THE FLORIDA STATE UNIVERSITY
DEPARTMENT OF OCEANOGRAPHY

FINAL REPORT

FOR THE CONTRACT PERIOD

1 APRIL 1982 - 31 MARCH 1988

TO

OFFICE OF NAVAL RESEARCH

FOR

CONTRACT NUMBER N00014-82-C-0404

AUGUST 1988

THE FLORIDA STATE UNIVERSITY
DEPARTMENT OF OCEANOGRAPHY

FINAL REPORT
FOR THE CONTRACT PERIOD
1 APRIL 1982 - 31 MARCH 1988

to

OFFICE OF NAVAL RESEARCH

PRINCIPAL INVESTIGATORS:

BENOIT CUSHMAN-ROISIN
DORON NOF
JAMES J. O'BRIEN
DAVID THISTLE
GEORGES WEATHERLY
D.C. WHITE and D. THISTLE

for

CONTRACT NUMBER N00014-82-C-0404

AUGUST 1988

TABLE OF CONTENTS

FINAL REPORT
ONR CONTRACT N00014-82-C-0404
APRIL 1, 1986 - MARCH 31, 1988

Dr. Benoit Cushman-Roisin, Principal Investigator

During the contract period of April 1, 1986 to March 31, 1988, my ongoing research program has been the investigation, by analytical and numerical models, of mesoscale fronts (including frontal eddies) and, to a lesser extent, of the large-scale circulation. My two doctoral students have concentrated their studies on their respective numerical models, adhering to an established timetable. Graduate student Edgar Pavia has applied his particle-method model to frontal systems; applications in progress include eddy merging and axisymmetrization under various conditions. Having developed a highly accurate spectral code, student B. Tang has investigated geostrophic turbulence at the deformation-radius scale and beyond, from quasi-geostrophic to frontal amplitudes. Both models are highly original and provide the community with solutions to problems never previously addressed.

In 1987, under the auspices of the ONR contract, the 3rd Annual Colloquium on Oceanic Vortices was held at Florida State University and was well attended by scientists from the physical oceanography community. The number of participants was 50 (40 from North America and 10 from Western Europe). A report and abstracts from this meeting were compiled and widely distributed.

Attached is a listing of the publications produced during the contract period. This was the first contract between ONR and Cushman-Roisin, P.I.

PUBLICATIONS BY B. CUSHMAN-ROISIN
PERIOD OF ONR CONTRACT N00014-82-C-0404

Refereed Publications

1986 "Linear stability of large, elliptical warm-core rings," J. Phys. Oceanogr., 16, 1158-1164.

1987 "Large-scale ocean dynamics," Climatology and Space Observations, Cepadues-Editions, France, 631-642.

1987 "The main ocean thermocline," Climatology and Space Observations, Cepadues-Editions, France, 643-654.

1987 "Wind and buoyancy driven ocean circulation," Climatology and Space Observations, Cepadues-Editions, France, 655-663.

1987 "Exact analytical solutions for elliptical vortices of the shallow-water equations," Tellus, 39A, 235-244.

1987 "On the role of heat flux in the Gulf Stream, Sargasso-Sea, Subtropical Gyre system," J. Phys. Oceanogr., 17, 2189-2202.

1987 (with V. Panchang and B.R. Pearce) "A finite-difference model for combined refraction-diffraction of water waves," Coastal Hydrodynamics, R.A. Dalrymple, Ed., 60-70.

1988 (with V. Panchang and B.R. Pearce) "Combined refraction-diffraction of short waves for large coastal regions," Coastal Engineering, in press.

1988 (with E.G. Pavia) "Numerical simulations of oceanic fronts using a particle method," J. Geophys. Res., 93, 3554-3562.

1988 (with E.G. Pavia and V. Tverberg) "A relaxation technique for the solution of internal waves in fjords and on shelves," to be submitted to J. Mar. Res.

1988 (with B. Tang) "Eddies and geostrophic turbulence beyond the radius of deformation," in preparation.

Other Publications

1987 "Modelling distinct vortices of the ocean" (Meeting report) Trans. Am. Geophys. U., 68, 677-678.

1987 "Subduction," Dynamics of the mixed layer, Hawaiian Winter Workshop Proc., U. of Hawaii at Manoa, 181-196.

