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SUBJECT: Final Technical Report
ONR Award No. N00014-95-1-0142
PI: Lanna Cheng

Enclosed for your records is the final technical report for the referenced grant along with the required number of copies as outlined in the award document.

Sincerely,

Judy Keplinger
Contracts & Grants Assistant

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
11/21/97

3. REPORT TYPE AND DATES COVERED
Final Technical Report

4. TITLE AND SUBTITLE
Correlations between *Halobates* distributions and physical processes at the sea surface

5. FUNDING NUMBERS
N00014-95-1-0142

6. AUTHOR(S)
Lanna Cheng

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Five sea-skater species, each with a well-defined geographical range, are specifically adapted to live on the surface film. 1) Analyses of an 18-month time series showed that the range of Halobates micans and H. sericeus in the Pacific Ocean are generally separate. H. micans is restricted to a zone between 11 deg. N and 10 deg S., with amphitropical populations of H. sericeus north and south of this region. The separate ranges of the two species are associated with permanent large-scale surface circulation patterns. 2) Theoretical calculations showed that oceanic diffusion alone could carry Halobates from an initial point of origin to 2500 m in 60 days. Mutual encounter rates due to oceanic turbulence could be as high as 11/day even at low population densities (110/km2), while the encounter rate due to random movements is less than 0.6/day. An individual could find mates even when it had been carried long distances away. 3) Preliminary results from mtDNA sequences of regions of cytochrome oxidase subunit I (COI) revealed that although North Atlantic and Arabian Sea *H. micans* appear to be closely related, there was high genetic divergence between N. Pacific and Arabian Sea populations.

14. SUBJECT TERMS
Surface film, oceanic diffusion, sea-skaters, Halobates, disuunct distribution, genetic exchange, mtDNA sequences

15. NUMBER OF PAGES
6

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unrestricted	Unrestricted	Unrestricted	None

Final Technical Report (ONR-N00014-95-1-0142)

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CORRELATIONS BETWEEN *HALOBATES* DISTRIBUTIONS AND PHYSICAL PROCESSES AT THE SEA SURFACE

LONG-TERM GOALS

Five species of Halobates (Hemiptera: Gerridae) are specially adapted to a pelagic life. They all occur in the Pacific Ocean, each with a well-defined geographical range. Since these insects live their entire lives on the sea surface, they are uniquely suited for studying sea-surface processes. The proposed study will enable us to test the validity of conventional theories of oceanic diffusion as it affects the distribution of strictly sea-surface objects, and will perhaps provide clues to solving problems of surface-film diffusion. If we can elucidate factors controlling the distribution patterns of Halobates species we may be able to use these insects as marker organisms for climatological studies at the sea surface, helping us to better understand air-sea exchange processes at the surface film which are important in modelling the global circulations of atmosphere and ocean.

SCIENTIFIC OBJECTIVES

Oceanic diffusion is not only of theoretical interest but also of practical importance, especially in relation to the distributions of surface pollutants and other contaminants. It is a complex process, and many theories have been put forward to explain it. One of these, the diffusion diagram developed by Dr. Akira Okubo, can be used to predict the rate of horizontal spread of a substance from an instantaneous point source. It is applicable to submerged materials and passive contaminants, but we do not know if it also applies to the diffusion of strictly surface-floating objects. The present project aims to investigate what controls the distribution ranges of Halobates, and to test the validity of existing oceanic diffusion laws by using this flightless insect as a model organism.

APPROACH

We used two approaches:-
1) Analyses of distribution patterns of Halobates spp., and comparisons with various conventional physical parameters.
2) Using contemporary genetic methodologies to compare the mitochondrial-DNA sequences of Halobates species.

TASKS COMPLETED

A) Samples from an 18-month time series collected between Hawaii and Tahiti were analysed. Two species of Halobates were caught: H. sericeus, with an amphi-tropical distribution, and H. micans, occupying the equatorial zone separating the northern and southern populations of the former. How this disjunct distribution pattern may be maintained by zonal equatorial current systems was investigated.

B) Using oceanic diffusion diagrams constructed by Okubo and the mathematical model developed by Kierstead and Slobodkin, and Skellam, effects of oceanic diffusion on 1) Patch expansion, 2) Mutual encounter rates, and 3) Growth rates of Halobates were investigated.

