Man and Aquatic Communities

Seminar Conducted by

WATER RESOURCES RESEARCH INSTITUTE

Oregon State University

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Preface

The correct functioning of aquatic ecosystems is of critical importance if we are to reap the full benefits from our streams: high quality municipal, industrial, and agricultural water supplies; productive fisheries; recreational opportunities; and aesthetic enjoyment. Wastes which enter streams are assimilated to varying degrees by the aquatic life. Hopefully, the rivers, lakes and estuaries will maintain the capacity to support multiple uses. An understanding of the composition and functioning of aquatic life in a body of water will enable us to determine its state of health.

As man's activities increase they tend to dominate the ecosystems. Sometimes changes are brought about which result in imbalances. We need to know more about these changes in order to be able to predict how much can be tolerated before irreversible reactions take place. Research regarding aquatic communities is progressing in natural and artificial streams at many sites. To focus on some of these investigations, a series of weekly seminars was arranged during Spring Quarter on Oregon State University campus.

All presentations were open to the general public, faculty members, and students. Representatives of some federal and state agencies were in attendance. The lectures are reproduced in this volume. Unfortunately, we cannot include the spirited debate which marked many of the seminars.

Robert M. Alexander
Director

Corvallis, Oregon
July 1970

The Institute

The Water Resources Research Institute was established at Oregon State University in 1960 by the State Board of Higher Education. It is designed to foster, encourage, and facilitate research and education related to all factors which affect the quantity and quality of water available for beneficial use. Membership includes personnel on campus who are engaged in water resources research and teaching, as well as those from other institutions of higher learning in the state who participate in the Institute's program.

Staff members provide both classroom and research instruction, and a graduate minor in water resources may be pursued by students majoring in one of numerous departments. At present, there are about 200 graduate students engaged in water-oriented programs in approximately 20 member departments.

Extensive facilities are available for both faculty and students. These include forested watershed lands and associated field equipment, soils laboratories, growth chambers, water and waste treatment plants, experimental waste treatment facilities, freshwater and marine science laboratories, experimental streams, a computing center, a hydraulics laboratory, a radiation center, and technical libraries.

Research assistantships and fellowships are available through many of the member departments. The Institute provides support for selected portions of the research and training program in water resources in Oregon. It works very closely with individuals and organizations off campus in helping to solve the state's water problems.

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Presented April 2, 1970 by DR. CHARLES E. WARREN, Department of Fisheries and Wildlife, Oregon State University.

Man and Aquatic Communities: A General Introduction

The basic theme of my discussion this afternoon will center around two problems in the philosophical, scientific, and practical affairs of men: the problem of wholes and parts and the problem of questions. This may seem a strange theme to take for an introduction to a series of seminars on "Man and Aquatic Communities." I do so for two reasons: in his resource and environmental management, man is now being plagued with these two problems; and studies of aquatic communities have been hindered too much by both of these problems.

The problem of wholes and parts derives from the universal fact that any system as a whole is more than the sum of its parts as they would operate separately. Aristotle recognized this when he wrote of a "single indivisible principle of unity." And in the twentieth century there have been at least two eloquent statements of this problem.

Alfred North Whitehead (1925) developed his theory of organic mechanism and applied it to the electron moving along a predetermined path, to the individual organism as a whole, and to the universe. He provided the philosophical basis for our idea of superorganism, so important in the community concept and in the idea of ecosystem. D'Arcy Wentworth Thompson (1942) wrote: "As we analyze a thing into its parts or into its properties, we tend to magnify these, to exaggerate their apparent independence, and to hide from ourselves (at least for a time) the essential integrity and individuality of the composite whole... We may study them apart, but it is as a concession to our weakness and to the narrow outlook of our minds."

But neither of these men in his own work showed the slightest tendency to ignore the importance of knowledge of parts in understanding wholes. I believe George Bartholomew (1964), in commenting on biology, has provided a useful statement on the problem of wholes and parts. He observed that a number of levels of organization can be recognized in any system. And, he suggested that each finds its explanation of mechanism in the preceding level and its significance in the succeeding level.

The asking of questions is the beginning of philosophical, scientific, and practical thought. The carefully formulated question is one of the most powerful and useful tools that man possesses for resolving problems. A carefully formulated question can define a problem and suggest the knowledge necessary for its solution. A poor question does not define a problem and may mislead and waste human effort. It can be said that there are big and little questions. Fred Hoyle has somewhere stated that only the very young and the very naive ask big questions; the remainder end frustrated. And Kenneth Boulding has facetiously suggested science to be the process of substituting unimportant questions we can answer for important ones we cannot.

It was only with the revolution in scientific thought beginning with Galileo that philosophy was separated into moral philosophy and natural philosophy, our natural science of today. Only then did the limited possibilities of science begin to be recognized; only then did the limited question come into general use and the rapid growth of scientific knowledge begin.

SOME ARE PHANTOM PROBLEMS

Now, what questions are big or little, what questions are important or unimportant, what questions can or cannot be answered are relative matters. They change through time with changes in the knowledge, needs, and thinking of men. Of course we should ask important questions, general as well as specific ones. But the purpose of a question is to advance our knowledge. It should conceivably have an answer. Too many are questions from the intellectual pretender.

Ecology is plagued with this today. I suspect other areas of human knowledge are also. I wonder how many of the questions today being asked about man and his environment are too big or unanswerable. A few such questions are obviously unavoidable; too many may dangerously impede our progress toward answers we need.

Max Planck (1949), in his scientific autobiography, considered some problems to be phantom problems, either because there is no indisputable method for their solution or because, considered in the cold light of reason, they are found to be devoid of all meaning. Do some of our questions about man and his environment fall into this category? What is the optimal environment for man? What is optimal use of land and water? If these are not phantom problems, I suggest they are dangerously near to being so.

Now we get to aquatic communities. What have they to do with the problem of wholes and parts? The community concept and the closely related concept of ecosystem are two of the important contributions of biology to man's thinking --- philosophical, scientific, and practical. The idea of the plant community can be traced in the writings of botanists over a period of 200 years, the animal community in the zoological literature for about 100 years. But it was perhaps not until Stephen Forbes (1887) wrote his paper on "The Lake as a Microcosm" or earlier, Karl Mobius (1877) wrote about an oyster-bank as a biocönose, or a social community, that the concept of the biological community of plants and animals began to take definite form. And not until this century has it been much used.

Biological communities, including aquatic ones, develop at locations having suitable physical and chemical conditions and resources where colonization by different species of plants and animals is possible. If conditions at such a location are not too variable, an assemblage of plant and animal species having many interrelationships among themselves and with the conditions and resources of the location will develop. This assemblage will have rather definite characteristics and can be considered a biological community.

Each species is a part of such a community and plays a role in the functioning of the whole. Tansley (1935) suggested that a biological community together with the physical and chemical conditions and resources of its location be called an ecosystem, a term that has now come into broad usage. More than others, Raymond Lindeman (1942), with publication of his classic "The Trophic-Dynamic Aspect of Ecology," stimulated ecologists to study ecosystems as wholes, particularly in regard to energy and material transfer in these systems.

But with admirable interest in the wholes of such complex systems, some ecologists have shown a deplorable carelessness with knowledge of the parts of the systems. This has led to spurious theory and bad science in an area of human knowledge that has become important to all of us.

COMMUNITIES ARE SENSITIVE

Why are aquatic communities important to man? Because certain species that are a part of them, that depend upon them, are of recreational or commercial importance. Because they can cause nuisance problems such as those experienced with taste and odor in water supplies. Because they work to maintain the quality of water. And because they have a beauty of their own and are an important part of the world in which we live.

Aquatic communities are terribly sensitive to many of the activities of man --- activities not directed toward the management of particular species or communities, though, of course, management activities profoundly influence species. Aquatic communities must be protected from destruction before positive management can yield results. This kind of protection is not necessarily a wilderness concept. It is that management focused only on a particular species is often ineffectual. Certainly the persistence of its biological community must be insured. And when we manage a particular aquatic species, we must take into account its dependence on its community and its role in that community. In managing certain species, we may be affecting others in undesirable ways.

Almost any change in water quality will bring some change in aquatic communities. Almost any use of water or change in land use will affect water quality. For most waters perhaps we must accept some change. The question is "how much?" This depends on what society decides, hopefully wisely, will in the long run be the most desirable ways in which to use particular waters.