Book Review

1988 "General Circulation of the Ocean" by H.D.I. Abarbanel and W.R. Young (Springer Verlag, 1986, 291 pp.), Pure & Appl. Geophys., 126, 165-168.

FINAL REPORT TO THE OFFICE OF NAVAL RESEARCH

For work under Contract N00014-82-C-0404
April 1, 1986 - March 31, 1988

MESOSCALE PROCESSES IN THE OCEAN

Doron Nof
Department of Oceanography
Florida State University
Tallahassee, FL 32306-3048

Analytical studies of eddy-environment interactions and polar eddies were conducted. The studies were motivated by observations which suggest that ring evolution in the world ocean is dominated by a series of strong interactions. Eddies interact vertically with the atmosphere or deep fluid, and horizontally with surrounding fluids or walls. The studies depart significantly from past theoretical efforts, which have concentrated on the evolution of *isolated* eddies on a beta plane.

Specifically, we examined: (1) the dynamics of ventilating warm rings, (2) the interactions of warm rings with western boundary currents, (3) the interactions of rings and neighboring mesoscale phenomena, (4) warm ring interactions with western meridional boundaries, (5) the structure and dynamics of "thick" eddies, and (6) the influence of the quadratic variation of the Coriolis parameter with (high) latitude on mesoscale processes. Observations documenting each of these interactions were reviewed and descriptions of their effects are discussed.

Preliminary calculations suggest that the above interactions are characterized by novel dynamics. It is hoped that our work will help to clarify the dynamical link between eddies and the large scale circulation.

PUBLICATIONS

* Nof, D. (1986): The collision between the Gulf Stream and warm-core rings. *Deep-Sea Res., 33*: 359-378.

* Nof, D. (1986): Geostrophic shock waves. *J. Phys. Oceanogr., 16*: 886-901.

* Nof, D. (1986): Comments on "The response of intense ocean current systems entering regions of strong cooling." *J. Phys. Oceanogr., 16*: 996-999.

Nof, D. (1987): The bifurcation of outflows. *J. Phys. Oceanogr., 17*: 37-52.

---

* *Preparation of these papers began prior to April 1986.*

Nof, D. (1987): Penetrating outflows and the dam-breaking problem. *J. Mar. Res., 45*: 557-577.

Nof, D. (1987): Vorticity control. *J. Phys. Oceanogr., 17*: 1758-1771.

Nof, D. and L. Simon (1987): Laboratory experiments on the merging of anticyclonic eddies. *J. Phys. Oceanogr., 17*: 343-357.

Nof, D. (1988): The fusion of isolated nonlinear eddies. *J. Phys. Oceanogr., 18*: 887-905.

Nof, D. (1988): Outflows dynamics. *Geophys. and Astrophys. Fluid Dynamics, 40*: 165-193.

Nof, D. (1988): Draining vortices. *Geophys. and Astrophys. Fluid Dynamics*, in press.

Nof, D. and S. VanGorder (1988): The propagation of gravity currents along continental shelves. *J. Phys. Oceanogr., 18*: 481-491.

Chapman, R. and D. Nof (1988): The sinking of warm-core rings. *J. Phys. Oceanogr., 18*: 565-583.

Nof, D. (1988): Eddy-wall interactions. To appear in *J. Mar. Res.*

Nof, D. (1988): The propagation of 'streamers' along the periphery of warm-core rings. *Deep-Sea Res.*, in press.

Nof, D. and J. Middleton (1988): Geostrophic suction and upwelling in barrier reefs. Submitted to *J. Phys. Oceanogr.*

Nof, D. and C. Shi (1988): Further study on the interaction of isolated eddies with shear flows. Submitted to *J. Phys. Oceanogr.*

Annual Progress Report

Research in Upper Ocean Predictability
Secretary of the Navy Research Chair in Oceanography

Chair Incumbent and P.I.: Dr. James J. O'Brien
Florida State University
Tallahassee, Florida 32306
904-644-4581

Technical Progress Report for 1 October 1986 - 31 March 1988

Dr. James J. O'Brien
Secretary of the Navy Professor
Meteorology and Oceanography
Tallahassee, Florida 32306-3041
Annual Report To ONR CODE 1122PO
Period 01 Oct 86 - 31 Mar 88

1. Papers submitted to refereed journals

Barnier, B., 1986: Testing a sponge layer in a two-layer quasi-geostrophic model, to appear in Ocean Modelling.

