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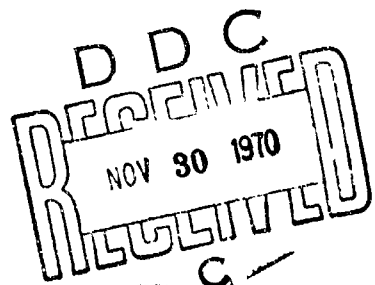
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ORGANIC PRODUCTION OF EPIFAUNAL ORGANISMS

W. E. Pequegnat

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13. ABSTRACT The studies pursued under the above referenced contract investigated the potential productivity of the epifaunal component of the benthos of the nearshore marine ecosystem off southern California. Some attention was also given to the ability of this system to absorb environmental perturbations induced by man before it suffered irreparable damage.			

FINAL REPORT

Contract No. Nonr-2119(05), NR104-814

Principal Investigator - Willis E. Pequegnat

Department of Oceanography

Texas A&M University, College Station, Texas

Project Title

Organic Production of Epifaunal Organisms

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Technical Reports

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M.S. Degree Thesis

Department of Oceanography, Texas A&M University, Mr. Glenn Whitley.
Title: The Microplankton off Southern California

The bulk of the work performed on the above referenced contract is being prepared for publication in book form. A few of the more salient points were presented by the author in a AAAS Symposium held in New York in 1967.

SUMMARY

Introduction

The nearshore marine ecosystem is one in which man has played a dominant role for a long time with some obvious and other more subtle effects. His dominance is exemplified by various types of biological harvests, including the sometimes unfortunate deprivations of biology classes and some nature lovers, by the dredging and filling of embayments, estuaries, and marshes, and by the development of the most ingenious ways of polluting its waters. These activities have had substantial impacts upon the populations of marine species; some have increased in numbers while others have decreased. These we must consider to be the normal behavior patterns of man. The ecosystem as a whole has sometimes absorbed these surges with little obvious change, but in other instances it has reacted rapidly and stabilized at a new level of equilibrium. In all instances known to me, it has adapted to the activities of man, but in so doing the worst

of the derived systems bear little favorable resemblance to the original. Up to now man's impact has emanated from what we might call point sources. What concerns us today, however, is the sobering possibility that his future impact will be applied on such broad fronts and will be so persistent that a more thorough degradation of the ecosystem will be inevitable, with a resultant decrease of species diversity and the ascendancy of thermophilic spoilers and the organo-pollution cloacophiles.

The coastward shifts of the U. S. population, particularly since World War II, are at this very time causing confluence of high-density suburbia into a coastal megalopolis. Already drawing close to reality from Santa Barbara to San Diego, California, the trend is accelerating between Houston and New Orleans, to say nothing of the East Coast of the United States. The demands for more and more electrical power and domestic water registered by these masses will inevitably require the installation of gigantic dual power-desalination plants. On paper at least, the impact of these on the marine environment, if we follow the easy way, will be of such magnitudes as to be beyond the ken of modern day conservationists to stem. The sensitivity of the populace to solid pollutants in air may well rule out the use of fossil fuels in these plants. Thus we are left with the alternative of some added thermal problems

coupled to the use of nuclear generators. If we must assume that such will be the case, let us call now for the laying down of thoughtful ground rules, and let us see to it that only the most imaginative engineers be assigned to fill these needs. As sites for the largest of these plants, let us attempt to rule out streams, rivers, estuaries and bays, and let's be completely heretical and rule out our coastal margins. What do we have left? Offshore islands are a possibility, as at Sunset Beach, California. But better yet, let's put a large part of each below the surface.

The latter suggestion is neither unrealistic nor irresponsible. Initial costs will rise. But against this we must balance the fact that our coasts are finite and nearshore environments have better uses for recreation and visual therapy. The technology is already available, costs can be amortized until eternity, and against these we can balance the fact that below the thermocline we have the best cooling water, less obnoxious biofoulers, and perhaps part of the effluents can be adjusted to cause upwelling that will increase surface productivity and others can be sent into deep circulations that will require tens or hundreds of years before they see the light of day again.

