Investigations of the magnetic field orientation (*1*) and plasma flow direction (*3*) in the near wake should provide additional experimental information with which to test these contentions and examine in detail the latitudinal dependence of the nightside ionopause on the direction of the solar wind flow and the interplanetary magnetic field.

H. PÉREZ-DE-TEJADA
Instituto de Geofísica, Universidad Nacional Autónoma de México, México 20, D.F.

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Nutrient and Oxygen Redistribution During a Spring Neap Tidal Cycle in a Temperature Estuary

Abstract. *Spring tidal currents produce homogeneous water columns in a number of estuaries that are moderately stratified during neap tides. In the York River estuary, this destratification redistributes ammonium and phosphate regenerated by the benthos as well as oxygen from the surface. This redistribution has significant implications for nutrient cycles, organism distributions, and the management of estuaries.*

Estuaries are characterized on the basis of their morphometry and salinity structure (*1*). For example, Pritchard (*2*) has conceptually modeled estuarine types according to three different density-stratification and circulation patterns: highly stratified (type A), moderately stratified (type B), and vertically homogeneous (type C). In contrast to highly stratified estuaries, vertically homogeneous ones are expected to be shallow, wide, and dominated by tidal currents rather than freshwater input (*3*). The Chesapeake Bay and its tributaries have been considered classical examples of moderately stratified estuaries. Indeed, when this system is viewed in the long-term average sense (that is, month to month), its salt distribution is well explained by such a model.

Recently, Haas (*4*) discovered that at least portions of the Chesapeake estuarine system alternate between vertical homogeneity and stratification within a time scale of days. Such a short time scale is an appropriate one for those seeking a relationship between biological or chemical processes and estuarine hydrography. Haas's analysis of the observed oscillation cycle of the York, James, and Rappahannock rivers revealed a strong positive correlation between destratification events and spring tidal height; thus these destratification events are predictable. Destratification at the mouth of the York River was most intense about 4 days after maximum spring high tides, and stratification was most evident during neap tidal periods. Surprisingly, neither short-term variation in freshwater flow nor meteorological events had much bearing on the occurrence of vertical mixing.

This report concerns the effects and implications of spring tidal destratification phenomenon on nutrient and O distributions in the York River during August 1978 (*5*).

We conducted intensive sampling of the water column during periods of neap tidal stratification (7 to 17 August), spring tidal destratification (21 to 24 August), and subsequent neap tidal restratification (24 to 31 August). Vertical profiles for NO_2^-, NH_4^+, PO_4^{3-}, and O strongly reflected the stratification state of the estuary (Fig. 1), which was primarily due to the salinity and not the temperature component of density (sigma t). During the first stratification period, O and NO_2^- concentrations were high above the halocline and low below it (Fig. 1, B and D) whereas the reverse was true for NH_4^+ (Fig. 1E) and PO_4^{3-} (Fig. 1C) (*6*). The destratification event, characterized by a virtually uniform distribution with depth of all constituents

Table 1. Mean water column concentrations (± standard deviation) for hydrocasts at the mouth of the York River for the range of days in August 1978; $\Delta\overline{X}$ is the salinity difference between top and bottom; ΣN is the sum of NO_2^-, NO_3^-, and NH_4^+. The N and P concentrations are in microgram atoms per liter. The numbers in parentheses indicate the number of hydrocasts averaged.

Date	$\Delta\overline{X}$ (per mil)	$\overline{X}$ (per mil)	$\overline{X}\,\Sigma N$	$\overline{X}\,PO_4^{3-}$	$\overline{X}\,NO_2^- + NO_3^-$	$\overline{X}\,NH_4^+$
7 to 17	3.94 ± 1.10 (13)	21.3 ± 0.33 (13)	9.85 ± 2.50 (11)	0.39 ± 0.11(10)	3.17 ± 1.27 (11)	6.68 ± 1.36 (11)
21 to 24	0.15 ± 0.39 (10)	20.4 ± 0.24 (10)	3.00 ± 0.81 (10)	0.27 ± 0.08(9)	1.40 ± 0.61 (10)	1.50 ± 0.51 (10)
24 to 31	5.43 ± 1.51 (9)	22.9 ± 1.88 (9)	8.30 ± 2.14 (9)	0.80 ± 0.46(8)	1.12 ± 0.77 (9)	7.18 ± 2.54 (9)

