

1989

2

DTIC
ELECTE
SEP 9 1992
S C D

AD-A257 701

FINAL REPORT
CLOSEOUT/(N00014-76-C-0274 and N00014-85-C-0230)
SER 462

Under this contract we have completed 28 projects that are summarized in the following publications. Except for those represented by the enclosed reprints, all the projects have been described in periodic progress reports to the project officer at the Office of Naval Research, Dr. Edward Green. A summary of our most recent progress follows the list of publications.

PUBLICATIONS (peer reviewed)

Christensen, J.P. and T.T. Packard. Sediment metabolism from the northwest African upwelling system. Deep-Sea Research, 24: 331-343 (1977).

King, F.D., A.H. Devol and T.T. Packard. On plankton biomass and metabolic activity from the eastern tropical North Pacific. Deep-Sea Research, 25: 689-704 (1978).

Christensen, J.P. and T.T. Packard. Respiratory electron transport activities in plankton: comparison of methods. Limnology and Oceanography, 24(3): 576-583 (1979).

Garfield, P.C., T.T. Packard and L.A. Codispoti. Particulate protein in the Peru upwelling system. Deep-Sea Research, 26/6A: 623-639 (1979).

Christensen, J.P., T.G. Owens, A.H. Devol and T.T. Packard. Respiration and physiological state in marine bacteria. Marine Biology, 55: 267-276 (1980).

Codispoti, L.A. and T.T. Packard. On the denitrification rate in the Eastern Tropical South Pacific. Journal of Marine Research, 38(3): 453-477 (1980).

Packard, T.T. and P.J. LeB Williams. Rates of respiratory oxygen consumption and electron transport in surface seawater from the northwest Atlantic Ocean. Oceanologica Acta, 4(3): 351-358 (1981).

Manley, T.O., L.A. Codispoti, K.L. Hunkins, H.J. Jackson, E.P. Jones, V. Lee, S. Moore, J. Morison, T.T. Packard and P. Wadhams. The FRAM III Expedition. EOS, 63(35): 627-636 (1982).



- Minas, H.J., T.T. Packard, M. Minas and B. Coste. An analysis of the production-regeneration system in the coastal upwelling area off N.W. Africa based on oxygen, nitrate and ammonium distributions. *Journal of Marine Research*, 40(3): 615-641 (1982).
- Packard, T.T., P.C. Garfield and L.A. Codispoti. Oxygen consumption and denitrification below the Peruvian upwelling. In: *Coastal Upwelling: Its Sediment Record*, E. Suess and J. Thiede, (eds.), Plenum Press, New York pp. 147-173 (1982).
- Packard, T.T., P.C. Garfield and R. Martinez. Respiration and respiratory enzyme activity in aerobic and anaerobic cultures in the marine denitrifying bacterium Pseudomonas perfectomarinus. *Deep-Sea Research*, 30(30A): 227-243 (1983).
- Garfield, P.C., T.T. Packard, G.E. Friederich and L.A. Codispoti. A subsurface particle maximum layer and enhanced microbial activity in the secondary nitrite maximum of the northeastern tropical Pacific ocean. *Journal of Marine Research*, 41(4): 747-768 (1983).
- Green, E.J., J.M. Edmond, T.T. Packard, A. Zirino, J.L. Bada, J.W. Farrington. Why is the sea salty and why does it vary? *Naval Research Reviews*, 35 (1): 14-31 (1983).
- Packard, T.T. Oxygen consumption in the ocean: Measuring and mapping with enzyme analysis. *Mapping Strategies in Chemical Oceanography*, A. Zirino (ed.), American Chemical Society, Washington, D.C. pp. 177-209 (1985).
- Packard, T.T. Measurement of electron transport activity of marine microplankton. In: *Advances in Aquatic Microbiology*, P.J. LeB. Williams and H.W. Jannasch (eds.), Academic Press, New York, pp. 207-261 (1985).
- Minas, H.J., M. Minas and T.T. Packard. Productivity in upwelling areas deduced from hydrographic and chemical fields. *Limnology and Oceanography*, 31(6):1182-1206 (1986)
- Codispoti, L.A. and T.T. Packard (Editors). *Biological effects on the chemistry of the sea: The legacy of F. A. Richards*. *Deep-Sea Research*, 34 (Nos. 5/6A), pp. 1065 (1987).
- Denis, M., T. Packard, and M. Rodier. Optical properties and respiratory activity in the marine dinoflagellate, Cryptocodinium cohnii. pp.401- 404. In Moore, A.L. and R.B. Beechey (eds.), *Plant Mitochondria*, Plenum Press (1987).
- Packard, T.T., M. Denis, M. Rodier, and P. Garfield. Deep-ocean metabolic CO₂ production: calculations from ETS activity.

