
2340	+1186	2.7	8.9	-	12.5	10.2	0.4	5.7	+25.0
0040	+1760	4.4	7.8	-	15.2	11.7	0.8	7.1	+23.0
0140	+2346	4.4	9.0	-	16.2	12.2	4.0	5.8	+24.0
0240	+2307	4.3	9.5	-	15.2	12.6	6.8	6.3	+24.2
0340	+ 742	4.8	6.2	-	11.3	11.9	7.5	6.5	+24.0
0355	0	1.7	7.0	-	10.5	10.2	7.3	6.7	+23.0
0455	-2277	2.2	8.3	-	11.5	12.0	5.9	5.1	+23.9
0555	-2424	1.8	7.0	-	10.5	10.4	2.7	4.3	+23.5
0655	-2116	7.1	7.8	-	15.2	10.9	1.1	3.2	+23.3
0755	-1353	6.1	8.5	-	16.2	13.4	0.7	3.1	+23.0
0855	- 789	5.5	9.5	-	15.7	16.3	0.5	1.3	+23.0
1010	0	4.3	10.1	-	15.7	21.1	0.5	4.1	+23.0

Table B7

WARE CREEK 7/28/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0845	0	0.4	13.9	21.3	13.0	8.0	0.6	2.8	+26.0
0945	+ 971	2.8	11.5	22.3	12.0	6.1	0.3	2.9	+26.2
1045	+1862	1.6	13.3	22.5	14.7	10.6	0.5	3.4	+27.0
1145	+2710	2.9	13.3	22.5	15.7	15.8	1.3	3.4	+27.5
1245	+3162	4.3	11.0	17.6	11.5	17.5	4.2	4.0	+28.0
1345	+2741	4.7	9.5	17.5	12.5	21.1	7.9	5.4	+28.5
1450	0	1.3	8.4	21.3	12.0	17.7	8.4	6.0	+28.5
1550	-2959	2.4	10.0	20.5	13.0	20.2	6.8	5.8	+27.8
1650	-3419	2.7	11.7	23.2	14.1	19.2	4.6	5.0	+27.5
1750	-2834	5.0	11.6	19.2	15.7	17.0	2.9	4.3	+27.5
1850	-2147	2.9	12.9	23.3	15.1	18.2	1.3	4.1	+27.5
1950	-1317	2.5	13.3	19.8	14.1	16.8	0.8	3.8	+26.5
2050	0	2.6	12.0	24.4	11.0	12.1	0.6	3.0	+26.5

Table B8

WARE CREEK 8/26/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0800	0	3.1	10.0	11.4	11.5	9.6	1.5	2.5	+24.5
0900	+ 557	1.1	7.9	11.4	16.2	8.8	1.0	3.2	+26.0
1000	+1315	0.8	9.6	13.3	16.2	11.4	1.5	3.3	+27.0
1100	+2138	3.3	8.4	13.7	16.8	14.2	2.9	3.8	+27.5
1200	+2837	5.0	8.4	12.8	15.1	19.6	5.6	4.2	+28.5
1300	+2534	1.6	8.0	11.3	13.0	23.6	9.6	5.0	+28.5
1400	+1372	2.8	6.7	15.1	12.5	23.0	9.8	4.6	+29.0
1430	0	1.1	8.0	22.8	9.0	20.2	9.9	5.8	+29.0
1530	-3167	2.0	8.5	16.6	13.0	23.0	8.8	6.1	+29.5
1630	-3332	5.0	8.9	14.6	14.1	22.4	7.0	6.1	+30.0
1730	-3147	2.2	8.7	12.3	10.5	22.2	4.4	5.4	+30.0
1830	-1978	6.0	10.1	12.9	15.1	17.4	2.9	5.0	+30.0
1930	-1014	2.8	10.6	10.4	16.2	14.0	2.0	4.3	+28.0
2040	0	0.2	9.7	10.4	18.3	11.0	1.5	9.7	+28.5