Cushman-Roisin, B., J. J. O'Brien, and W. H. Heil, 1987: Realizing two-dimensional, continuous directed fields by vector fields and an algorithm to remove dichotomous ambiguity in a discrete field, to appear in Int. J. Math. Model.

Dube, S. K., M. E. Luther and J. J. O'Brien, 1988: Relationships between the interannual variability of ocean fields and the wind stress curl over the central Arabian Sea and the Indian summer monsoon rainfall, to appear in J. Geophys. Res., Oceans.

Ehret, L. L. and J. J. O'Brien, 1988: Scales of north Atlantic wind stress curl determined from COADS, to appear in J. Geophys. Res., Oceans.

Kubota, M. and J. J. O'Brien, 1988: Variability of the Upper Tropical Pacific Ocean Model, submitted to J. Geophys. Res. - Oceans.

Legler, D. M., and J. J. O'Brien, 1987: Tropical Pacific Wind Stress Analysis for TOGA, to appear IOC Technical Series on Time Series on Ocean Measurements, 4.

Luther, M. E., 1986: Indian Ocean Modelling, Further Progress in Equatorial Oceanography, E. J. Katz and J. M. Witte, eds., Nova University Press, Dania, FL, 303-316.

McCalpin, J. D., 1987: Reflection of low-frequency equatorial Rossby waves from realistic western boundaries, J. Phys. Ocean., Oct. 1987.

Navon, I. M. and D. M. Legler, 1987: Conjugate-gradient Methods for Large Scale Minimization in Meteorology, Mon. Wea. Rev., 115, 1479-1503.

2. Papers published in refereed journals

Häkkinen, S., 1987: A constitutive law for the sea ice and some applications, Int. J. Math. Modelling, 9, No. 2, pp. 81-90.

McCalpin, J. D., 1987: On the adjustment of azimuthally perturbed vortices, J. Geophys. Res., Oceans, 92, No. C8, pp. 8213-8225.

O'Brien, J. J. and D. M. Legler, 1986: Tropical Wind Stress Analysis for TOGA, TOGA TOPICS, 2, No. 3, pp. 3-6.

O'Brien, J. J., 1986: An Important Scientific Controversy: Oceanic CO_2 Fluxes, J. Geophys. Res. - Oceans, 91, No. C9, p. 10,515.

Smedstad, O. M. and J. E. Weber, 1986: Geostrophic currents in shelf areas, Continental Shelf Research, 6, No. 5, pp. 655-670.

3. Papers published in non-refereed journals

None.

4. Books or chapters submitted for publication

None.

5. Books or chapters published

Jensen, T. G., 1986: Chapter 3c in Advanced physical oceanographic numerical modelling edited by J. J. O'Brien, Reidel Press, pp. 87-110.

Luther, M. E., 1986: Chapters 3b, 9a and 9c in Advanced physical oceanographic numerical modelling edited by J. J. O'Brien, Reidel Press, pp. 73-86, 255-256, 265-298.

O'Brien, J. J. , 1986: Chapters 1-6 in Advanced physical oceanographic numerical modelling, edited by J. J. O'Brien, Reidel Press, pp. 1-186.

6. Patents field (inventor, title, filing date)

None.

7. Patents granted (inventor, title, number, date)

None.

8. Invited presentations at conferences

O'Brien, J. J., Invited Laboratory Lecture, "Modelling the Indian Ocean", Goddard Space Flight Lab, October 3, 1986.

O'Brien, J. J., Forecasting El Niño, Climate Dynamics Workshop, Champaign, Illinois, October 22, 1986.

O'Brien, J. J., Modern Ocean Modelling, SCOR Meeting, Hobart, Australia, October 22, 1986.

O'Brien, J. J., Space and Time Scales of the Tropical Pacific, TOGA Pacific Workshop, Hobart, Australia, October 26, 1986.

O'Brien, J. J., The California Current Variability is Remote, Kiel Univeristy, West Germany, May 21, 1987.

O'Brien, J. J., The California Current Variability is Remote, NATO SACLANT, June 1, 1987.

O'Brien, J. J., Modelling the Indian Ocean, NATO SACLANT, June 2, 1987.

O'Brien, J. J., Modelling the Indian Ocean, Naval Postgraduate School, July 6, 1987.

O'Brien, J. J., The California Current is Remote, IUGG, Vancouver, August 13, 1987.