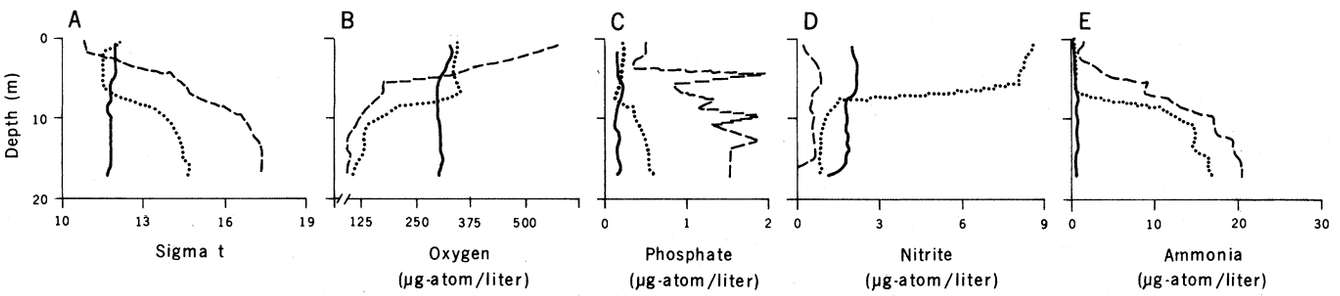

Fig. 1. Profiles of (A) sigma t, (B) oxygen, (C) phosphate, (D) nitrite, and (E) ammonia for 10 August (.....), 23 August (_____), and 29 August (------). Profile depths vary slightly because of tidal fluctuation and slight positional changes of the vessel.

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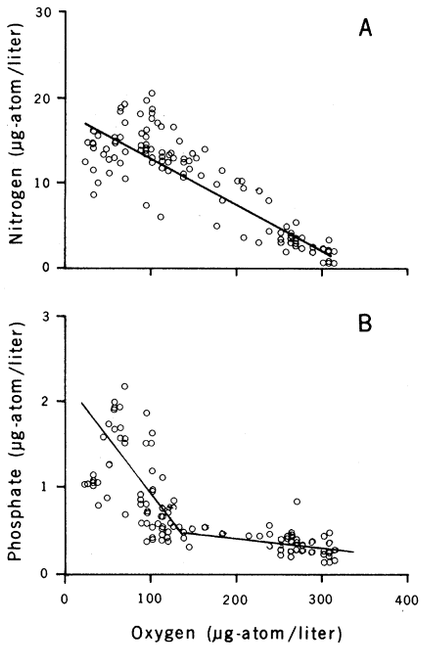

Fig. 2. (A) Sum of the inorganic nitrogen (NO_3^-, NO_2^-, and NH_4^+) concentrations as a linear function ($y = ax + b$) of the O concentration for all samples below 14 m [$N = 125$, $r^2 = 0.771$ (r is the correlation coefficient), $a = -0.0543$, $b = 18.3$] by least-squares fit. (B) Phosphate concentration as a linear function of the O concentrations for all samples below 14 m (for O concentrations below 125 μg-atom per liter, $a = -0.0135$; for O concentrations about 125 μg-atom per liter, -0.00115) fitted by eye.

measured, oxygenated the deep waters (Fig. 1B) and was followed by a period of stratification exhibiting the characteristics of the earlier one, except that the NO_2^- concentration was low in the surface layer (Fig. 1D); NO_3^- was virtually undetectable at all times (*7*).

Destratification was associated with a vertical redistribution of nutrients and O in the water column. The total amounts of most constituents were less during destratification than before or after (Table 1). Since inorganic N and P did not change in proportion to changes in total salinity, we assume dilution did not cause the disappearance of the nutrients. We are uncertain how to explain this; we speculate that the forms we measured were converted into other forms (for example, particulate N and P, N_2O, or N_2) which we did not measure, and that the mixing of water from above and below the pycnocline contributed to biological transformations. We conclude that during stratified periods benthic fluxes were the dominant factors resulting in nutrient and O changes observed in the water column below the pycnocline. We base this conclusion on the steep concentration gradients of NH_4^+, PO_4^{3-}, and O detected near the benthos during restratification.