Such things will not eventuate over night. Hence biologists may have to be somewhat more imaginative and resourceful too. Parts of terrestrial United States are populated with imported trees, shrubs, and beasts. Some unfortunate importations have

upset native balances with resultant reductions of local species. But in the case I envisage the destruction will be fait accompli; the substitutions, if properly selected, may improve upon the ecosystem's unmanipulated new steady state.

Let me now give you some conception of the nearshore marine ecosystem as it is today, say, off the coast of southern California.

The General Nature of the Nearshore Marine Ecosystem

The milieu in which the ecosystem functions is comprised of both the bottom or benthic region and the water column or the pelagic region. The term nearshore is indeterminate. Hence we can draw the boundaries of the nearshore marine ecosystem so that the benthic covers the subtidal zone and the pelagic encompasses the neritic zone of the water mass. This would carry us from shore to the intersection of the continental shelf and continental slope. There are good physical, chemical, and biological justifications for using this outer boundary, but the area is just too big. I choose, therefore, to set the outer boundary at, say, 40-50 m depth, which in southern California would be found less than a mile offshore with but few exceptions. Such a boundary includes the outer limit of growth of the kelps, often includes a major part of the very productive rocky bottoms, and is surely the place where man's impact on the marine environment is most notable.

At this point I shall attempt to delineate those physical, chemical, and biological characteristics of the nearshore marine environment

that are most germane to this discussion. Comparative statements are made with off-the-shelf or oceanic regions in mind as our standard. Physically one is impressed by the vertical compression of the ecosystem - things exist in strata, and these are close together. The seasonal thermocline is distinct and shallows as we approach shore. There are characteristic, slow-moving along-the-shore surface currents, and only a few meters below there may be distinct counter currents. Wave induced water movements, including substantial inputs from internal waves and tides, are constant and important to the biological component. Temperature and salinity extrema are noteworthy. And above all, these and other parameters are susceptible to terrestrial influences.

Biologically one is impressed by the fact that the shallow thermocline requires the primary producers, the phytoplankton, to exist in a thin surface layer, often no more than 6 m thick. This means that it is extremely vulnerable to discharge of low-density thermal effluents. Normally these primary producers are much more productive than in the open ocean (on a unit-volume basis). The benthic consumers are also very productive, in part because they either live very close to the photosynthesizers or actually among them where rocky bottoms carry epifaunal species above the thermocline. Another biological feature of note is the fact that higher percentages of both soft-bottom infaunal species and epifaunal species produce pelagic larvae which move aloft above the thermo-

cline to feed on the phytoplankton and small zooplankton. These meroplankters develop rapidly and eventually descend to the bottom, metamorphose and develop into adults of such widely varied animals as sponges, ectoprocts, polychaete worms, clams, snails, and even fishes, to mention but a few. Their existence should be understood by appropriate coastal engineers, for low-density effluents will flood the meroplankter's domain as well as that of the phytoplankton producers - and these juvenile stages are often more sensitive to environmental manipulations than adults of the species. On the other hand, high-density effluents will affect the adults, and we can get these benthic species, including demersal fishes, both coming and going, so to speak. Various experiments presented in the literature demonstrate that some pelagic fishes easily avoid unfavorable effluent fields - indeed some may thrive at the interface - but such may not be true of their larvae. Thus, if the day comes when there are no nearshore retreats for tens or hundreds of miles, the ecosystem will suffer a short circuit.

Perhaps one of the most important messages that I can attempt to convey here is a plea for a change in the common conceptualization of the sea. We can no longer afford to consider it a homogeneous mass that is huge and inviolable. Its weakest link is the nearshore environment. In spite of apparently erratic water movements very near shore, there are definite patterns of water circulation on the shelf. Parts of these currents flow north or south along our

coasts for many miles. And the volumes of water so transported are not so large that they cannot be affected by billions of gallons of effluent discharged ad seriatum into these salty rivers. If discharge points are more closely spaced than required recovery times, cumulative effects will be felt downstream.