C) About 100 samples of Halobates were collected for DNA studies. All 5 pelagic species (H. micans, H. sericeus, H. germanus, H. sobrinus and H. splendens) were represented as well as the following coastal species: H. hawaiiensis, H. flaviventris, H. robustus, H. fijiensis, H. salotae, H. mariannarum, and H. nereis. DNA was extracted from some of the specimens on site, or from samples preserved either in liquid nitrogen or 80% ethanol after they had been received at the laboratory.

RESULTS

A) The time series analysed shows that, even on a limited temporal and spatial scale, the ranges of H. micans and H. sericeus in the Pacific Ocean are generally separate. H. micans is restricted to a zone between 11°N and 10°S, with amphitropical populations of H. sericeus north and south of this region. The separate ranges of the two species are associated with permanent large-scale surface circulation patterns. However, although the separation of northern and southern populations of H. sericeus appears to be permanent, there is evidence of mixing between the two species. Data from the present series do not allow us to speculate on whether inter-mingling of individuals from the two populations ever occurs. We are sequencing mitochondrial-DNA fragments of preserved H. sericeus specimens in an attempt to find out whether the two disjunct populations are genetically distinct.

B) In theory the estimated diameter of a patch of Halobates could be expanded by oceanic diffusion alone from an initial point of origin to 2500 km in 60 days (i.e. the average time required for an egg to develop into an adult). This distance is about one-sixth of the maximum distributional range of H. micans in the Pacific Ocean. It is possible that within its range each species forms only one mega-population in which local aggregates may be found.

Mutual encounter rates due to oceanic turbulence could be as high as 11 /day even at low population densities ($100/km^2$), while the encounter rate due to random movements is less than 0.6/ day. This suggests that a Halobates could find a mate even when an individual had been carried a long distance away from its initial patch. Thus, extensive gene mixing may occur over the whole range of a species' distribution.

Estimated growth rates for pelagic Halobates are rather low (0.0026-0.0079/day) compared with those of other insects. However, they are offset by a long life span (over 60 days) and an extended oviposition period (perhaps over 2 months).

c) We were able to amplify and sequence certain fragments of the cytochrome oxidase subunit I (COI) region of the mtDNA of Halobates. This molecule has been found to be an excellent genetic marker for phylogenetic and systematics studies in several other insects. Using primers developed specifically for the Gerridae by Dr. Felix Sperling at UC Berkeley we were able to obtain complete sequences for two regions containing 440 and 436 base pairs respectively, with some overlap between the two. Preliminary analyses indicated a high degree of genetic divergence between North Pacific and Arabian Sea H. micans, but close similarity between North Atlantic and Arabian Sea populations. The coastal H. hawaiiensis was also found to be closely related to H. micans. This work is continuing.

WORK STILL IN PROGRESS:

1. Distributions: With the collaboration of Drs. Hidehiko Okabe and Terumi Ikawa, a computer databank containing some 5,000 sample data has been established at the National Institute for Material Sciences, Tsukuba, Japan. This database contains information for all 5 pelagic Halobates species. We plan to correlate the distribution patterns of each species with surface temperatures, winds and currents obtained from SVP drifters.

2. Modelling: In collaboration with Dr. Mark Luther's group at the Department of Marine Science, University of South Florida, St. Petersburg and Dr. Martien Baars, Netherlands Institute of Sea Research, we are trying to find out how the distributions of Indian Ocean Halobates agree with those of passsive tracers like FCC's simulated by Luther's model. Similar studies are being carried out by Dr. Don Olson, RSMAS, University of Miami, using

models involving surface currents and winds derived from data obtained by Lagragian drifters.

3. Molecular studies: Work on mtDNA sequencing in collaboration with Drs. Felix Sperling and Andrew Shedlock, University of California, Berkeley, is continuing. This project did not proceed as smoothly as we had hoped since we have encountered several problems which had not been anticipated. For most other insect species studied in the Sperling lab PCR results were predictable when similar primers were used. In the case of Halobates we found unpredictable PCR results even though samples had been collected, extracted and processed in the same way. We are trying to solve this problem.

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