This must be determined, insofar as possible, for whole systems including not only the biological communities involved but also man's use of these communities and of the water for agriculture, power, navigation, industry and municipalities. In managing aquatic communities, we must go beyond the waters to where and how we live and work.

We can accept as fact that there is a population and environmental crisis of some magnitude. There is considerable question, however, as to what its dimensions really are. They are probably being overstated; to create awareness, this may be necessary. But in the present atmosphere, the hurry for answers may cause thoughtful people to doubt and retire, and too many false prophets may come forward. Realistic definition of our problems and orderly progress in their solution may be impeded.

Ecologists and social scientists have not been too successful in predicting the outcome of events in complex systems. Historical information is of value in prediction, but as conditions change it is not an adequate basis for accurate prediction. In complex systems, the only satisfactory basis for prediction is understanding their operation --- knowing how the parts relate to the whole. If we are to deal with complex systems, we need people who can analyze them.

What are these systems and who are these people? If it is an aquatic system, we probably need aquatic ecologists. We also need others able to evaluate social and technological factors impinging on the aquatic system. We need all kinds of relevant knowledge, which we usually do not now have. Into the gap comes the systems analyst, who does not know the relevant information but hopes to put together what he thinks others know.

DIFFERENT TYPES OF MODELS

We have some biological models and some social models. How do they relate? First, they are not very good. Second, the interfaces between biological and social models are poorly understood. We all use models in our every day thinking, in our planning, and in our research. This is necessary. They put our thoughts in order and give us a way of thinking, sometimes even advancing it a little. But, I am concerned with the more elaborate models of the systems analyst. These are sometimes grouped into two kinds: associational models and causal models. In biology, I think of the former as being only descriptive, the latter as being biological.

Descriptive models to me are those that only mathematically describe existing data and in which constants and variables have no biological meaning. Biological models are those based on known biological relationships, and their constants and variables have demonstrable biological meaning. Descriptive models have predictive value only so long as conditions do not change. Biological models should have predictive value in the face of changing conditions.

To develop a biological model of the growth of an individual plant or animal would seem a simple problem in relation to the objectives of some models now being developed. Some of the best minds in twentieth century biology have failed to develop more than descriptive models of growth. We should be trying to model. For social and biological systems, however, modeling is more an area of research than it is a management tool to produce quick answers. We should not expect too much of models until we really understand what we are putting into them. This involves both the problem of wholes and parts and the problem of questions.

Man now faces environmental problems ---land, air, and water ---of unknown dimensions. He has always faced environmental problems and he always will. His success as an animal indicates that in the past he has found solutions. I believe he will continue to do so. But I am troubled by the ways in which these problems are now being presented. We need awareness. We do not need hysteria.

All man's knowledge is relevant in the solution of his problems. Once the real questions are identified, we can then proceed with the analysis of the parts of systems and their operation within the wholes. But it seems almost characteristic of man that when he is concerned about a problem he believes his particular knowledge to be not only relevant but the most relevant to solution of that problem.

It might be well for ecologists, social scientists, systems analysts, and others to bear in mind that their present popularity rests on the nature of man's problems---not on their past successes in solving problems. They should also bear in mind that their particular knowledge represents only part of the needed knowledge.

And, finally, I would point out that it is one thing for us to believe or even to know we have a problem; it is another thing altogether to learn the solution to the problem. Then, we all must face the question of whether or not man has the wisdom to apply known solutions to his most encompassing problems.

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Presented April 9, 1970 by CHARLES F. POWERS, National Eutrophication Research Program, Pacific Northwest Water Laboratory, Federal Water Quality Administration, Corvallis, Oregon.

Eutrophication of Lakes

The aging of a lake is a natural process. In this sense it is much like a human being: a lake is born, grows old, and, in many cases, dies. It is this maturation process of a lake that is called eutrophication, and it leads to some of the most serious water quality problems we face today.

Lakes are formed, or born, in a number of ways. In the United States the great majority of lakes were brought into being by the continental glaciers. The many lakes of the upper midwest, for example, are Pleistocene in origin. Many of these lakes are so-called "ice block" lakes, created by masses of ice which formed depressions in the earth that eventually filled with melt water. Lakes are also formed by landslides, cut-off bends of rivers (oxbows), in craters of extinct volcanoes, and other means, but most of the natural lakes which concern us are glacial.

A newly-formed glacial lake is of the type known as oligotrophic; the name derives from the Greek and means essentially "poorly nourished." The young lake is poorly nourished because the concentrations of dissolved nutrient materials in its waters are low.

There has not yet been time for such materials as phosphorus, nitrogen, carbon, and so forth, essential to the production of biological material, to be carried in from the surrounding watershed. Algal growths in oligotrophic lakes are small; the algae that do occur are the single-celled diatoms which do not form objectionable nuisance blooms. Since production is low, there is relatively little particulate matter in suspension and the water is normally of a high degree of transparency.

Also, because there is little plant and animal respiration in such a lake, the water is well oxygenated at all depths in all seasons of the year. The fish populations of oligotrophic lakes are made up of cold-water forms - trout, salmon, whitefish, and the like, which require low temperatures and high oxygen levels.

An oligotrophic lake, then, is a lake containing high quality water and is suited to a variety of uses; it is a good multi-purpose lake.

NUTRIENTS AND PRODUCTION

Under natural conditions nutrients will be added to the lake through runoff and leaching from the soils and rocks of the surrounding drainage basin. The result is increased concentration of minerals and other materials essential to the production of plant material, principally algal forms. Progressive nutrient buildup is accompanied by increased species diversity of the phytoplankton and increase in the total algal biomass.

As eutrophication proceeds, however, diversity will decrease and the flora will tend to be dominated by a few species of green and blue-green algae, with the blue-greens in particular appearing in nuisance masses. Such genera as *Aphanizomenon*, *Anabena*, and *Microcystis* become common.

The progressive enrichment and increased biological production of the lake are accompanied by a gradual filling in of the lake basin by inflowing sediment and by the remains of weeds, algae, and other organisms. This decrease in depth leads to an increase in average lake temperature. The warmer waters, coupled with the greatly increased oxygen demand resulting from bacterial breakdown of decaying organic matter and the respiration of increased numbers of other organisms, result in deficits of dissolved oxygen in the deeper waters, especially in the summer and early fall months.

The lake, then, gradually changes, through natural aging, from a deep, clear, cold, well-oxygenated body of low productivity to a relatively shallow, warm, turbid, highly productive lake whose water is of greatly decreased quality and of limited usability. The lake has evolved from an oligotrophic to a *eutrophic* situation. Eutrophic, also from the Greek, means "well-nourished." Such a lake will no longer support the oligotrophic cold water fauna. Trout, whitefish, and like forms will have disappeared, to be replaced by "warm water" forms.

In many cases, where the nutrient supply from the drainage basin is adequate, eutrophication may continue until the lake is completely filled in, and natural succession will result in the establishment of purely terrestrial conditions.

Many of our Pleistocene lakes are still in a condition of oligotrophy. These are lakes in which the accumulation of nutrients has proceeded very slowly, either because the lakes are large and deep, the surrounding land is poor in nutrients, the drainage basin is quite small, or a combination of such factors.

Large numbers of lakes, however, have eutrophied to various degrees. This may be due principally to naturally fertile drainage basins, or, relatively recently, to induced fertility associated with increased human population.

THE ROLE OF MAN

The role of man in the eutrophication process has been recognized by limnologists for some time, and in recent years has received a great deal of attention. Human waste disposal may greatly increase the rate of flow of nutrients into lakes and thereby profoundly affect the eutrophication process. This phenomenon is usually referred to as accelerated or "cultural" eutrophication. Conventionally treated, as well as untreated, human wastes contain large amounts of algal growth stimulants, and many lakes receiving such effluents are currently exhibiting symptoms of rapidly increased deterioration. Massive algal blooms are one of the most serious and objectionable of these symptoms.

The classical view of the eutrophication process has been that it is an inevitable, irreversible process that, having advanced to any given stage, becomes a condition that may at best be slowed down but can neither be stopped nor reversed. Recent research, however, has modified this viewpoint and has resulted in increased optimism as to the possibilities of not only halting the deterioration of lakes, but even restoring at least some to their earlier, less eutrophic states.