ECOSYSTEM FUNCTIONS

We may now discuss in a little greater detail some of the parameters that determine the functioning of the nearshore marine ecosystem. Abiotic materials and physical conditions are as integral a part of the ecosystem as are producers, consumers, and decomposers. Emphasis will be placed on data derived from the nearshore environment of southern California.

Physical Parameters

The nearshore flow of water is southeasterly and is influenced both by wind fields and tidal movements. The speeds involved range from 0.14 to about 0.25 kts. (a knot = ca. 52 cm/sec). From time to time with a deterioration of the East Pacific High a change in the California Current results in a flow of water from the south bringing a general warming. There may be a substantial shift in the pelagic fauna to more tropical species, and some kelps such as

Macrocystis pyrifera and Lqregia australis and others may die out.

Local water movements resulting from the propagation of surface waves or the breaking of internal waves result in high-velocity water movements (up to 2 or more kts.) over irregular bottoms.

The temperature of surface waters near shore range from a winter minimum of 10°C to 25°C in summer. The maximal range is seldom achieved in a single season. Ordinarily the nearshore water is nearly isothermal in December-January with its temperature depending upon prevailing conditions (recently about 14-15°C). Marked thermal stratification occurs from April to September. Below the thermocline, the lowest temperatures occur in May-June and rise thereafter into winter. This phenomenon accentuates the thermocline, and means that the epifauna of rock-reefs rising near the surface have epilimnion species with southern affinities and hypolimnion species with northern affinities.

This marked thermal stratification which occurs at a time when light and temperature conditions are ideal has a limiting effect upon phytoplankton growth because it impedes recharging of surface waters with chemical nutrients. The latter could be facilitated by proper management of thermo-effluent release.

Most nearshore animals are pretty well adapted to rather rapid temperature change but may fail to sustain themselves when extrema

persist for prolonged periods.

Salinities are generally low in the nearshore surface waters, holding near to 33.0 to 33.7%, except during rainy periods when they may drop temporarily to 27% or long dry periods when they may rise above 33.8%. From 5 to 80 m depth at all seasons salinities rise to about 34%. But water of this salinity may fluctuate in depth from 190-200 m in August to as little as 80 m in May-June.

Dissolved oxygen is not a limiting factor to the growth and development of organisms in this nearshore environment. In the upper 50 m it ranges from supersaturation at 8 or more ml/l down to nearsaturation at 2.5 ml/l. A rapid drop occurs at the thermocline, following a similar decline of phytoplankton populations.

Biological Parameters

We shall discuss the distribution of both dissolved and particulate organic carbon in this section because they are so intimately related to biological components of the ecosystem.

Phytoplankton populations (producers) vary widely on both seasonal and daily bases. There is a tendency toward both vernal and autumnal blooms of phytoplankton, but these are less pronounced than in offshore waters because high levels may persist in winter. In fact, it is not unusual to find here that on some days in January phytoplankton counts exceed those found during "low-count" days in

April-May. It is also characteristic of these inshore waters that phytoplankton cell counts drop sharply below depths of 5-8 meters.

It is characteristic also that there is great variability of productivity (carbon fixation) in shallow water and the uniformity at low levels at depths between 10-20 m. Ordinarily rates at 10 m are less than 10% those above 5 m. Nevertheless, the highest rates in nearshore waters tend to be well above those in oceanic regions. Even though our cell counts may not be reflecting all of the smaller flagellates, our ^{14}C curves closely approximate the total-count curves for the producers.

The same is true of both soluble and particulate carbon. Samples for these determinations were filtered from the same large water samples used for plankton counts and rates of carbon synthesis. Here again we see the great reduction of carbon assimilation levels with very slight increases in depth. We observe also that only at exceptional times do we obtain particulate carbon values above those for soluble carbon. We may note, however, that there are substantial increases in soluble carbon during those times that blooms are in process. Particulate carbon suffers rapid reduction as a result of intake by zooplankters. In open tropical seas, Steemann Nielsen suggests that more than 95% of the living algae consumed are eaten in the upper 200 m. The same trend quite evidently holds in nearshore waters, but it is clearly compressed and benthic animals take their toll along with zooplankters.