Table B9

WARE CREEK 10/24/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_20 Temp. Deg. C
0800	0	2.0	8.7	3.1	15.7	6.8	1.6	4.4	+15.0
0900	+ 594	0.7	7.4	2.5	13.6	5.8	1.1	5.9	+15.0
1000	+1449	2.7	7.9	4.3	13.6	8.0	1.8	5.5	+15.0
1100	+2228	4.4	7.9	7.8	14.6	8.0	3.4	6.3	+15.0
1200	+2933	5.5	7.4	3.4	15.1	9.2	6.9	7.6	+15.5
1300	+2486	2.9	6.8	5.8	15.7	9.6	11.6	7.2	+16.0
1400	+1811	2.1	6.4	5.6	15.1	9.4	5.3	7.4	+16.0
1438	0	1.0	6.9	7.3	14.6	10.6	11.9	7.0	+16.0
1540	-3065	1.1	7.9	6.1	13.6	9.4	10.7	7.8	+16.5
1640	-2507	2.1	7.4	4.8	14.1	9.2	8.8	7.4	+16.5
1740	-2212	2.3	8.4	3.2	13.6	9.2	6.0	7.1	+17.0
1840	-1897	3.9	8.4	4.0	14.1	8.2	4.1	6.2	+16.5
1940	-1472	2.9	8.9	3.2	14.1	7.8	2.8	6.2	+16.5
2040	- 507	2.4	8.4	3.7	15.7	6.4	2.2	6.1	+16.5
2115	0	1.5	7.4	2.5	13.6	4.6	1.6	5.9	+16.5

Table B10

WARE CREEK 9/24/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0800	0	0.2	9.9	4.1	13.6	5.0	1.5	4.0	+18.5
0900	+1144	1.8	7.6	4.7	12.0	5.0	1.6	4.2	+19.0
1000	+2268	1.7	10.5	6.1	12.5	4.4	2.4	4.1	+20.0
1100	+3185	5.4	7.9	4.7	14.6	5.8	4.9	4.9	+20.5
1200	+3300	3.1	6.3	6.7	15.7	5.0	12.1	5.9	+21.0
1300	+2677	3.8	6.3	6.1	15.7	4.6	12.7	6.1	+21.5
1400	+1181	1.2	6.8	8.4	15.7	5.8	13.1	6.6	+22.0
1420	0	1.6	5.7	8.3	15.7	6.0	13.1	6.3	+21.5
1520	-2749	1.8	5.8	4.9	16.2	6.8	12.2	6.4	+22.0
1620	-3134	3.5	6.3	6.0	15.7	5.4	10.6	6.8	+22.0
1720	-3067	4.3	6.9	3.9	15.1	5.0	7.7	6.6	+22.0
1820	-2791	5.0	7.9	7.2	14.6	4.4	5.4	6.1	+22.0
1920	-2328	4.9	7.4	10.4	14.6	10.2	4.0	5.8	+21.2
2020	-1160	6.6	6.8	7.0	15.7	5.8	3.2	5.7	+21.2
2055	0	0.7	7.9	4.4	14.6	4.8	2.4	5.6	+21.2

Table B11

WARE CREEK 11/24/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0840	0	2.4	8.7	0.9	14.1	4.2	1.0	10.2	+01.0
0940	+ 453	1.7	6.7	0.4	12.0	3.4	0.5	10.7	+02.5
1940	+1207	0.7	8.4	0.3	12.0	3.8	0.6	10.3	+03.0
1140	+2088	2.0	8.5	0.6	12.5	4.2	1.0	10.4	+04.5
1240	+2443	4.4	8.6	0.8	12.0	4.8	2.1	8.9	+04.5
1340	+2440	2.3	7.1	1.4	11.0	4.8	5.5	9.8	+05.5
1440	+1264	2.3	7.1	1.7	11.0	3.6	5.8	11.6	+05.5
1508	0	0.6	8.2	2.9	10.5	3.6	5.8	10.3	+05.5
1610	-2251	3.2	8.3	2.2	11.0	4.4	5.8	10.8	+05.5
1710	-2701	2.7	9.3	2.8	10.5	4.4	3.4	10.8	+04.5
1810	-2475	4.1	8.9	3.2	12.0	5.4	1.9	11.9	+04.5
1910	-1962	4.8	8.4	1.7	12.0	5.4	1.2	10.9	+04.0
2010	-1189	3.7	9.0	0.8	12.5	5.2	0.8	10.2	+03.5
2110	- 326	2.7	10.0	0.9	12.5	5.0	0.8	9.6	+03.5
2145	0	1.7	9.4	1.1	13.6	3.8	0.8	9.6	+03.0