Bigelow Lab for Ocean Sciences,
West Boothbay Harbor, ME.

2

Per telecon ONR 12/3/92

cl

Deep-Sea Research, 35:371-382 (1988).

Packard, T.T., H.J. Minas, B.Coste, R.Martinez, M.C.Bonin, J.Gostan, P. Garfield, J. Christensen, Q. Dortch, M. Minas, G. Copin-Montegut, C. Copin-Montegut. Formation of the Alboran Sea oxygen minimum zone. Deep-Sea Research 35:1111-1118 (1988).

Dortch, Q. and T.T.Packard. Differences in biomass structure between oligotrophic and eutrophic marine ecosystems. Deep-Sea Research, 36 (2):223-240 (1989).

Codispoti, L. A., G.E. Friederich, and T.T.Packard. Remotely driven thermocline oscillations and denitrification in the eastern south Pacific: The potential for high denitrification rates during weak coastal upwelling. The Science of the Total Environment, 75:301-318 (1988).

Christensen, J.P., T.T.Packard, F.Q. Dortch, H.J. Minas, P.C. Garfield, and C.Richez. Carbon oxidation in the deep Mediterranean Sea: Evidence for a dissolved organic carbon source. (Submitted).

TECHNICAL and DATA REPORTS

King, F.D. and T.T. Packard. ETS activity in the equatorial upwelling system in the vicinity of the Galapagos Islands. Bigelow Laboratory Technical Report No. 1 (1979).

King, F.D. and T.T. Packard. An analysis of chemical, physical and biological parameters in the vicinity of Costa Rica Dome in early 1973. Bigelow Laboratory Technical Report No. 2 (1979).

Oslund, H.G., L.A. Codispoti, D. Dryssen, J. Kelley, R. Moore, I.V. Olsson, T.T. Packard and W. Reeburgh. Chemical Oceanography. By the working group on Chemical Oceanography-from the Workshop on Eastern Arctic Science. Commission for Scientific Work in Greenland, pp. 123 (1979).

Hays, E.E., B.C. Coull, F.H. Farmer, M. Karneit, T.T. Packard and P.S. Tabor. Instrumentation concepts for measurement. In: Advanced Concepts in Ocean Measurements for Marine Biology. F.P. Diemer, F.J. Vernberg and D.Z. Mirkes (eds.). University of South Carolina Press. pp. 572 (1980).

Packard, T.T., J.A. Morgui, J.R. Penuelas. Mesura de la capacitat de transport d'electrons dels organismes. Butlleti de la Institutio Catalana d'Historia Natural (in press).

Statement A per telecon Edward Green
ONR/Code 1123
Arlington, VA 22217-5000
NWW 9/4/92

Accession For	
NTIS	<input checked="" type="checkbox"/>
DTIC	<input type="checkbox"/>
Other	<input type="checkbox"/>
Availability Codes	
Dist	Special
A-1	

RESEARCH SUMMARIES

DTIC QUALITY INSPECTED 1

Formation of the Alboran Oxygen Minimum Zone

The enhanced oxygen minimum in the western Alboran Sea is the result of a chain of processes starting with nutrient injection into the inflowing Atlantic water at the Strait of Gibraltar. These nutrients originate in the outflowing Levantine Intermediate Water, outflowing Mediterranean deep water, and inflowing North Atlantic Central Water (from 200 m). They are injected into the inflowing Atlantic surface water by strong mixing at the eastern end of the Strait. They move with Atlantic surface waters along the Spanish coast, mix with nutrients upwelling in the northwestern Alboran Sea and stimulate phytoplankton productivity. The organic matter produced by this mechanism is transported both with the anticyclonically flowing waters of the Alboran gyre and with the waters that converge at the center of the gyre. Sedimentation in this convergence zone helps to deliver this organic matter to the Levantine Intermediate Water where bacteria metabolize it to CO₂ at the expense of the existing oxygen. This mechanism develops the most intense oxygen minimum zone in the Mediterranean Sea.