It is evident now that, under natural conditions, the nutrient supply from the soils and rocks of the drainage basin will not necessarily continue unabated (continued leaching and erosion depletes the supply), and the lake may actually, after achieving its peak of eutrophy, become less productive with continued time as the nutrients are washed out or otherwise removed from circulation.

In addition, evidence now indicates that the large quantities of nutrients commonly found in the sediments of lakes are not constantly recycled and that there is, with time, a gradual net loss of nutrients to the sediments as they are progressively covered up. The bulk of the evidence, then, is that if we can significantly decrease the nutrient supply, we have a fighting chance of restoring the lake to at least some semblance of its former condition.

PRACTICAL RESEARCH APPROACHES

The National Eutrophication Research Program (NERP) of the Federal Water Quality Administration has the responsibility for conducting research directed toward halting and preventing eutrophication of our waters. The National headquarters for these research activities is located in the Pacific Northwest Water Laboratory at Corvallis, Oregon.

Both preventive and remedial procedures are being investigated and developed. In considering avenues of approach, four general possibilities present themselves: (1) Ecological Control; (2) Mechanical Control; (3) Chemical Control; and (4) Biological Control. Of these possibilities ecological control represents methods which are more preventive, while the others represent methods which are either remedial or palliative.

The major emphasis, therefore, is on ecological control with the prime objective to keep the water environment at a preferred low level of fertility and production. This method is less likely than the other approaches to destroy those conditions which are desirable and is likely to have more lasting effects.

The most obvious approach to ecological control is to prevent or decrease the nutrient input to the water. Most of the nutrient input comes from municipal sewage, urban and rural runoff, soil erosion, agricultural activities, industries, and precipitation. Nutrient control can often be accomplished by diversion of nutrient-containing waters, especially sewage effluents, away from the lake.

Another method, of course, is to strip sewage effluents of their nutrients, especially nitrogen and phosphorus, by tertiary treatment processes. For the past two years NERP has operated a pilot scale chemical tertiary treatment plant at Ely, Minnesota, on the shores of Shagawa Lake. This 2-1/2 square mile lake receives treated sewage from the city and this sewage accounts for 80% of all phosphorus entering the lake.

Experience with the pilot plant has shown that removal of this phosphorus from the municipal effluent should result in control of nuisance algal conditions which occur in the lake. It is, therefore, planned to initiate a full-scale treatment program. Details in the pattern of recovery of the lake as it responds to phosphorus starvation will then be studied closely.

Such knowledge will form the basis for predicting how other lakes will respond to similar control programs. Facts on eutrophication of Shagawa Lake will be incorporated into a mathematical model in order to predict the pattern of recovery.

After a lake has accumulated large amounts of nutrients, curtailing further input may not in itself be sufficient to improve or restore the lake to an acceptable condition, particularly if dilution by flow-through is small. NERP, therefore, is developing and evaluating techniques for either removing or rendering unavailable nutrients for algal and aquatic weed growth. Several possibilities are under study: (1) harvesting of algae; (2) harvesting of water weeds; (3) dredging out nutrient-rich sediments; and (4) nutrient inactivation.

A NUMBER OF PROJECTS

Present methods for harvesting algae are generally inefficient and costly. Present efforts are supported entirely by grants and contracts, and are aimed at developing efficient harvesting equipment and identifying chemical components of blue-green algae that may be useful as pharacenticals.

At Detroit Lakes, Minnesota, a project is underway to determine the quantity of nutrients that can be removed from a lake through mechanical harvesting of rooted aquatic plants. Baseline data are being gathered on the ecology of the lake and its tributaries. This will permit an assessment of eutrophication reversal when the actual harvesting is initiated this summer. Mathematical modeling will also be employed in predicting and establishing the rate and extent of lake improvement.

As mentioned earlier, substantial quantities of nutrients are tied up in lake sediments. This potential source of nutrients may be of particular importance in shallow, non-stratifying lakes. This may be true in shallow, eutrophic Upper Klamath Lake, for example, where our studies indicate that agitation of the sediment by waves and currents causes transfer of nutrients to the overlying water with resulting stimulation of algal growth. The sediment-water interchange problem is being approached along three lines: (1) learning the fundamental nature of the recycling mechanism; (2) developing procedures to prevent recycling; and (3) dredging out sediments.

Results of laboratory studies at Corvallis suggest that chemical treatment of a eutrophic lake with rare earths or aluminum compounds will precipitate out nutrients and slow down their recycling from the sediments. Candidate lakes are now being selected for full-scale nutrient inactivation and dredging studies and actual treatment will proceed when funds are available.

The annual temperature-chemical cycle which takes place in lakes and reservoirs due to seasonal climatic variation greatly affects the characteristics of the water. Algae tend to proliferate in the warmer upper layers and eventually die, sink to the bottom, and decay, thus creating a high oxygen demand there. The dissolved oxygen is depleted and, if the lake is in a stratified condition, there is no replenishment of oxygen in the bottom waters, or hypolimnion.

Experimental destratification by aeration in a small pond near Corvallis this past summer virtually eliminated this condition. Further, the usual crop of blue-green algae did not appear. Aeration is a promising tool in the fight to rehabilitate lakes.

Personnel at our Corvallis laboratory are also looking into the significance of rain and snow as sources of nutrients. Analyses of samples collected in and around Oregon show that they frequently contain sufficient nitrogen, phosphorus and micro-nutrients to stimulate algal growth.

The use of bioassay procedures for detecting increased enrichment in the aquatic environment holds considerable promise. In many cases these bioassays appear to be more sensitive than chemical determinations. Such assays, however, would have much more value with respect to comparing data among laboratories and geographic areas if they were standardized. NERP, with industry and university cooperation, is working to develop these vitally needed standard procedures to assay algal growth possibilities in waters of various kinds.

It should be pointed out that work on these various areas of research, sponsored by FWQA grants and contracts, is being carried on at universities and other research centers throughout the country. These extramural investigations constitute a most critical portion of the overall NERP program, and permit studies of many facets of eutrophication-related phenomena which otherwise could not be pursued.

SUMMARY

Most lakes appear to experience a physiological aging process known as eutrophication.

Essentially, this process comprises increased nutrient concentration and consequent increased biological production. Newly-formed lakes, or lakes situated in non-fertile locations, are poor in dissolved nutrients and relatively unproductive, and are known as oligotrophic lakes. With time, gradual enrichment from the watershed may result in production of large quantities of organic matter, especially undesirable algae; oxygen deficits; and a gradual filling-in of the lake.

The change is therefore from oligotrophic to eutrophic. The introduction of the effluents of human populations may greatly increase the eutrophication rate, and the quality of many lakes has been seriously impaired through this accelerated or "cultural" eutrophication.

The research activities of the National Eutrophication Research Program are aimed at the development of methods for the control and alleviation of accelerated eutrophication and include both applied and fundamental studies. The more applied investigations relate to the limitation and removal of plant nutrients, and to the elimination and control of algae and waterweeds.

The applied investigations are supported by more fundamental studies relating to the metabolism and the physiological requirements of algae and other aquatics associated with eutrophic conditions as well as to the development and evaluation of assay procedures for detecting increased enrichment and predicting its effects on the aquatic environment.

Presented April 16, 1970 by DONALD E. GILES, Oregon State University, Marine Science Center, Newport, Oregon.

Rational Utilization of Oregon Rocky Shores

The edge of the sea has fascinated man since earliest times. He used the margin to find a source of food primarily, and many of his gods were to be found in the sea. When man became "civilized" and developed governments, these governments became interested in the edge of the sea as defensive barriers against marauding enemies or as passageways to trade with other units of society. In some areas rulers robes were dyed with chemicals extracted from certain snails inhabiting the coastal areas.

We have an early account of Alexander the Great being outfitted with a primitive bell-type helmet walking on the floor of the Aegean Sea under the watchful tutelage of his mentor Aristotle. Why man is drawn to the sea has been the subject of philosophers, poets and physiologists. That he is drawn to the sea today is the concern of land developers, ecologists and citizens.