Table B12

WARE CREEK 1/7/73

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0740	0	5.5	5.5	5.3	9.4	7.8	0.4	10.0	+00.0
0840	+ 339	1.1	3.2	2.7	8.9	7.8	0.2	10.0	+00.0
0940	+ 405	1.7	3.2	4.1	8.9	6.0	0.2	10.5	+07.0
1040	+ 514	2.3	3.2	1.9	8.9	6.4	0.2	12.3	+08.0
1140	+1127	1.1	4.3	2.6	8.3	6.4	0.3	10.7	+07.0
1240	+1174	0.6	4.3	1.5	8.9	5.0	0.4	10.9	+07.0
1350	0	1.7	3.8	1.4	9.4	6.0	0.7	10.3	+07.0
1450	-1525	3.3	3.7	1.6	8.9	5.0	0.4	13.0	+07.0
1550	-1624	2.7	3.8	2.0	8.3	6.0	0.3	12.5	+07.0
1650	-1128	2.3	3.7	4.4	8.9	5.2	0.3	11.7	+06.0
1750	- 589	2.8	4.3	4.7	8.9	7.8	0.3	11.7	+05.0
1850	- 298	2.8	4.8	4.2	8.9	8.2	0.4	12.1	+05.0
2010	0	3.3	4.8	5.0	8.9	8.2	0.4	10.9	+04.0

Table B13

CARTER CREEK 3/7/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. *a* ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
1030	0	3.5	7.5	1.6	18.3	4.7	1.6	10.3	+12.0
1130	+ 54	6.0	5.0	1.9	13.0	11.0	9.9	10.2	+13.0
1230	+169	12.5	5.0	3.0	12.5	15.1	10.5	10.3	+14.0
1330	+491	10.2	5.6	1.4	13.6	13.0	9.0	10.2	+14.0
1440	0	2.7	7.2	4.1	14.1	7.3	9.1	9.2	+14.5
1540	-401	2.8	5.6	4.6	13.6	4.6	9.2	9.4	+15.0
1640	-283	3.7	5.1	3.7	13.6	8.5	9.5	9.2	+15.0
1740	- 95	4.8	7.2	2.5	15.8	8.3	4.1	10.1	+14.5
1840	- 16	4.3	7.7	2.2	15.8	7.0	3.2	10.0	+14.0
1940	- 12	1.5	7.3	2.7	17.3	7.2	2.4	10.1	+14.0
2040	- 14	6.8	6.9	2.9	18.9	9.2	2.4	6.6	+14.0
2140	- 9	5.4	6.2	5.0	18.4	9.8	2.3	9.8	+14.0
2240	0	5.5	7.3	2.9	17.9	7.8	1.9	10.2	+13.0

Table B14

CARTER CREEK 3/23/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
1050	0	2.2	7.9	-	16.2	6.1	5.1	6.4	+13.0
1150	+ 199	1.0	5.8	-	16.2	4.4	4.4	8.2	+13.0
1250	+ 299	2.1	5.1	-	15.8	6.3	4.1	8.3	+13.0
1350	+ 576	2.3	5.0	-	15.2	3.9	6.0	8.3	+13.0
1443	+ 669	1.5	5.5	-	14.7	10.5	6.9	8.4	+13.0
1550	+ 862	0.6	4.0	-	15.2	9.0	7.7	8.7	+13.0
1650	+ 455	0.6	6.2	-	13.6	9.3	8.4	8.6	+13.0
1718	0	0.6	5.1	-	14.7	10.5	8.6	8.7	+13.0
1755	- 623	1.7	4.0	-	14.1	6.3	8.7	8.8	+13.0
1855	-1048	1.6	4.5	-	14.1	5.6	8.4	8.7	+13.0
1955	- 901	1.6	5.0	-	13.6	5.8	8.8	8.8	+13.0
2055	- 382	1.6	5.7	-	15.2	2.2	6.5	7.6	+13.0
2155	- 118	1.6	6.2	-	16.8	2.4	6.0	7.7	+12.0
2255	0	2.9	7.9	-	16.2	2.9	4.3	7.5	+11.0