Deep-Sea CO₂ Production

A biochemical mechanism that could cause changes in the atmospheric CO₂ is the change in the deep-sea CO₂ production rate, or in other words, the deep-sea metabolic rate. This is the rate at which the deep-sea community of organisms degrades organic carbon and generates carbon dioxide. How much must this process be changed for the ocean to sequester a significant fraction of the new CO₂ that is annually appearing in the atmosphere? To answer this question the amount of CO₂ vented to the atmosphere and the amount injected into the deep sea via metabolism must be known. Sediment traps provide one way of assessing this rate. Calculating it from an understanding of the way CO₂ is produced during the degradation of organic matter is another way. Recently this approach has yielded some interesting results. From respiratory electron transport system measurements made in the Sargasso Sea and in the central tropical Pacific the CO₂

production rates for the Atlantic and the Pacific have been calculated. These calculations showed that if the deep-sea metabolic CO₂ production rate increased by only 15% it would cause an additional 1 gigaton (Gt) carbon per year to be sequestered in the deep sea. Since the amount of carbon that can not be accounted for by existing global carbon budgets is of the order of 2 Gt per year, the 15% increase in deep-sea metabolism that we calculated above would be significant (Packard et al., 1988).

Peru Current Oxygen Minimum Zone Studies

We have recently discovered a potential couple between El Nino events in the Pacific Ocean and the rate at which CO₂ and N₂O are absorbed and released by the ocean. Between El Nino events, cold deep water in the eastern Pacific ocean rises close to the sea surface and brings nutrients that stimulate plankton growth. This enhanced productivity has two effects on the green house gases. First, it increases the rate at which CO₂ is removed from the atmosphere and the rate at which it is transported, in the form of particulate organic matter, to the deep-sea. Second, this enhanced productivity leads to additional organic matter in the sub-surface waters which stimulates denitrification, consumes N₂O, and thus leaves less to be vented to the atmosphere.

New Production in the World Ocean

Deep-ocean respiration, in terms of CO₂ production, was calculated from measurements of the respiratory electron transport system in microplankton samples from the north central Pacific Ocean and from the northeastern Sargasso Sea. These calculations support recent arguments that the Pacific Ocean supports more phytoplankton productivity in its surface waters than does the Atlantic. However, more importantly, these measurements facilitate the calculation of new production because the new production of the phytoplankton must balance the respiration (CO₂ production) of all of the deep-sea organisms below the surface layer. When this calculation was made the result was 21.9 Gt C per year, 4 to 11 times greater than previous calculations, but very close to a recent computation made from satellite color scanning data and a separate computation made from a global integration of carbon productivity data.

Phytoplankton Ecology

The results of a collaborative project with Quay Dortch of

LUMCOM suggest that the trophic pyramids of oligotrophic and eutrophic plankton ecosystems are the inverse of one another. Before our study it was thought that a normal trophic pyramid, with most living biomass comprised of plants, represented all marine ecosystems. However, oligotrophic and eutrophic environments differ markedly in phytoplankton biomass, but, due to difficulties sampling and quantifying the small, non-plant organisms, it has been difficult to determine the relative plant and non-plant biomass. We calculated the chlorophyll a /protein ratio (Chl/Pr) of oceanic particulate matter from our very extensive suites of field data. This ratio serves as an index of phytoplankton (plant) biomass to total biomass. We found that in eutrophic areas with high chlorophyll concentrations, the Chl/Pr ratio approaches that of pure phytoplankton cultures, suggesting that phytoplankton constitute most of the biomass. In contrast, the Chl/Pr ratio from oligotrophic areas is low, indicating that most of the biomass consists of bacteria and zooplankton and that in these areas an inverted biomass pyramid better describes the system. Thus, ecosystem structure must be fundamentally different between eutrophic and oligotrophic areas.