WHOI-90-23

Woods Hole Oceanographic Institution
Massachusetts Institute of Technology

Joint Program
in Oceanography
and
Oceanographic Engineering

DOCTORAL DISSERTATION

Dinoflagellate Blooms and Physical Systems in the Gulf of Maine

by

Peter J. S. Franks

June 1990

WHOI-90-23

Dinoflagellate Blooms and Physical Systems in the Gulf of Maine

by

Peter J. S. Franks

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

and

The Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

June 1990

Doctoral Dissertation

Funding was provided by the Office of Naval Research and the Woods Hole Oceanographic Institutions Sea Grant Program.

Approved for Distribution:

Peter H. Weibe, Chairman
Department of Biology

Craig E. Dorman
Acting Dean of Graduate Studies

DINOFLAGELLATE BLOOMS AND PHYSICAL SYSTEMS IN THE GULF OF MAINE

by

Peter John Selwyn Franks

B.Sc. Queen's University (1981)
M.Sc. Dalhousie University (1984)

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

and the

WOODS HOLE OCEANOGRAPHIC INSTITUTION

May 1990

Signature of Author ______________________

Joint Program in Oceanography,
Massachusetts Institute of Technology/
Woods Hole Oceanographic Institution

Certified by ______________________

Donald M. Anderson
Thesis Supervisor

Accepted by ______________________

John Stegeman
Chairman, Joint Committee for Biological Oceanography
Massachusetts Institute of Technology/
Woods Hole Oceanographic Institution

DINOFLAGELLATE BLOOMS AND PHYSICAL SYSTEMS
IN THE GULF OF MAINE

by

PETER JOHN SELWYN FRANKS

submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy

ABSTRACT

Numerous studies have shown dinoflagellate blooms to be closely related to density discontinuities and fronts in the ocean. The spatial and temporal patterns of the dinoflagellate population depend on the predominant mode of physical forcing, and its scales of variability. The present study combined field sampling of hydrographic and biological variables to examine the relationship of dinoflagellate population distributions to physical factors along the southwestern cost of the Gulf of Maine.

A bloom of *Ceratium longipes* occurred along this coast during the month of June, 1987. A simple model which coupled along-isopycnal diffusion with the logistic growth equation suggested that the cells had a growth rate of about 0.1 d^{-1}, and had reached a steady horizontal across-shelf distribution within about 10 d. Further variations in population density appeared to be related to fluctuations of light with periods of ~10 d. To our knowledge, this was the first use of this simple diffusion model as a diagnostic tool for quantifying parameters describing the growth and movement of a specific phytoplankton population.

Blooms of the toxic dinoflagellate, *Alexandrium tamarense* have been nearly annual features along the coasts of southern Maine, New Hampshire and Massachusetts since 1972; however the mechanisms controlling the distribution of cells and concomitant shellfish toxicity are relatively poorly understood. Analysis of field data gathered from April to September, 1987-1989, showed that in two years when toxicity was detected in the southern part of this region, *A. tamarense* cells were apparently transported into the study area between Portsmouth and Cape Ann, Massachusetts, in a coastally trapped buoyant plume. This plume appears to have been formed off Maine by the outflow from the Androscoggin and

Kennebec Rivers. Flow rates of these rivers, hydrographic sections, and satellite images suggest that the plume had a duration of about a month, and extended alongshore for several hundred kilometers. The distribution of cells followed the position of the plume as it was influenced by wind and topography. Thus when winds were downwelling-favourable, cells were moved alongshore to the south, and were held to the coast; when winds were upwelling-favourable, the plume sometimes separated from the coast, advecting the cells offshore.

The alongshore advection of toxic cells within a coastally trapped buoyant plume can explain the temporal and spatial patterns of shellfish toxicity along the coast. The general observation of a north-to-south temporal trend of toxicity is consistent with the southward advection of the plume. In 1987 when no plume was present, *Alexandrium tamarense* cells were scarce, and no toxicity was recorded at the southern stations. A hypothesis was formulated explaining the development and spread of toxic dinoflagellate blooms in this region. This plume-advection hypothesis included: source *A. tamarense* populations in the north, possibly associated with the Androscoggin and Kennebec estuaries; a relationship between toxicity patterns and river flow volume and timing of flow peaks; and a relationship between wind stresses and the distribution of low salinity water and cells.

Predictions of the plume-advection hypothesis were tested with historical records of shellfish toxicity, wind speed and direction, and river flow. The predictions tested included the north-south progression of toxic outbreaks, the occurrence of a peak in river flow prior to the PSP events, the relationship of transit time of PSP toxicity along the coast with river flow volume, and the influence of surface wind stress on the timing and location of shellfish toxicity. All the predictions tested were supported by the historical records. In addition it was found that the plume-advection hypothesis explains many details of the timing and spread of shellfish toxicity, including the sporadic nature of toxic outbreaks south of Massachusetts Bay, and the apparently rare occurrence of toxicity well offshore on Nantucket Shoals and Georges Bank.

Thesis Supervisor: Donald M. Anderson, WHOI

This thesis is dedicated
to
my wonderful brother

Timothy Christian Selwyn Franks

TABLE OF CONTENTS