Tintinnid ciliophora, copepods, meroplankters and a variety of other forms comprise the principal zooplankton in these near-shore waters. This aspect of pelagic life differs greatly from oceanic waters. There are far fewer euphausiids, mysids (especially lophogastrid species) and other types. In fact, as we might expect from depth relations, the so-called mid-water fauna is scarcely represented at all. Here again another level of the trophic structuring of the water column is missing, a fact that is a distinct advantage for the benthic species.

It is no surprise, therefore, that the greatest difference between the nearshore and oceanic biological systems is related to the diversity and production of benthic species. Zenkevitch finds that in the Pacific and Indian Oceans the standing-crop biomass of the nearshore region may be 20,000 times that of the abyss ($1,000 \text{ g/m}^2$ vs. $.050 \text{ mg/m}^2$, probably wet weight). And I believe this ratio to be conservative, in part because it does not in the main reflect the epifauna of hard substrata. Working in the English Channel, Harvey estimated the standing crop biomass of the benthos amounted to 17 g/m^2 of dry organic matter; Sanders found something over twice this level in Long Island Sound. On rocky biotopes in the nearshore ecosystem off southern California I have found on the order of $1,000 \text{ g}$ of dry organic matter per m^2 . The most productive sites are those above the thermocline that have a moderate

degree of water movement. This large standing crop may be distributed among 100 or more species per square meter, but invariably 85% or more of it is accounted for by 5-15 species among which the dominants are invariably suspension-feeders that take both living and nonliving particulate organic matter directly from the water column. These communities appear to be extremely productive, but this can only be estimated when turn over rates are better known.

For example, Cushing estimated the standing stocks in g dry wt/m² in the English Channel to be Phytoplankton, 4; Zooplankton, 1.5; Pelagic fish, 1.8; Benthos, 17; and Demersal fishes 1.13. These figures are of relative interest, but they do not reflect the rates of carbon synthesis by the autotrophs nor the rates of carbon assimilation by the primary, secondary, and other consumers.

The rate of turn over of organic material (or the rate of replacement of biomass) in terms of mean standing crop may be achieved 10s (35-40) of times per year by the phytoplankters. Conditions are somewhat more variable among benthic forms, where we are dealing with a range of size from a few microns (the microbenthos),, through a few tenths of millimeters (the meiobenthos), to the macrobenthos which range from 1 mm to several decimeters. Sanders estimated the production of species living more than a year to be about twice standing crop per year and used a factor of 5 for short-lived species. McIntyre estimates a factor of at least 10 for

the meiobenthos. And although Mare estimates that the microbenthos (ciliates, flagellates, amoeba, bottom diatoms, and bacteria) may have standing crops less than .5% that of the infaunal biomass, the turn over rates are probably very rapid, possibly 30-50 times the standing crop. Thus the carbon assimilation of these smaller forms is way out of proportion to their standing crop. Indeed Zobell suggests that as much as 10 g dry wt. of bacterial substance may be produced daily in a cubic ft. of shallow marine sediment. The important things to be noted here are that the rates of energy flow through various components of the ecosystem are not determinable by visual evidence. For example, in some places the production (assimilation) of the microbenthos may exceed that of the macrobenthos by a factor of 1.5 to 2. If after calculating annual production by correcting standing crop biomass with the turn over rate, one can relate this to rates of carbon fixation by the primary producers, provided some value can be given to the growth (or ecological) efficiency of the species involved. Thus, if the principal producers of the California epifaunal producers have a growth efficiency of 15%, then an annual production of 100 g dry wt. or 50 g carbon would require $333 \text{ g C/m}^2/\text{yr.}$

We must also note that the probable high rates of carbon assimilation by the decomposers on and in the sediments are of prime importance to the welfare of the ecosystem, for from their activities come the return of nutrients to the soluble state in the water column

where they must move into the optimal levels for the basic producers through various mixing processes.

These nearshore marine systems are very productive, and must therefore be preserved intact while we are learning what they can contribute to man's need for foodstuffs in the future.