9. Contributed presentations at conferences

None.

10. Honors

Dr. James J. O'Brien was awarded the 13th Sverdrup Gold Medal in Air-Sea Interaction by the American Meteorological Society.

Dr. James J. O'Brien was elected President, IAPSO, August 1987 for 4 years.

Dr. James J. O'Brien was elected Fellow, AGU, January 1988.

Dr. James J. O'Brien was elected Fellow, AAAS, January 1988.

11. Professional personnel associated with ONR Contract

Principal Investigator:	Dr. James J. O'Brien Secretary of the Navy Professor Meteorology and Oceanography Director, Mesoscale Air-Sea Interaction Group
Research Associate:	Dr. Mark Luther
Meteorologist:	Mr. David Legler
Computer Research Specialist:	Mr. Jim Merritt
Grants Specialist:	Mrs. Ruth Pryor
Word Processor:	Mrs. Rita Kuyper

12. Graduate Students

1. Mr. Tommy Jensen (Denmark)
   Topic: Indian Ocean Model
   Degree: Ph.D., Physical Oceanography
   Date: 1988

2. Mr. John McCalpin (USA)
   Topic: Indian Ocean Eddies
   Degree: Ph.D., Physical Oceanography
   Date: 1988

3. Lt. Ray Simmons (USA-USN)
   Topic: Verification of Arabian Sea Model
   Degree: M.S., Physical Oceanography
   Date: 1987

4. Mr. Ole Martin Smedstad (Norway)
   Topic: Data Assimilation of Sea Level
   Degree: Ph.D., Geophysical Fluid Dynamics
   Date: 1987

13. Principal Investigator

Dr. James J. O'Brien
The Florida State University
Meteorology Annex
Tallahassee, Florida 32306-3041
(904) 644-4581

Contract Number: N00014-85-G-0240
Contract Title: Upper Ocean Forecasting
Telex Number: 509525
Telemail: J.OBRIEN/OCEAN

FINAL REPORT TO THE OFFICE OF NAVAL RESEARCH

For work under Contract N00014-82-C-0404

by

David Thistle
Department of Oceanography
Florida State University
Tallahassee, FL 32306
904-644-6700

Under this contract, I participated in the High Energy Benthic Boundary Layer Experiment (C.D. Hollister and A. R. M. Nowell, scientific directors). The HEBBLE project required an assessment of the likely impact of biological effects on parameters of an emerging sediment-transport model. In outline, the approach of the HEBBLE biologists to such an assessment was to determine the abundance and distribution of organisms at the HEBBLE site. From these data and a knowledge of the natural history and probable fluid-dynamic consequences of the organisms (or their shallow-water relatives), we identified taxa or functional groups of organisms that seemed most likely to influence sediment motion. These organisms were nominated for study in laboratory flumes or with SEADUCT to quantify their effects on sediment transport.

The approach was implemented as follows. In July 1982, sixteen navigated box cores were taken at the HEBBLE site in a stratified random manner. From each, the central nine subcores were processed for macrofauna, and two of these subcores were also processed for meiofauna. The polychaetes from the two subcores per core were sent to K. Fauchald for identification. The remaining noncrustacean taxa from these subcores were sent to Josie (Yingst) Aller. In my laboratory, we have worked up the tanaids, isopods, harpacticoid copepods, and nematodes.

The most dramatic result is that the major macrofaunal taxa (polychaetes, bivalves, isopods, and tanaids) are conspicuously more abundant than elsewhere in the deep sea at comparable depths (Thistle et al., 1985). Also, more than 60% of the polychaetes make tubes, as do a substantial number of the crustaceans. Because of the potential impact of small-scale roughness on sediment transport, this information has been conveyed to the experimentalists. Other likely effects of the organisms on sediment transport are less clear. Two polychaete species are very abundant and appear likely to dominate the budget of sediment processing by deposit feeders, focusing this aspect of the investigation of potential biological effects.