Apparent nutrient regeneration relative to O utilization has been estimated by techniques comparable to those used by oceanographers to measure "apparent oxygen utilization" (*8*). Linear regression of NH_4^+ versus O concentrations from below the pycnocline revealed a strong negative correlation (Fig. 2A). The regression coefficient, $-.054$ ($\pm .00267$ standard error), is close to the Redfield ratio of -0.058 N/O from the oxidation of biogenic particulate material (*9*). Simple linear regression was not the best treatment for the comparable P and O data; these data are better described by a biphasic linear relationship having an inflection point at about 125 μg-atom of O per liter (2 mg/liter). Below that O concentration, linear regression yielded a P/O ratio of -0.0135, and above it the P/O ratio was -0.00115 (Fig. 2B). This observation is consistent with reports (*10*) that the release of PO_4^{3-} from sediment is enhanced at low O tensions. Dividing the slopes of the curve in Fig. 2A by those of the curves in Fig. 2B, we obtain N/P ratios of 4 and 47 for O concentrations below and above 125 μg-atom of O per liter, respectively. This empirically derived relationship implies that, with increasing O demand in the bottom water, the relative availability of P to N in the water will increase. This greater release of P relative to N between destratification events not only relates to nutrient cycles in the estuary but may affect the phytoplankton species composition in the euphotic zone as a result of nutrient input during the destratification event.

We conclude that the spring-tidal destratification phenomenon has substantial effects on the distribution of O and nutrients in the lower York River. Vertical mixing accompanying destratification replenishes O in the deep water, allowing aerobic processes to proceed again until the O is depleted. This mixing will also accelerate the input of benthic-regenerated nutrients into the euphotic zone. This pulsing of nutrients into the euphotic zone may support phytoplankton growth during the stable conditions of the stratified period immediately after the destratification event (*11*).

The destratification phenomenon may be important elsewhere in the Chesapeake estuary and in other estuaries (*12*). We think it needs further study in Chesapeake Bay, and we are concerned that important management decisions on water quality are being made on the basis of monthly or less frequent samplings that appear to miss important short-term phenomena such as the one discussed here.

KENNETH L. WEBB
Virginia Institute of Marine Science and School of Marine Science, College of William and Mary, Gloucester Point 23062
CHRISTOPHER F. D'ELIA
Chesapeake Biological Laboratory, Center for Environmental and Estuarine Studies, University of Maryland, Solomons 20688

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5. The Interdisciplinary York River Study of the Virginia Institute of Marine Science used the R.V. *Retriever* and R.V. *Ridgely Warfield*. The station was located at the mouth of the York River (37°14′40″N, 76°23′28″W). Samples were taken by pump at 1-m intervals to within 0.5 m of the bottom, filtered (0.45-μm pore size), and analyzed according to Technicon AutoAnalyzer techniques for NO_2^-, NO_3^-, NH_4^+, and PO_4^{3-}. Standardizations and calibrations were carried out frequently to detect potential interferences in water samples with low O tension. The O was determined with a polarographic O probe, and salinities were determined with an inductance salinometer.
6. Several transects across and up and down the river showed that our station profiles were representative for the lower York River basin during the time of the study.
7. Others have also observed unexpectedly high NO_2^- concentrations in the Chesapeake estuary [J. J. McCarthy, W. R. Taylor, J. L. Taft, *Limnol. Oceanogr.* **22**, 996 (1977)]. Obvious biological sources of NO_2^- are as the intermediate in assimilatory or dissimilatory NO_3^- reduction or in nitrification (NH_4^+ oxidation). All of these biological processes are widely documented. Also possible are NO_2^- inputs from freshwater runoff, rain, photochemical processes, and other processes. Export from salt marshes by tidal flushing also appears likely. We believe that biological processes are the more significant contributors to a late summer NO_2^- maximum in the Chesapeake estuarine system [K. L. Webb and C. F. D'Elia, in preparation].
8. This approach assumes that the water mass is saturated with O when it is cut off from the euphotic zone, a depth of about 4 m at our deep channel station, and that subsequent observations of lower concentrations result from O utilization and will also be associated with elevated nutrient concentrations as a result of the corresponding mineralization [A. C. Redfield, *Pap. Phys. Oceanogr. Meteorol.* **9**, 1 (1942)]. Thus, simple regression of O concentration against nutrient concentration for a given water mass will provide an estimate of nutrient regeneration per unit of O utilized.
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11. Contemporary thought [J. J. McCarthy and J. C. Goldman, *Science* **203**, 670 (1979)] indicates that nutrient-limited phytoplankton may possess enhanced uptake capacity for nitrogenous nutrients and thus grow at the expense of increased concentrations of N which are available for only short periods of time. Whether the phytoplankton are nutrient limited in this estuary is a spatially, temporally, and species-dependent question and is presently not resolved. The fact that N, the nutrient most often considered limiting in marine waters, rapidly disappeared during destratification in this study suggests an enhanced potential for uptake beyond that previously taking place, if not in fact N limitation. The presence of NO_2^- in the surface waters during the initial stratified period greatly confuses this