While uses of coastal zones have been the subject of many studies, we will concentrate on that area we identify as the rocky intertidal. Along the Oregon shore there are many areas of basaltic rocks jutting out into the ocean where life abounds in beautifully complex communities. This type of coast may be less desirable in the eyes of some exploitors but it is certainly receiving a considerable amount of use. Indeed, a growing body of evidence indicates that, in some areas at least, the proper term is misuse. When there are broad stretches of sandy beaches for strolling, swimming, surf fishing, sun bathing, hunting for agates and Japanese glass floats, picnicking, and watching sunsets, why are rocky shores receiving so much attention?

Rocky shores are the habitat of a variety of macroscopic animal and plant life occuring in numbers probably unequaled in any other part of the planet. A few years ago a student of mine, as part of a class project, took a 100 cubic inch sample from a mussel bed, placed it in a bucket and returned to the laboratory to count all macroscopic animals. He found 7,863 individuals representing 18 species and 6 phyla. Because of the phenomenon of tides this life is uncovered, more or less, twice a day.

FIELD TRIPS TO EDUCATE

Increasing human population, shortened work weeks, and increased mobility, popularity of "environmental awareness", all contribute to greater numbers of people examining the magnificent beauty available to the human eye at low tide in a rocky shore area. The word "oceanography" has captured the imaginations of our citizens including school teachers and their students. The edge of the sea is most accessible to them and field trips are being taken by an ever increasing number of groups and individuals. In too many places the result of this increased utilization of the environment has resulted in the modification of that environment from a veritable jungle to that of a desert.

Let it be clearly understood, however, that in Oregon in 1970 we do not have as serious a problem as found on certain beaches of our neighbor to the south, California.

Excluding the values of getting away from the classroom and going on a picnic what can be derived from a field trip to the intertidal by an organized school group? The most obvious aspect of this region is the numerous species which exist giving the student a broad spectrum of the biotic world. Living creatures on this planet exist in populations and communities in an organized fashion. Admittedly communities are complex, but at few (if any) places can this organization or stratification of life be better illustrated than in a twelve foot verticle strip of basalt along the Oregon coast. Teachers whose background have been textbook oriented have told me such trips increase their understanding of the real biological world.

Organisms living in different environments have to solve similar problems and the solutions to each of these problems are varied. Students may investigate adaptations by life on the shore to the following requirements: 1) resisting the actions of waves -- look at several algal solutions, compare to mussels or sea urchins, or rock oysters or kelp worms; 2) resisting dessication -- compare the mussel method with that of a limpet or barnacles, or starfish or sea anemones; 3) heat and cold resistance -- look at the shells of mussels exposed on the southwest sides of rocks compared to shady exposure on the northeast sides of rocks; 4) obtaining food -- look for the paths of limpets, open a mussel or starfish and observe how they may feed, look at the underside of a sea urchin, take a kelp worm and gently pinch its head area; 5) exchanging respiratory gases -- look again at the inside of a mussel or the plumed end of a tube worm and compare this to a rubber worm or a sea anemone or a sea urchin or starfish.

Teachers often talk about genetic variability. At the shore a survey of snails of the genus Thais will illustrate this text book material most vividly. Look at a mussel bed; again genetic variability of the mussels is quite apparent. Our most common starfish, Pisaster ochraceous, is another organism demonstrating this biological concept.

Whenever one goes to the shore he is certain to run into areas that have been denuded because of wave action or boulders crashing against the rocks or some other physical phenomenon and he can observe recruitment or community succession. If in the middle of a mussel bed there is a bare spot what kinds of organisms are beginning to inhabit that apparent bare spot? These kinds of examples could go on over many paragraphs. What can be done by a field trip to the coast is really limited only by the imagination and/or experience of the field trip leader.

Man is a predator here. The prey species, that is the flora and the fauna, will make a recovery if given the opportunity. It is generally recognized that it may take between 5 and 10 years for a decimated area to return to a semblance of the less-disturbed status. But usually it does occur, all other things being equal. Of course there are certain organisms which require much longer to recover. As an example, our common turban snail may take 25 years to reach a diameter of one inch and a half. These snails generally inhabit the high tide areas of the beach and are rather conspicuous making them easy picking for the casual beach visitor - easy to slip into one's pocket. By doing so we may be destroying 25 years of growing.

Removal of life forms by people through ignorance, non-thinking or vandalism destroys the community and disorders energy cycles. Wesley Marks reports some observations by Dr. Gilbert Bane, formerly of the University of California at Ervine, of a college science class using the intertidal to collect class specimens.

After the class left Dr. Bane and his students counted the remaining casualties: 1,175 purple sea urchins, 118 common starfish, 27 wooly sculpins, 21 shrimp, 16 octopuses, 11 cling fish, 9 blennies, 8 bat stars, 8 red sea urchins, 4 crabs and 2 opal eyes. Plastic buckets have been the vehicles of death of many of our rocky shores. The mere act of a thousand pairs of feet walking across a sea urchin bed can wipe out years of growing up by sea urchins. On Duxbury Reef near Bolinas, California it has been found that hunters of rock oysters or piddocks on the average reduce the reef level about one foot every time he goes after these organisms. This kind of activity is certain to destroy the narrow band of habitat necessary for piddock life.

REGULATIONS ARE IN EFFECT

Almost everyone is aware that food animals along the shore are regulated by state agencies. Bag limits are set by the Fish Commission of Oregon after study of their life habits by biologists. Few of our citizens are aware that in the Oregon Administrative Rules, chapter 625, section 10-670 through 10-740, regulations are set forth for the harvest of non-food intertidal animals.

It is unlawful to take any intertidal non-food animals between Cape Foulweather and Devils Punch Bowl. There are seven coastal areas where a permit from the Fish Commission is required before intertidal non-food animals may be harvested. These are Boiler Bay, Depoe Bay, Yaquina Head, Neptune State Park, Sunset State Park, Cape Arago State Park, and Harris Beach State Park. The regulations state that in all other intertidal areas a bag limit of 10 animals per day is allowed.

Illegal activities in these areas are very difficult to spot. However, the Oregon State Police are training their coastal game officers in the regulations and enforcement is intensifying.

The Oregon Marine Science Education Advisory Council is attempting to foster better use of the rocky shore in several ways. We have produced a guide to rocky beach sites on the Oregon coast. We have noted that there are three beaches traditionally used by visitation groups. These are Boiler Bay, Yaquina Head and Cape Arago. Our guide names thirty-four possible sites for field trips.

In addition to those beaches mentioned above as being over used we include the following: Ecola Point, Haystack Rock, Arch Cape, Bar View, Cape Meares (south side) ocean side, Cape Lookout, Cape Kiwanda, Roads End, Depoe Bay, Shell Cove, Seal Rock, Yachats State Park, Cape Perpetua, Neptune State Park, Bob Creek to Bay Point, Fossil Point, Sunset Bay State Park, Five Mile Point, Coquille Point, Cape Blanco, north of Humbug Mountain State Park, Humbug Mountain State Park, Samuel Boardman Wayside (north), Lone Ranch State Park, North of Harris Beach, and Mill Beach.

We have also produced guidelines for conducting a rocky intertidal field trip. Included in these are suggestions for the type of preparations a group should have before venturing into the field. We have suggestions for activities to get the most valuable educational experience possible while actually on the rocky sites, and we include a section of some follow up procedures back at the home base. The guide to the rocky beaches and the guidelines for field trip activities have been widely distributed to teachers throughout the state of Oregon.

We are trying to activate the program of field trip coordination through our office at OSU's Marine Science Center. If the program gets going, group leaders planning field trips will contact the Center giving us the date and place they intend to visit with numbers of people going on the trip. We will then plot this on a master calendar. If we find, for example, that four or five large groups are planning to visit Yaquina Head at a given low tide we will inform the last group writing of the crowded conditions and offer suggestions of alternative sites. We do not intend to dictate to people when or where field trips are to be taken. Our intention is to encourage proper use of the environment -- proper both biologically and educationally.

Rocky shores are rewarding to visit. If we wish to use them for these purposes that they best fulfill, we must walk lightly now.

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This and the following two presentations were made on April 23, 1970 by three staff members from Weyerhaeuser Company, Longview, Washington. EUGENE P. HAYDU, author of the paper below, is Manager, Air and Water Quality Research.