Although the primary mandate for HEBBLE biology was the determination of its importance in sediment transport, coordinated studies of deep-sea biological questions have had a legitimate, if secondary, role. Using the data from two preliminary samples, Thistle et al. (1985) presented an overview of the ecology of the area, noting strong contrasts with that of more tranquil deep-sea areas. In particular, the fauna seemed to be modified by the risk of erosion posed by the strong bottom currents while benefiting from the increased food flux. Using the data from the main HEBBLE samples, I was able to confirm that tanaids (Reidenauer and Thistle, 1985) and isopods (Thistle and Wilson, 1987) were unusually abundant for the depth and that epifaunal forms were rare. My student Kevin Sherman put a heroic effort into working up the nematodes (260 species), which allowed us to describe the composition and some of the ecology of this important component of the fauna (Thistle and Sherman, 1985; Carman et al., 1987). I also

showed that benthic storms displace harpacticoid copepods from site and thus participate in the organization of the community there (Thistle, in press).

HEBBLE Publications from a previous contract

Thistle, D. (1983): The stability-time hypothesis as a predictor of diversity in deep-sea soft-bottom communities: a test. *Deep-Sea Res. 30*: 267-277.

Reidenauer, J. A., and D. Thistle (1983): *Sarsameira* (Copepoda, Harpacticoida): an update and a new species from the deep sea. *Trans. Amer. Micros. Soc. 102*: 105-112.

Thistle, D. (1983): The role of biologically produced habitat heterogeneity in deep-sea diversity maintenance. *Deep-Sea Res. 30*: 1235-1245.

Sherman, K. M., D. A. Meeter, and J. A. Reidenauer (1984): A technique for subsampling an abundant taxon while completely sorting other taxa. *Limnol. Oceanogr. 29*: 433-439.

HEBBLE Publications under N00014-82-C-0404

Thistle, D., J. Y. Yingst, and K. Fauchald (1985): A deep-sea benthic community exposed to strong near-bottom currents on the Scotian rise (Western Atlantic). *Mar. Geol. 66*: 91-112.

Thistle, D., and K. M. Sherman (1985): The nematode fauna of a deep-sea site exposed to strong near-bottom currents. *Deep-Sea Res. 32*: 1077-1088.

Reidenauer, J. A. and D. Thistle (1985): A current-molded tanaid fauna from the deep North Atlantic. *Oceanologica Acta 8*: 355-360.

Thistle, D. and G. D. F. Wilson (1987): A hydrodynamically modified, abyssal isopod fauna. *Deep-Sea Res. 34*: 73-87.

Carman, K. R., K. M. Sherman, and D. Thistle (1987): Evidence that sediment type influences the horizontal and vertical distribution of nematodes at a deep-sea site. *Deep-Sea Res. 34*: 45-53.

Thistle, D. In press. A temporal difference in harpacticoid-copepod abundance at a deep-sea site: caused by benthic storms? *Deep-Sea Res.*

Other Publications in which N00014-82-C-0404 is acknowledged

Thistle, D., J. A. Reidenauer, R. H. Findlay, and R. Waldo (1984): An experimental investigation of enhanced harpacticoid (Copepoda) abundances around isolated seagrass shoots. *Oecologia 63*: 295-299.

Carman, K. R. and D. Thistle (1985): Microbial food partitioning by three species of benthic copepods. *Mar. Biol. 88*: 143-148.

Baird, B. H. and D. Thistle (1986): The uptake of bacterial exopolymer by a deposit-feeding holothurian (*Isostichopus badionotus*). *Mar. Biol. 92*: 183-187.

Thistle, D. and J. E. Eckman. In press. Response to habitat structure in the deep sea. *Hydrobiologia*.

FINAL REPORT TO THE OFFICE OF NAVAL RESEARCH

For work under contract N0014-82-C-0404

April 1, 1982 - March 31, 1988

BOTTOM BOUNDARY STUDIES AS PART OF HEBBLE
(High Energy Benthic Boundary Layer Experiments)

Georges Weatherly
Department of Oceanography
Florida State University
Tallahassee, FL 32306

My objectives in HEBBLE were (1) to obtain and to analyze long-term abyssal current meter records from the HEBBLE area, (2) to obtain and to analyze current meter records completely spanning the HEBBLE site bottom boundary layer, and (3) to obtain a better understanding of the bottom boundary layer and its importance in the general ocean circulation.

PUBLICATIONS

Weatherly, G.L. and E.A Kelley, Jr. (1982): Too cold bottom layers at the base of the Scotian Rise, J. Mar. Res., 40, 985-10 2.

Kelley, E.A., G.L. Weatherly, J.C. Evans (1982): Correlation between surface Gulf Stream and bottom flow near 5000 meter depth, J. Phys. Oceanogr., 12, 1150-1153.