Table B15

CARTER CREEK 4/19/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0900	0	1.3	4.2	4.4	7.3	4.1	4.8	4.8	+20.0
1000	+ 176	4.6	5.9	4.5	4.6	11.9	10.9	7.0	+21.0
1100	+ 436	4.5	4.3	5.5	3.5	10.2	10.8	6.0	+21.0
1200	+ 797	2.4	5.4	5.8	8.9	11.4	12.4	6.9	+22.0
1300	+ 761	0.4	5.7	8.9	4.5	10.5	13.5	7.0	+22.0
1400	+ 488	2.0	6.5	9.3	11.5	12.9	13.8	7.8	+22.0
1420	0	1.3	4.2	12.2	4.6	12.9	13.4	8.2	+23.0
1520	- 855	3.4	2.1	16.2	4.6	16.8	13.5	8.1	+23.0
1620	-1005	1.0	3.5	17.2	4.6	12.4	12.8	7.8	+24.0
1720	- 920	1.3	4.2	16.6	4.6	16.8	11.2	4.7	+25.0
1820	- 254	0.7	6.4	11.9	6.8	17.7	7.5	7.7	+25.0
1920	- 81	8.8	7.2	4.5	12.0	15.3	4.5	5.0	+23.0
2020	- 29	11.7	5.3	4.6	7.9	13.4	4.6	4.9	+21.0
2040	0	7.7	4.9	4.3	6.1	10.9	4.5	4.8	+20.0

Table B16

CARTER CREEK 5/19/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
1000	0	3.1	5.5	13.2	11.5	2.8	7.5	3.4	+21.0
1100	+ 354	4.6	4.1	15.6	16.8	3.1	7.1	5.0	+21.0
1200	+ 730	2.5	3.4	14.2	14.6	4.1	8.8	6.0	+22.5
1300	+1265	4.4	4.5	15.0	12.5	15.0	8.4	6.4	+22.5
1400	+2882	4.3	2.4	17.6	13.0	23.5	12.4	7.4	+22.0
1500	+3365	3.4	3.0	14.6	12.0	13.4	13.2	7.5	+21.5
1600	+2662	5.3	3.0	9.1	12.0	10.5	13.5	7.4	+21.0
1700	0	2.2	2.3	11.3	12.0	10.9	13.0	7.3	+21.5
1800	-2778	2.7	2.3	10.7	12.0	17.2	12.8	6.8	+21.5
1900	-4235	3.8	3.4	16.1	12.0	22.4	12.4	6.9	+22.0
2000	-1864	4.1	2.4	13.8	13.0	12.9	11.7	6.5	+22.0
2100	- 958	5.0	3.0	15.5	13.0	10.7	10.9	6.1	+21.5
2200	- 552	3.5	2.4	18.7	13.6	10.2	10.0	6.2	+21.0
2300	0	2.7	2.4	18.3	14.1	8.5	9.1	4.7	+21.0

Table B17

CARTER CREEK 8/29/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0820	0	0.5	12.2	20.4	34.8	22.8	8.0	3.8	+24.0
0920	+ 110	2.5	9.9	33.5	24.6	31.6	10.0	5.3	+24.5
1020	+ 847	2.7	9.8	33.8	22.0	27.6	10.9	4.9	+25.0
1120	+1380	3.2	8.4	37.3	19.6	28.2	12.1	5.4	+26.0
1220	+2488	1.1	7.7	36.0	17.5	23.8	14.1	5.9	+26.5
1320	+1612	1.2	8.6	37.7	17.2	18.0	14.3	6.9	+27.5
1340	0	1.7	7.4	31.6	17.2	26.8	14.6	6.7	+27.5
1440	-3530	2.0	7.4	31.7	17.2	19.6	14.2	7.5	+28.5
1540	-1859	1.6	8.0	37.6	15.0	24.0	13.8	7.7	+28.0
1640	- 883	2.0	8.6	31.5	19.4	21.4	21.6	7.5	+28.0
1740	- 731	2.9	9.8	35.5	22.0	18.4	16.4	7.0	+27.5
1840	- 331	1.3	11.9	23.0	25.3	15.0	9.3	6.7	+27.5
1940	- 32	1.7	13.7	10.5	27.3	14.2	10.1	4.7	+26.3
2000	0	2.4	7.0	15.5	20.0	13.2	7.9	4.4	+26.0