One Industrial Firm and Aquatic Life

The original title of this seminar, "Relationships between the Lumber Industry and Aquatic Life," was somewhat misleading. While timber is the basic resource for Weyerhaeuser Company it supports a great variety of manufacturing operations and products other than lumber. Each of these operations has, to some extent, some effect on receiving water quality or on aquatic life. I will attempt to identify some of the existing or potential aquatic environmental problems associated with each of the major operating units and how we try to cope with them. Concerning the latter, I believe it may be helpful to briefly describe what organizational structures are in existence at Weyerhaeuser for implementing these efforts.

I will also describe the functions of our corporate environmental quality research team. In view of the magnitude of our research efforts in dealing with aquatic biology, I have asked Bob Herrmann and Rudy Thut to describe each of their areas of study. Bob will discuss his oyster ecology investigations at Grays Harbor and Rudy will talk about our experimental stream studies at the company's St. Helens tree farm in Washington State.

All of the company's corporate efforts having to do with the social, political, legal, and technical aspects of environmental quality are coordinated. Each company pulp and paper mill maintains a technical staff consisting of at least one professional (biologist, chemist, or sanitary engineer) and two or more lab technicians. This staff characterizes and monitors the liquid wastes and their effects on the quality of the receiving waters. In addition, they are responsible for the proper operation and performance of the various waste treatment facilities.

The company has also established environmental protection committees at nine of the operating mills. The purpose of these committees is to inform, educate, or merely discuss with operating personnel the nature and significance of their pollution problems, and to encourage them to seek means of abatement or prevention. There is also a corporate environmental protection advisory committee, consisting of representatives from all important segments of the company.

The function of the corporate committee is to inform members of the company's environmental problems and concerns, and to disseminate such information to their constituents. This committee also assists top management in making various recommendations including the formulation of company policy dealing with environmental matters.

I would now like to discuss the structure, the function, and the activities of our corporate environmental quality research department. The team consists of five professionals and four lab technicians. The specialties represented include two fisheries biologists, a limnologist, an analytical chemist, and an air pollution specialist. Some of the major functions and activities performed by our group are as follows:

1) Serve as clearing house for water quality and waste monitoring data.

2) Coordinate consulting and outside research activities.

3) Maintain awareness of technological developments in and out of the company.

4) Provide technical services:
   a) Waste treatment problems and needs.
   b) Receiving water quality and biological problems.
   c) Sample and analyze wastes.
   d) Instruct operating mill personnel on testing and analytical techniques.
   e) Set up biolgical and water quality surveys for operating mills and evaluate results.

5) Evaluate new mill sites to anticipate the impact of their operations on the environment.

6) Conduct research:
   a) Ecological monitoring, e.g., Grays Harbor.
   b) Experimental streams.

7) Determine biological and water quality effects of forestry chemical applications as well as other forestry practices in the high yield forestry programs.

8) Participate in activities related to regulatory agencies, professional societies, and educational institutions.

The following are some of the real or potential water related problems which we have identified in each of the major operating units of the company. Some of the activities related to the Timberlands Division which can or do have an impact on receiving water quality and on aquatic life are as follows:

1) Road Building (on company tree farms) if not properly done can result in siltation.

2) Logging Practices - the manner in which trees are cut and removed can also have significant hydrologic effects such as siltation, temperature changes, stream flow, log jams, debris, and chemical changes. It is interesting to note that Weyerhaeuser Company and the Washington Departments of Fisheries and Game have entered into a trial agreement to determine best logging practices, including road building, according to specific areas prior to harvesting. If this arrangement works it could well set a precedent for all future logging operations which can have a significant impact on reducing adverse effects on water quality.

3) Forestry Chemical Applications - use of fertilizers, herbicides, insecticides, chemical carriers, etc. These materials have to be applied with great care to prevent or minimize possible harmful effects on water quality and aquatic life. For example, we are investigating different methods of applying the fertilizer urea and under different soil and topographical conditions, and evaluating the effects on nearby streams.

4) Avoidance of Accidental Spills - by proper storage practices of oil and other chemicals in the various tree farms.

5) Watershed and Fisheries Management - it is quite possible that at some future time the company will become involved in watershed and fisheries management.

The following are some of the water related areas of concern associated with the pulp and paper division of the company. The biggest problem with pulp and paper liquid wastes is, of course, the tremendous volume involved. Accordingly, much of our work for the pulp and paper mills is related in some way to their liquid wastes.

1) Characterization of Effluents - Here we are concerned with the sources and volumes of various effluent streams, and with their physical and chemical characteristics. Examples of the latter are pH, BOD, and color and suspended solids.

2) Waste Treatment Needs - All of the company's pulp and paper mills have some form of waste treatment and most have both primary and secondary treatment. Primary treatment results in suspended solids removal and secondary treatment results in BOD reduction.

3) Effects of Mill Effluents on Receiving Waters - The degree to which pulp mill effluents affect water quality depends, among other things, on the efficiency of the operation of the mill, the degree to which the effluents are treated, and the amount of dilution available in the receiving water. Some of the water quality criteria most affected are dissolved oxygen, pH, and turbidity. Each mill conducts routine water quality surveys during the critical parts of the year, usually in the summer and early fall. Biological surveys of some kind are also conducted either by the mills' technical staff or by contract with a local university.

4) New Mill Site Evaluations - This activity requires considerable effort from our group. With the passage of time, suitable mill sites are becoming more difficult to locate. Among many factors to be considered there must be an ample supply of water for process use and for waste disposal. We are concerned primarily with the latter. We must take into account the various uses to which the receiving water is being put and what impact our wastes will have on such uses.

   Fortunately we have accumulated considerable information about pulp mill wastes and their effects on water quality. Most of our effort is therefore directed towards acquiring as much background information as possible on the quality and quantity of the receiving water. This involves establishing water quality and assimilation capacity studies.

   Generally we arrange for such work to be conducted by the environmental engineering department of a local state university. We also arrange, when possible, for fish population studies by the State Department of Fisheries and for benthological and planktonic studies by some appropriate department of a local university.

All of this information is developed as background knowledge prior to mill construction. Water quality and biological surveys are conducted routinely after the new mill has been constructed and in operation. All of these activities imply considerable liaison, discussion, and agreement with various regulatory agencies.

In many respects these mill site evaluations are the most challenging and interesting aspects of our work. The conditions vary from the turbulent, fast-flowing, salmon producing streams of the northwest to the sluggish, slow-moving streams of the southeast. Mill sites may also include estuaries and other marine bodies of water.

Our involvement with the Wood Products Division includes dealing with such problems as treatment and disposal of glue and other adhesive wastes, with dyes, with hydraulic barker wastes, and with problems resulting from log handling and storage. We are also confronted with some unexpected problems from time to time as, for example, with accidental oil spills.

ROBERT B. HERRMANN, author of this paper, is an aquatic biologist with Weyerhaeuser Company.

Marine Studies

Since I began with the Air and Water group much of my work has been in the marine environment. I have been asked to review some of these projects to indicate the scope of our environmental research. Before proceeding I should first explain that our work is more oriented to long-term studies of natural systems and our effects on these systems. Normally, we are not involved in the routine water quality and biological monitoring programs carried out at many of our mill sites.

Our group's work in marine situations began 20 years ago, in 1951. Grays Harbor and Willapa Bay were being considered for a pulp mill site and only scanty information was available on the toxicity of pulp effluents to oysters and other marine animals. This bay produces almost half of Washington's oysters and we wanted to keep this industry out of jeopardy. During the six years the laboratory operated at Willapa Bay our studies generated much basic information on oyster physiology, bioassay methodology and waste toxicity.

Our interest in oysters began at that early date and has continued even though we no longer maintain a marine laboratory.

More recently, from 1964 to 1966, we participated in a comprehensive survey of upper Grays Harbor by federal and state agencies and ourselves. This survey documented in detail physical and chemical conditions, biological resources of the area, and sources of pollution. The published information from this study provides a sound basis for improving conditions in the area to enhance the resource.

Our current research includes a clam inventory of Willapa Bay and Grays Harbor. Along with species distributions, densities, and the like, we also collect water quality and substrate information to correlate with the clam data. Besides providing some necessary information on clam abundance and where they are found, our studies indicate quantitative relations between these factors and tide flat composition - sand, shell, organic matter, and also salinity.