issue. A number of lines of evidence indicate that NO_2^- was not being utilized during this period.

12. Direct evidence indicates that the St. Lawrence estuary [M. Sinclair, *J. Fish. Res. Board Can.* **35**, 1171 (1878)], Charleston Harbor [(T. A. Wastler and C. M. Walter, *J. Sanit. Eng. Div. Am. Soc. Cin. Eng.* **94**, SA6, 1175 (1968), paper 6311], and the Gironde estuary [G. P. Allen, *Bull. Inst. Geol. Bass-d'Aquitaine Mem. 5* (1973)] all undergo a similar cycle of stratification-destratification related to the neap-spring tidal cycle. Indirect evidence indicates that Puget Sound [D. F. Winter, K. Banse, G. C. Anderson, *Mar. Biol.* **29**, 139 (1975)] and Saanich Inlet [M. Takahashi, D. L. Seibert, W. H. Thomas, *Deep-Sea Res.* **24**, 775 (1977)] do also.

13. This research was supported in part by the Virginia Institute of Marine Science; by the Oceanography Section, National Science Foundation, under NSF grant OCE75-2041; and by the Office of Sea Grant, National Oceanic and Atmospheric Administration, U.S. Department of Commerce grants to the Virginia Institute of Marine Science and the University of Maryland. We thank numerous colleagues, especially L. W. Haas, D. Hayward, M. Petty, and R. Wetzel as well as the crews of the R.V. *Retriever* and R.V. *Ridgely Warfield* (special thanks to V. Figuenick and M. E. Loftus) for their efforts in acquiring this data base, for computer data management, and for critical reading of the manuscript and valuable discussions. Contribution 920 of the Virginia Institute of Marine Science and contribution 875 of the Chesapeake Biological Laboratory.

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Inhibition of Cellular Proliferation of Imaginal Epidermal Cells by Diflubenzuron in Pupae of the Stable Fly

Abstract. *A second mode of action has been found for the inhibition of chitin synthesis by diflubenzuron. This compound blocks synthesis of the imaginal cuticle by preventing formation of the adult epidermis in the pupal stage of the stable fly* (Stomoxys calcitrans *L.*).

One means of designing methods of insect control is to exploit the basic physiological and morphological differences between vertebrates and invertebrates. One of the basic differences is that vertebrates do not synthesize chitin, a compound found in some invertebrate phyla and a major component of insect cuticle. On the basis of this difference, a new class of insecticides that inhibits chitin synthesis appears promising. One of these insecticides, diflubenzuron [Dimilin; 1-(4-chlorophenyl)-3-(2,6-difluorbenzoyl)urea], prevents synthesis of chitin in both larval and adult insects (*1-3*). Since many of these studies were made on species of insects in which the larval epidermis persists throughout the life cycle, we undertook to determine the effect of diflubenzuron on chitin synthesis during the pupal stage of the stable fly (*Stomoxys calcitrans* L.). During this stage, the larval epidermis degenerates and is replaced by an imaginal (adult) epidermis, which then proceeds to synthesize the adult cuticle (*4, 5*). We found that diflubenzuron topically applied at the white prepupal stage prevented formation of the imaginal epidermis and thus the subsequent synthesis of adult cuticle.

To determine the effect of diflubenzuron on the chitin synthesis occurring in this type of transitional epidermis, we performed the following experiments. (i) Histological preparations were made of pupae topically treated with diflubenzuron to determine whether this compound had any effect on the morphology of the larval or adult epidermal cells and (ii) radioactively labeled *N*-acetyl-D-glucosamine (GlcNac) was used in a biochemical analysis to determine the extent of inhibition of chitin synthesis, if any, produced by diflubenzuron.