Table B18

CARTER CREEK 9/27/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0750	0	2.2	6.9	25.3	31.5	18.0	10.9	3.0	+21.0
0850	+ 229	3.9	5.4	18.9	23.1	17.2	13.5	5.8	+22.0
0950	+ 852	3.9	6.5	15.9	22.0	15.2	14.3	4.8	+23.5
1050	+1256	4.9	7.0	23.3	21.0	25.2	15.0	6.1	+24.0
1150	+2291	2.5	6.5	21.8	21.0	19.0	15.5	7.0	+25.0
1250	+2934	2.8	5.7	26.9	19.5	19.4	16.2	6.5	+25.0
1340	0	3.7	5.3	27.3	19.5	18.6	16.6	7.5	+25.0
1440	-2840	3.5	6.0	38.1	20.0	18.0	16.1	7.6	+25.5
1540	-1717	4.5	5.3	21.1	21.0	22.4	15.6	7.6	+25.5
1640	-1074	4.3	6.0	21.7	21.5	21.0	15.0	7.7	+25.5
1740	- 684	1.8	7.5	21.0	22.5	17.0	14.2	5.5	+25.0
1840	- 398	14.6	8.3	9.9	24.7	20.8	10.6	4.7	+24.0
1940	- 137	15.5	10.4	5.1	22.0	36.0	6.8	4.4	+23.5
2030	0	5.7	11.8	12.8	20.0	26.4	6.3	4.1	+23.0

Table B19

CARTER CREEK 6/17/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
1000	0	5.3	9.7	16.2	33.6	12.2	4.0	6.0	+26.0
1100	+ 176	5.4	8.4	17.0	23.5	23.5	6.7	9.1	+27.0
1200	+ 422	6.1	8.2	13.8	23.1	24.8	7.3	7.8	+27.0
1300	+ 908	3.4	7.5	15.5	21.0	14.6	8.6	6.8	+27.0
1400	+1145	1.2	7.4	16.8	17.8	12.2	10.3	5.4	+27.2
1500	+1342	1.2	6.3	13.0	17.3	10.5	11.0	5.7	+27.8
1540	0	1.7	6.3	14.5	17.3	11.5	10.8	6.8	+29.0
1640	- 772	0.5	7.0	16.4	17.8	11.5	9.7	6.5	+28.0
1740	- 467	2.2	7.4	23.5	18.9	15.8	9.7	6.0	+27.5
1840	- 740	3.4	8.0	23.6	20.0	18.7	8.4	5.9	+27.5
1940	- 461	3.8	8.7	16.7	22.0	17.2	7.2	4.2	+27.5
2040	- 151	2.6	10.6	12.5	26.8	12.9	5.2	3.1	+27.5
2140	0	2.6	10.0	12.3	29.4	7.6	4.7	1.9	+27.0

Table B20

CARTER CREEK 7/31/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0840	0	9.6	14.2	102.0	25.8	202.4	3.8	5.2	+23.0
0940	+ 684	5.3	9.8	24.4	22.0	30.8	6.5	4.0	+24.0
1040	+1105	1.0	10.5	19.0	9.3	17.0	8.0	4.0	+24.0
1140	+2477	9.4	6.2	22.8	19.0	13.3	9.6	5.6	+25.0
1240	+4507	0.6	9.6	17.8	17.3	11.2	10.9	5.3	+25.0
1340	+1029	2.4	7.7	15.1	17.8	12.0	11.2	5.0	+26.0
1400	0	0.6	9.5	21.8	16.8	17.0	11.2	5.2	+26.0
1500	-2622	0.5	9.0	22.9	16.8	16.2	10.7	6.0	+27.0
1600	-3308	0.3	9.0	28.8	17.3	11.2	9.9	6.4	+27.0
1700	-2140	7.9	10.0	21.7	12.0	23.6	10.4	5.8	+27.0
1800	-6814	15.2	8.5	28.3	11.5	26.8	6.2	5.2	+26.0
1900	- 830	14.2	12.8	12.5	13.5	29.6	2.0	4.1	+24.0
2000	- 169	23.9	17.0	16.9	11.0	43.8	0.9	2.6	+23.0
2117	0	7.0	14.4	25.4	14.1	69.4	0.9	2.5	+22.0