A major ongoing project is studying oysters in Grays Harbor; this began in 1963. Our concerns here are identifying environmental factors affecting oysters, including whether or not low levels of pulp mill effluents are harmful to oysters. Grays Harbor has two pulp mills.

MANY WATER FEATURES STUDIED

In this field study we continuously monitor oyster quality (related to palatableness), growth and survival, and environment conditions at stations on two commercial oyster grounds. We spend one day each week water sampling to establish basic water chemistry and composition of the suspended material in the water. This latter is important since oysters are mainly filter feeders and concentrate suspended matter.

In all, some two dozen features of the water are studied plus such other factors important to oysters as currents, tide flat composition, river runoff, and meteorology.

Our monitoring of the oysters establishes the magnitudes and seasonal cycles for growth and such major tissue constituents as protein, glycogen, water, and ash. In similar manner, our environment monitoring accomplishes the same objective.

In relating the many environmental features to oyster condition, growth, etc., an objective of the study, we found only a few features were really important. This isn't too surprising. In selecting commercial oyster grounds for our study we automatically had optimum conditions for oysters through trial and error site selection by the oyster growers.

Through our studies we find oyster growth is most affected by phytoplankton density, water temperature, and salinity. Phytoplankton and detritus suspended in the water are generally considered to be the oysters' food. We did not find detritus was important, however. Temperature, of course, controls metabolic rate, affecting growth through filtration and digestion rates. Higher temperatures benefit growth more than low temperatures. In addition, temperatures below 5° or 6°C and salinities below 10 to 12 o/oo were related to a cessation of growth.

Regarding the oysters' apparent preference for phytoplankton food the best relationship developed for growth used phytoplankton pigments. When pigment levels are 4 ug/L and less, indicating a low plankton level, little growth occurs.

SALINITY AND GLYCOGEN CONTENT

Salinity is a major factor controlling moisture content of oyster tissues. Wateriness of the oyster meats occurs mostly in winter and is correlated with the low salinities accompanying high river runoff. Since oystering began in Grays Harbor in 1930 there has been an increasing trend in river flows in the winter months and river flows now average 3500 cfs higher than in the 1930's. The resultant lowered salinities not only lower oyster quality through increased wateriness but also, at one station, salinities are now so low in winter as to cause a cessation of oyster feeding.

Glycogen content is another measure of oyster quality. Oysters store glycogen much as higher animals store fat. We found glycogen storage, except in summer, is related to the same factors affecting growth - food levels, temperature and salinity, plus the carryover of sex products from the preceding summer.

Tide flat character - physical and chemical, important in the clam study - was pretty much of a constant at each of the two oyster stations since there were only small seasonal and yearly changes in mud organic content. At the station where organic levels were higher, oysters reared on trays only an inch above the bottom showed improved quality and growth. This effect was not present at the other location where the organic levels were lower.

The normal levels of pulp mill effluents occurring at our stations are not related to deterioration of quality or growth, or oyster deaths. Occasionally in past years levels above 100 ppm were sampled in winter. Based on laboratory studies, such levels are borderline for damage. Since these high effluent levels were mostly correlated with high river runoff, separating the effect of the effluents was impossible.

The information generated through this study is useful to us and also to oyster growers. The information is not confidential and much of the material mentioned today has been reported at regional shellfish meetings. Our growth-environment relation was studied extensively using multiple regression analyses. We hope to predict short-term growth, an obvious advantage to the oyster industry. Thus far we have not been successful except on seasonal estimates.

RUDOLPH N. THUT, author of this paper, is an aquatic biologist with Weyerhaeuser Company.

Freshwater Studies

Although our environmental group performs several functions, our primary concern is research. Fundamentally, we do this in two ways: 1) by measuring in the field the effects of company operations on the physical and chemical properties of the water - and any obvious changes in the biota; and, 2) by studying the effects of physical or chemical alterations in marine or freshwater communities in a laboratory situation. The first of these steps is an important prerequisite to the latter in order to determine what kinds of environmental parameters to manipulate and to what extent.

In the laboratory, we have several set-ups which aid us in assessing the effects of environmental factors on aquatic communities. There are simple aquaria used for bioassays. There are more elaborate designs where, for example, we can monitor the various life functions of oysters as they are affected by changes in temperature, salinity, etc. We have an indoor artificial stream -- 16 inches wide and about 20 feet long.

The current is provided by a motor-driven paddlewheel; light by high intensity fluorescent and incandescent bulbs; the temperature of the water is maintained at the appropriate level with a compressor and cool ing coils. This artificial stream has been used to measure the metabolism of trout. How much food do they require? How much is added to their body tissues? How much excreted?

Our most ambitious project is a 5-acre experimental stream facility in the Cascades of southwestern Washington. On the site, a large constant-temperature spring issues from the ground with a flow approximating 16 cfs. The water has a temperature of 6° C and has a low total dissolved solids content - less than 50 ppm. Part of this water is diverted into a distributing pond and from there into each of three man-made stream beds. The volume of water flowing into each stream is 3/4 cfs. The streams are all 4 feet wide and range in length from 400 to 700 feet. The substrate in the stream beds is homogeneous - small, smooth stones varying in size from 3/4 to 1-1/2 inches.

The streams contain a number of riffles each separated from the other by a pool 10 feet long. The riffles are alternately 25 and 50 feet long. Beginning at the head, the streams have the same sequence, 25- and 50-foot riffles at 0.5%, 1.5%, and 2.5% gradients. The seventh riffle is identical to the first, the eighth to the second, etc. The riffles at the 0.5% gradient have a current velocity of approximately 1 foot per second; at the 1.5% gradient, 1.4 feet per second; and at the 2.5% gradient, 1.75 feet per second. All of the vegetation of any size surrounding the streams has been removed.

CHEMICALS ARE INTRODUCED

All of our efforts have been directed to making the three streams as nearly alike as possible. When the experimental phase of our study begins, we will be able to introduce varying quantities of some chemical, for example, fertilizer, herbicides, or mill effluents, into each of the three streams with the assurance that the background conditions will be virtually identical in each. Light levels are manipulated by placing shade screens of varying opacity over the streams. We have attempted to manipulate temperature levels, which also can be affected by logging, but so far have been unsuccessful.

Also on this site we have concrete and wooden troughs which are meant to replicate the experimental streams on a smaller scale. These will permit us to use much smaller quantities of chemicals and still achieve the same relative concentrations. There is also a pond of about one-half acre on the site which at present is being used to hold the trout used for stream experiments. Eventually, we hope to use the pond to study the ecology of small standing waters as related to company operations.

Most of our work to date on the experimental streams has been concerned with gaining a sufficient background of the chemistry and biology of the streams in their natural state. This is necessary in order to be able to correctly interpret any changes that occur as a result of our manipulations. We are now in the middle of a second phase of study where we are trying to determine how best to monitor the biological community. For example, we have spent a considerable amount of time trying to determine the best way to measure primary production and fish production.

The flora and fauna in our streams are typical of most clean waters. The principal components of such streams are a) bacteria which break down organic matter, particularly dead algae, b) attached algae and other plants, c) bottom animals, primarily insects, feeding on the algae and in some cases on other insects, and d) fish, feeding on the insects. In some streams, fish-eating birds are an important part of the economy of the system. In our case, a small bird called the Dipper has eaten several of our trout.

COMPONENTS OF POLLUTED STREAMS

In polluted streams, the same components are present but the species are different and the relative importance of each of the components may change. For example, in a stream with a heavy load of dissolved organic material, the bacterium, Sphaerotilus natans, becomes very prevalent and will occupy most of the sites formerly held by attached algae. If the temperature of the water is increased and/or the concentration of dissolved oxygen is lowered, then trout will be replaced by carp, and mayflies and stoneflies replaced by diptera.

In our experimental streams, there are very heavy growths of filamentous algae between June and December. The situation is reminiscent of many polluted streams but, in this case, the heavy growth is due to the incidence of full sunlight. The species of algae which are found at a particular time of year vary much as the kinds of wildflowers change from spring to fall. In addition to sunlight, the algae require a full complement of macro- and micro-nutrients.