The histological study was performed

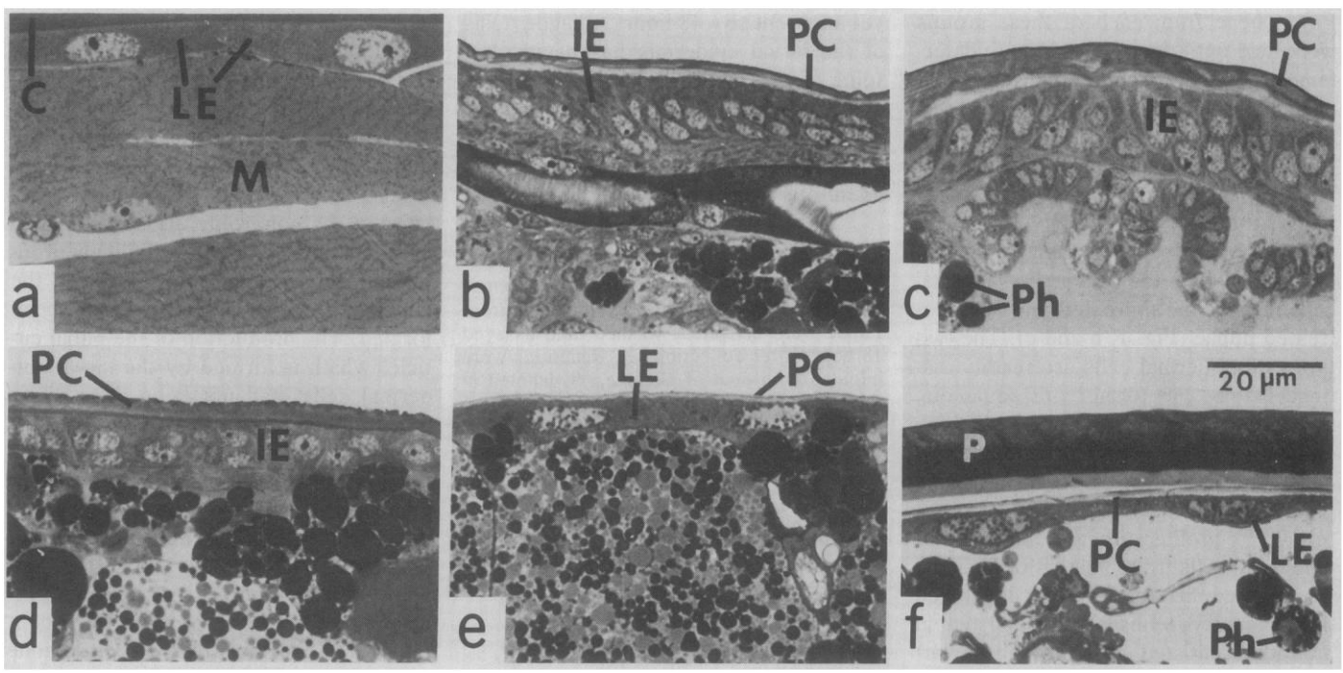

Fig. 1. (a) Transverse section through the integument of a white prepupal larva of *S. calcitrans*, the stage at which the various treatments were begun. The large squamous larval epidermal cells (*LE*) are still closely opposed to the thick larval cuticle that forms the puparium (*C*). Apolysis has not yet occurred nor has a pupal cuticle been secreted at this time (*M*, muscle). (b) Transverse section through epidermis of untreated pupa 24 hours after prepupal formation. The larval epidermis has been replaced by columnar, imaginal epidermal cells (*IE*) which is now overlain by the pupal cuticle (*PC*) formed by the larval epidermis. (c) Epidermis of a pupa 24 hours after treatment with acetone. The larval epidermis has been histolyzed and the imaginal epidermis has been formed (*Ph*, phagocyte). (d) Epidermis of a pupa 48 hours after treatment with acetone. The imaginal epidermal cells have lost their columnar appearance and have formed the cuboidal, monolayered adult epidermis. (e) Epidermis of a pupa 24 hours after treatment with diflubenzuron. The larval epidermis is still present. The pupal cuticle produced by these cells covers their apical surface. (f) Epidermis of a pupa 48 hours after treatment with diflubenzuron. No imaginal epidermis has formed. Histolysis of the larval epidermal cells has begun, resulting in loss of a large portion of the cytoplasm of these cells (*P*, puparium).

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