Weatherly, G.L. and E.A. Kelley (1982): Storms and flow revessals at the HEBBLE site, Mar. Geol., 66, 205-218.

Weatherly, G.L. (1984): An estimate of bottom frictional dissipation by Gulf Stream fluctuations, J. Mar. Res., 42, 289-301.

Kelley, E.A. and G.L. Weatherly (1985): Abyssal eddies near the Gulf Stream, J. Geophys. Res., 90, 3151-3159.

Weatherly, G.L. and E.A. Kelley, Jr. (1985): Two views of the cold Flament, J. Phys. Oceanogr., 15, 68-8.

Gust, G. and G.L. Weatherly (1985): Velocities, turbulence and skin friction in a deep-sea logarithmic layer, J. Geophys. Res. 90, 4779-4792.

Ionov, V.V., G.L. Weatherly, and R. Harkema (1986): On the temporal variability of the surfacr Gulf Stream and near-bottom flows., J. Geophys. Res., 91, 2661-2666.

SUBMITTED PUBLICATIONS

Peggion, G. and G.L. Weatherly (1988): On the interaction of the bottom boundary layer and deep rings, submitted to Deep-Sea Res.

Ezer, T. and G.L. Weatherly (1988): Small-scale structure and long-term variabiltity of near bottom layers in the HEBBLE area, submitted to Deep-Sea Res.

Ezer, T. and G.L. Weatherly (1988): On eddy diffusion profiles in oceanic bottom boundary layers associated with cold eddies and filaments, submitted to Boundary-Layer Met.

REPORTS

Koenig, P., R. Harkema and G.L. Weatherly (1983): A compilation of moored current meter data at the HEBBLE site October 1980 - October 1981, Florida State University, Department of Oceanography, Tech Rep 83-01, 92pp.

Koenig, P., R. Harkema and G.L. Weatherly (1983), a complation of moored current meter data at the HEBLE site, January - July, 1982. Florida State University, Department of Oceanography, Tech. Rep. 83-02, 100 pp.

Koenig, P. , R. Harkema and G.L. Weatherly (1983): A compilation of Non-vane corrected moored current meter data at the HEBBLE site, January - July 1982, Florida State University, Department of Oceanography, Tech. Rep. 83-03, 68 pp.

Weatherly, G.L., E.A. Kelley, M. Lopez, and R. Harkema (1984): The Gulf Stream system's frontal position and near-bottom flow at the HEBBLE site (40°N, 62°W), from January 1987 to September 1983, Florida State University, Department of Oceanography, Tech. Rep. 84-01, 63 pp.

Harkema, R. T. Ezer and G.L. Weatherly (1986): A compilation of moored current meter data at the HEBBLE site, July 1982 - September 1983., Florida State University, Department of Oceanography, Tech. Rep. cmf-86-01, 92 pp.

Harkema, R. and G.L. Weatherly (1987): A compilation of moored current meter data at the HEBBLE site, June 9-15, 1983, Florida State. University, Department of Oceanography, Tech. Rep. CMF- 187-02, 85 pp.

Harkema, R. and G.L. Weatherly (1988): A compilation of moored current meter data at the HEBBLE site, September 17, 1983 - December 14, 1984, Florida State University, Department of Oceanography, Tech. Rep. CMF-88-01, 98 pp.

Harkema, R. and G.L. Weatherly (1988): A compilation of moored current meter data at the HEBBLE site, August 19, 1984 - September 21, 1985, Florida State University, Department of Oceanography, Tech. Rep. CMF-88-02, 21 pp.

THESES

Kelley, E.A., 1983. A study of highly energetic near-bottom flow at the base of the Scotian Rise, Ph.D. Thesis, Flrodia State University, 108 pp.

Peggion, G., 1984. The effect of the benthic boundary layer on the Physics of intense mesoscale eddies, Ph.D. Thesis, florida State University, 137 pp.

FINAL REPORT TO THE OFFICE OF NAVAL RESEARCH

For work under Contract N00014-82-C-0404

THE ROLE OF EXOPOLYMER IN ADHESION OF THE INITIAL MICROFOULING COMMUNITY AND IN BIOFILM STABILITY

D. C. White
Institute for Applied Microbiology
University of Tennessee
Knoxville, TN 37932-2567

and

D. Thistle
Department of Oceanography
Florida State University
Tallahassee, FL 32306-3048

OBJECTIVES

The long-term objective of the work performed under this contract has been to define the role of the microbial film in initiating the biofouling sequence and to determine the role of exopolymers in irreversible attachments in biofilms and in stabilizing sediments.