In the experimental streams, the abundance of algae and the low initial concentrations of certain nutrients combine to account for much higher biomasses at the head of the stream than at the foot. This is particularly obvious in the case of nitrate where the concentration at the head may be 30 ug/l or more while at the foot of the stream the concentration approaches zero. As a result of this, the density of algae at the foot of the stream is quite low since the availability of nitrogen is limiting its growth.

Within these mats of algae, several kinds of creatures live, particularly chironomid, or midge, larvae, copepods, and ostracods. These are small animals which live in and feed on this algae. They have short life cycles and thus are capable of responding quickly to changes in the amount of food, or algae, available.

These animals, and the midge larvae, in particular, can be found in enormous numbers. Over 160,000 midge larvae per m^2 were found in the summer of 1966. The larvae, when they approach maturity pupate and later pick up and float downstream. The pupae eventually find their way to a backwater or eddy in the stream and there they emerge as adults. The adults are similar to mosquitoes but are not capable of biting.

Shortly after they emerge, the midges mate and the female lays her eggs in the water and the cycle is begun again. While the pupae are floating downstream or the adults are in the water surface attempting to break free of the pupal cast, they are very vulnerable to trout predation. It has been demonstrated by Dr. Warren and his associates here at Oregon State that trout can do very well on a diet of these midges.

Most of the remaining animals in the benthos are considerably larger and have one-year life cycles. The details of their life cycles can be elucidated if one constructs a length-frequency histogram. This is done by counting the numbers of each species and measuring their length. In this way we can determine when an insect hatches from its egg, how fast and in what manner does it grow, and when it emerges and leaves the stream.

LOCATION OF ORGANISMS

We are also interested in the factors which dictate where in a stream a particular organism will be found. As already mentioned, the midge larvae and other small animals are found wherever there are large growths of algae. Other species do not show this degree of dependence on algae mats.

The speed of the current seems to be the dictating factor for the stoneflies and caddis flies; most prefer the faster current speeds but some prefer the slower. There are some organisms which are found in the greatest numbers toward the foot of the streams, for example, many species of mayflies. This appears to be due to the fact that the mayfly nymphs have a propensity to leave the substrate and drift downstream, thus they tend to be concentrated there.

We are also interested in the interactions between different organisms particularly where one species competes with another. There is an important idea in ecology called the competitive exclusion principle, which in its simplest statement says that two species with the same ecological requirements cannot live together in the same place.

Yet in many systems, including our streams, two species which are very close taxonomically and anatomically are found together. It can generally be demonstrated in such cases that these species apportion the environment in very subtle, but important, ways. For example, insect-eating birds in tropical forests may specialize on particular strata of the forest (crowns of tall trees, bushes, etc.). Among the aquatic insects in the streams, three very similar species of the stonefly genus, Nemoura, all emerge and begin their life cycles at different times of the year, winter, spring, and fall.

Thus, they are assured that when one species is present in large numbers the other two are not. This happens to an extent among some seven species of the caddis, Rhyacophila, but diet plays an important role here as well. We have dissected the stomachs of 200 plus of the larvae to learn something of their diets.

Each species has a particular diet which is significantly different than that of its relatives. Some feed very heavily on midge larvae, others on copepods, detritus, or algae. These differences in food preference assure that they will not be competing for the same resources and thus can co-exist.

Presented April 30, 1970 by DR. HARRY K. PHINNEY, Department of Botany, Oregon State University.

The Algae and Man

When possible topics for this presentation were discussed, we chose this title as one that would permit the greatest freedom in selecting what would be included. At the time, I thought I would probably use some variation of a discussion used previously, or possibly I would combine parts of three or four discussions to bring you something a little different. After all, it is not too difficult to document the importance of the algae in some area of human economy or welfare (exploitation of marine colloids, algal toxins), or how the algae can be utilized to gain objectives of human importance (close system ecology - waste disposal), or how they can contribute to the production of certain species of animals of importance in various human activities (insects to whales). After all, the importance of the algae becomes explicit when it is pointed out that they produce:

1. Most or perhaps all of the oxygen available for life on earth today;
2. Essentially all of the food produced over 70% of the earth's surface;
3. Much of the fixed nitrogen available for the metabolism of plants and animals;
4. Many commercially valuable products;
5. Some of the most violent toxins known to man;
6. A large proportion of the lime deposits of biogenic origin - and so on!

But as I continued to consider the topic for today, I became increasingly disturbed by the obviously academic approach that emphasizes the importance in human terms. Perhaps as a backwash of last week's furor over "the environment", I felt a desire to document the importance of the algae in biological terms.

We find it difficult to appreciate the ramifications of interactions between an entity (or specific organism) and its total environment and yet this is where the real importance lies. Most frequently we discuss the ecological or other relationships of an organism or group of organisms in terms of a particular category of factors. We become engrossed with a restricted line of reasoning, and, failing to remember that "life" follows the laws of nature rather than human logic, attempt to explain natural phenomena in anthropocentric terms.

This is a characteristic human failing to which, at some time, we must all plead guilty. Any explanation of the importance of the algae that is based on their relationship to the economy or welfare of man begs the question.

Because of our individual interests or the training we have received, we examine organisms in terms of formalized categories of information such as their taxonomic relationships, or their morphology or physiology, or their ecology, and in very few instances have any organisms been sufficiently studied to allow the formation of a reasonable concept of the manner in which they are integrated into the biosphere. Because of the existence of a number of uncontrollable factors, we seldom perform extended studies of an organism in the field.

We isolate the organism from its natural environment, transport it into the laboratory and manipulate it in a variety of ways, and then all too often we assume that the responses observed in the laboratory will parallel the responses of the organism in nature. We assemble the available "data" and interpret them in terms of preconceived anthropocentric parameters. We compose definitions from a highly technical jargon and assume them to be exhaustive and comprehensive.

We write detailed descriptions of entities and their relatives and assume again that the information selected to form the characterization has biological importance because it is information that interests us as humans.

I am in possession of a considerable amount of heterogeneous information concerning the algae, but little of it can be made to fit into a framework that details the true importance of the algae in the "real" world. After consideration of this problem, I have decided to merely attempt to first establish some kind of general understanding of how the algae relate to other organisms, what kinds of algae exist today, what the importance of the algae is to life in general and, in particular, how the algae may relate to some of the environmental problems. Then, if there is some time left, perhaps there will be some questions from the audience.

HISTORICAL REVIEW

The geological record yields presumptive evidence of biological activity about 3.4 billion years ago. The biogenic origin of deposits has not been proven by association with recognizable organic remains. Rather, it is a matter of evidence of fixation of carbon, plus evidence that at a somewhat later date rather elaborate systems of biosynthesis had been developed, and this would appear to be the age of the putative ancestral forms.

At about 2.8 billion years, the accumulation of oxides of iron, nitrogen, and sulfur give evidence of the development of photosynthetic processes that result in the release of O_2 into an otherwise reducing atmosphere. At approximately 2.4 billion years, sufficient oxygen had accumulated to support aerobic life.

The studies of Precambrian microfossils by Barghoorn, Taylor and Schoph have provided physical evidence of algal entities approximately 2×10^9 years ago. They appear to have been rather typical blue-green algae while from more recent Precambrian strata there has been described an assemblage of blue-green and green algae of about 900 million years in age. In the Cambrian (550 million years) there developed massive bioherms or reefs of calcareous algal deposits of definite organization.

The lower Cambrian (525 million years) deposits have been assigned to the blue-greens, while the Greens and Browns appear to have developed more abundantly in the middle Cambrian (500 million years) and the Rhodophyta were well developed and abundant by the Ordovician (400 million years). It is not until the Devonian (350 million years) Period that humus coals with origin obviously depending on the high land plant begin to appear. These coals produce phenols upon sublimation.

The logical extrapolation in time back to the ancestral prokaryote (lacking a definite nucleus) would place these at about 4×10^9 years. This means that prokaryotic plants constituted the whole of the biota for approximately 1.6 billion and probably dominated the flora for another 0.5 billion. Algal types, both prokaryote and eukaryotes, have formed a major fraction of the biota for an additional 2×9^{10} years. My purpose in detailing this geological history of plants has been to emphasize the importance of the algae, not only as progenitors of the plant line of evolution, but also their significance as an important segment of the biota throughout geological history to the present time.