Table B21

CARTER CREEK 10/27/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0800	0	1.6	9.0	3.5	30.0	5.2	9.1	5.9	+08.0
0900	+ 229	1.6	9.0	3.4	29.4	5.4	10.2	5.4	+08.5
1000	+ 639	1.2	7.6	8.0	22.0	5.8	13.4	5.7	+11.0
1100	+1130	1.7	7.0	8.3	21.5	6.6	13.9	6.8	+12.5
1200	+1826	1.0	7.0	4.4	20.0	6.4	14.2	7.3	+14.0
1300	+3669	1.1	7.5	7.2	18.9	11.4	15.3	8.0	+14.0
1400	+1128	2.6	5.4	5.8	18.4	8.0	15.7	8.1	+14.5
1420	0	2.2	7.4	7.0	17.3	20.8	15.7	9.5	+14.5
1520	-2355	2.4	7.7	10.5	17.5	16.0	15.6	9.7	+14.5
1620	-2114	3.5	7.4	10.3	18.4	13.8	15.4	8.3	+14.5
1720	-1079	2.0	9.6	11.5	18.4	12.0	14.7	8.0	+14.0
1820	- 619	2.5	8.1	10.0	20.4	8.6	13.9	7.8	+13.5
1920	- 293	1.0	9.3	3.8	22.5	5.0	12.4	7.5	+13.5
2020	0	1.2	10.5	6.6	24.6	4.6	10.8	7.6	+13.5

Table B22

CARTER CREEK 11/27/72

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
1020	0	4.5	12.6	2.1	25.8	6.8	2.4	7.5	+08.5
1120	+214	6.3	10.2	1.8	26.8	9.6	4.2	9.2	+09.0
1220	+154	8.1	8.8	1.7	24.7	10.8	5.6	9.8	+09.5
1320	+345	2.3	8.5	3.1	20.5	8.6	8.7	9.6	+09.5
1420	+161	1.5	8.5	5.2	20.5	6.6	8.9	10.3	+09.0
1500	0	3.3	7.5	3.2	20.5	6.8	9.0	10.0	+09.5
1600	-316	1.7	10.8	5.3	19.4	7.0	8.8	10.3	+09.2
1700	-290	1.5	10.0	4.6	21.5	5.2	6.9	9.3	+09.5
1800	-195	3.4	10.8	3.5	24.7	4.0	4.5	8.8	+09.5
1900	-128	7.3	11.8	2.3	24.7	7.4	3.7	8.2	+09.0
2000	- 10	7.0	13.1	1.6	23.7	7.2	2.3	7.2	+08.0
2100	- 5	7.0	11.9	1.6	25.1	8.2	2.1	7.7	+07.0
2200	- 1	12.2	11.3	1.8	26.2	8.8	2.2	7.1	+06.5
2240	0	7.1	12.2	1.2	27.3	6.0	2.3	6.5	+06.0

Table B23

CARTER CREEK 1/11/73

Time	Instantaneous Water Transport 1/sec	POC mg/1	DOC mg/1	ATP 10^{-4}mg/1	DIC mg/1	Chl. a ug/1	Sal. ppt	DO mg/1	H_2O Temp. Deg. C
0900	0	2.8	6.3	2.3	18.4	4.6	2.9	9.3	+01.0
1000	+472	1.1	5.2	1.8	18.4	2.6	3.9	5.2	+01.0
1100	+805	1.0	4.7	1.3	16.2	3.0	6.5	9.1	+02.0
1200	+914	0.5	6.3	1.3	15.7	2.6	6.3	9.2	+02.0
1300	+869	0.5	5.2	1.4	16.3	3.0	7.2	9.3	+02.5
1420	0	1.1	4.7	2.1	16.3	3.6	7.0	8.9	+03.0
1520	-818	1.0	5.2	1.3	16.3	2.6	6.9	9.4	+03.0
1620	-816	0.5	5.7	1.4	15.8	2.6	6.4	9.1	+02.0
1720	-561	1.6	6.2	1.6	15.8	3.0	4.8	8.9	+02.0
1820	-145	1.7	7.2	2.1	15.8	3.0	3.2	8.4	+00.5
1920	- 24	1.1	6.8	2.1	16.2	4.0	1.8	6.5	+00.2
2020	0	1.7	6.8	1.8	16.2	4.0	1.8	8.1	+00.0

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