ABSTRACT

The community structure of the biofouling film can be determined by examination of the patterns of polar lipid ester-linked fatty acids (PLFA). By examining the shifts in cyclopropane and trans/cis monoenoic proportions, as well as the accumulation of the exogenous storage polymer poly-beta-hydroxy alkanoate, the nutritional status of the microbes can be determined. The extraordinary resolution of the capillary gas chromatograph (GC) coupled with the diversity of bacterial fatty acids provides a means of quantitatively measuring microbial community structure. The creation of electron-withdrawing derivatives of the PLFA followed by GC analysis with chemical-ionization mass spectrometry and negative-ion detection has increased the sensitivity to femtomolar levels (hundreds of bacterial cells). The specificity of the analysis has been increased by a new derivatization with dimethyldisulfide that provides clear separation of trans/cis isomers and specific fragmentation that defines the position of the unsaturation in monoenoic fatty acids. This new technique has allowed identification of monocultures from the initial phases of microfouling.

With these new methods and the use of the GC/CINIMS at Lund Sweden, we were able to show that there appears to be an initial microfouling community consisting of typical gram-negative, "Vibrio-like" bacteria that attaches to Teflon surfaces in hours and that community did not change significantly in the first week of exposure. A specific portion of that community was removable with gentle washing. The accumulation of high proportions of trans-monoenoic and cyclopropane fatty acids accompanying the starvation sequence of *V. cholerae* was also shown. This change is associated with changes in the adhesive properties of the organisms. The source of the initial microbial microfouling community was examined by fractionating the inlet waters of the microfouling test beds with Nucleopore filters and then using a newly developed method

for quantitatively recovering the PLFA from them. Studies have shown that the community structure of the initial microbial microfouling community most closely resembles the microbiota associated with particulate material in the estuarine source waters. The free bacteria (retained by 0.4-um filter) and the particulates retained on a 10-um filter are much more like the initial microbial microfouling community than the microbes retained on a 3.0-um filter.

CURRENT REPORTS AND PUBLICATIONS

Dowling, N. J. E., F. Widdel, and D. C. White (1986): Phospholipid ester-linked fatty acid biomarkers of acetate-oxidizing sulfate reducers and other sulfide forming bacteria. *J. Gen. Microbiol., 132*: 1815-1825.

Mancuso, C. A., P. D. Nichols, and D. C. White (1986): A method for the separation and characterization of archaebacterial signature ether lipids. *J. Lipid Res., 27*: 49-56.

Nichols, P. D., J. B. Guckert, and D. C. White (1986): Determination of monounsaturated fatty acid double-bond position and geometry for microbial monocultures and complex consortia by capillary GC-MS of their dimethyl disulphide adducts. *J. Microbiol. Methods, 5*: 49-55.

Guckert, J. B., M. A. Hood, and D. C. White (1986): Phospholipid, ester-linked fatty acid profile changes during nutrient deprivation of *Vibrio cholerae*: increases in the *trans/cis* ratio and proportions of cyclopropyl fatty acids. *Appl. Environ. Microbiol., 52*: 794-801.

Hedrick, D. B. and D. C. White (1986): Microbial respiratory quinones in the environment I. A sensitive liquid chromatographic method. *J. Microbiol. Methods, 5*: 243-254.

Nichols, P. D., C. A. Mancuso, and D. C. White (1987): Assessment of methanotrophic and methanogenic biomass and community structure from environmental samples using signature phospholipids. *Organic Geochemistry, 11*: 451-461.

Guckert, J. B., D. B. Ringelberg, and D. C. White (1987): Biosynthesis of *trans* membrane fatty acids from acetate in the bacterium, *Pseudomonas atlantica*. *Canad. J. Microbiol., 34*: 748-754.

Kerger, B. D., P. D. Nichols, W. Sand, E. Bock, and D. C. White (1987): Association of acid producing *Thiobacilli* with degradation of concrete: analysis by "signature" fatty acids from the polar lipids and lipopolysaccharide. *J. Industrial Microbiol., 2*: 63-69.