EXIST IN GREAT VARIETY

Not only were the primitive algae responsible for initiating the whole evolutionary line of aerobic, pigmented autotrophic organisms, but they have competed successfully with all the newly evolved forms and still occupy an exceedingly important position in the biosphere today. This success in long term competition is proof of the inherent plasticity of the alga lines.

"Algal" evolution has not resulted in any great degree of cellular differentiation, with the result that even the most "specialized" of the algae are highly responsive to environmental stress and can survive and evolve with changing ecological conditions. Whereas some plant groups of a later date of origin are now extinct or have undergone great reduction in the numbers and varieties with time, the algae probably exist in as great a variety today as at any time in geological history.

Just what the numbers of kinds of algae might be is a little obscure. I remember a discussion between Dr. Paul Conger, the diatom specialist who used to be at the Smithsonian Institution, and Dr. G.W. Prescott, who retired recently from Michigan State. Dr. Conger remarked that it was his opinion that there are probably as many species of diatoms as all other kinds of algae and Dr. Prescott replied that this remark intrigued him greatly since he was of the opinion that there are as many species of desmids as there are all other kinds of algae.

The point I wish to make is this: the algae are of great importance to Man because they are ancestral to all other eucaryotic life. But in addition, they have occupied a very important position in the biosphere and continue to do so at the present time.

I believe that the importance of the algae to the total environment cannot be too greatly appreciated. Most are aware of the algae functioning as the important primary producers in marine and freshwater habitats, but it is not generally recognized how common and important the algae are in subaerial and terrestrial habitats. In fact, I believe that I can document with facts that viable, physiologically active algal organisms occur in more extreme and varied habitats than any other group of plants except the bacteria. For the most part, only a total lack of air, water, essential minerals or light would exclude the growth of algae.

As a result, they are the sole primary producers of organic materials in some very severe habitats.

1. Members of several Divisions of algae are regularly found growing on, in, or under snow and ice in alpine and arctic regions.
2. The only plants, other than bacteria, capable of withstanding the high temperatures found in some hot springs and industrial hot water discharges are some blue-green algae.
3. Some algae are able to exist successfully at extreme salinities. Dunalliela can grow and multiply on the surface of moist crystalline salt. The algae are the only plants to grow on some alkali soils and have been deliberately cultivated in India for the improvement of such soils. (Singh - The Blue-green Algae in Indian Agriculture.)
4. Some algae (i.e. Desmids) can grow in water of extremely low dissolved solids content. My friend, Winton Patnode, in Eugene, Oregon, has cultured a great many species of Desmids in rainwater.
5. Some algae can grow at extremely low light intensities. Some of the marine rhodophytes (red algae) have been reported from depths between 500-600 ft in the tropical Pacific. In tropical areas of the Atlantic the Chlorophytes (green algae) have been reported at the same or greater depths.
6. Algae have been found viable and physiologically active in the interstitial spaces of soil and sediments down to depths where light penetration seems impossible.
7. Some algae are characteristic of arid soils and there are wide-spread and abundant algal forms in the Sonoran Desert of the Southwest and Northern Mexico, in Death Valley, and in the Sahara.
8. Some algae can grow at concentrations of toxic mineral ions or at H^+ ion concentrations that are toxic to all other life.
9. Some algae, i.e. blue-greens, are microaerobes and can grow in the presence of heavy organic pollution and high bacterial populations.
10. Various algal groups have established beneficial symbiotic relationships with protozoa, Turbellarians, Coelenterates, Mollusca, and vertebrates among the animals and with fungi, ferns, and gymnosperms among the plants.

In compiling this list, it was not intended simply as a Gee-Whiz or Believe-It-Or-Not exercise. It was my intention to illustrate how, in the course of evolution, the algae have been able to insinuate themselves into a tremendous variety of niches that probably otherwise would not be supporting aerobic, photosynthetic producers. This does not mean that algal types have been forced to retreat to these unlikely situations by competition with more recently evolved plant forms. Quite the reverse is true. In any habitat where any other type of plant finds it possible to exist, we can find algal types co-existing.

In many habitats, the algae are functioning in much the same way they did 2 billion years ago. They are establishing and/or maintaining conditions necessary for aerobic life. But, in addition to this very important function, they are also providing very important supplies of fixed carbon and fixed nitrogen under conditions few if any other plants could survive. As a matter of fact, the oceanographers have made some computations that indicate that the marine phytoplankton is responsible for about 4/5 of the oxygen in our atmosphere.

When one considers the rate at which the use of fossil fuels is consuming our supply of oxygen, the necessity for assuring the continued health and well-being of the algal flora become apparent. Again, the potential importance of the algae in providing fixed N_2 under conditions that would normally result in dentrification is made very real as more intensive agriculture becomes necessary to support the rapidly increasing populations in the Orient.

FUTURE CONSIDERATIONS

The students of food chain patterns say that there are only four steps fromthe primary producer to the ultimate consumer. If indeed we are going to try to exploit our marine and freshwater fisheries as protein sources, we'd better be sure to do nothing to limit the spectrum of primary producers.

Parenthetically, I'd like to add my two cents' worth in that discussion by pointing out that every fishery that has been intensively exploited has experienced serious decline in 20-40 years. I am not at all convinced that this resource can be depended upon for any long term demands. It may prove possible to apply some means of management or "cultivation" that may increase the supply or shorten the generation time, but the supply is relatively inelastic.

Furthermore, as the populations of desirable species are reduced, space and means of support may be left that will allow for increase in populations of undesirable species. One can forsee a time when most of the productive capacity of the earth is devoted to the production of just two general categories of organisms. Those Man makes use of directly, and those Man shuns at all times because of undesirable attributes.

I'm sure that most of those in this audience who have some familiarity with my interests in the algae expected me to discuss the manner in which Man exploits the algal resources. In fact, it had been my intention to touch on this briefly, but I have not, hoping thereby to leave some time for questions.

I want to make this one observation. In the past 35 years, there has been a great technological development in the exploitation of storage substances from marine algae. This is presently a multi-million dollar a year business.

I am convinced that the next area of exploitation of the algae that will be developed will be those compounds that exercise control of the physiological and developmental processes. These are the auxins, gibberellins, vitamins, cytokinins, hormone-inhibitory substances, attractants, repellants, antibiotics, sirenins, and toxins. However, the proposals to exploit the algae, marine or freshwater, for their food value overlook a number of very serious practical problems that presently appear insoluble.

Presented May 7, 1970 by DR. COLBERT E. CUSHING, Ecosystems Department, Battelle Memorial Institute, Richland, Washington.

Radiation Ecology in Freshwater Communities

Since our waters seem destined to be used as disposal receptors of our society's waste products, they will, no doubt, receive their share of radioactive wastes as uses of nuclear energy increase. Today, I would like to discuss some of the aspects of radiation ecology and radionuclide cycling in the freshwater environment.

Two reasons why people are interested in radionuclides in water are: (1) from a health-safety aspect, radioactive wastes must be monitored to insure that undesirable amounts of radioactive elements are not passed through food-webs to man, and (2) radioactive nuclides are excellent tracers to use in scientific investigations. I will devote my remarks today to the latter aspects, that of using radionuclides as tools for ecological research.

RADIONUCLIDES IN THE ENVIRONMENT

There are four sources which may contribute radionuclides to freshwaters, and these contributions vary in composition and amounts. The first source is that of the naturally occurring radionuclides including ^{238}U, ^{226}Ra, ^{232}Th, ^{40}K, ^{14}C, ^{210}Po and ^{210}Pb. These may be found in concentrations ranging from 10^{-9} to 10^{-10} $\mu Ci/ml$ ($\mu Ci = 1 \times 10^{-6}$ curies; curie = quantity of a radioactive nuclide disintegrating at the rate of 3.700×10^{10} atoms per second). In some of the radium hot springs, concentrations may reach 10^{-4} $\mu Ci/ml$. A second source of radionuclides in water is from the disposal of wastes from users or producers of nuclear energy.

These include AEC facilities such as Hanford, Oak Ridge, and Savannah River; wastes from experimental use in laboratories and institutions throughout the country; by-products of the use of radionuclides for medical purposes; and disposal of wastes from nuclear powered vessels and fuel processing plants. Radionuclides from these sources include the fission products ^{89}Sr, ^{90}Sr, ^{91}Y, ^{95}Zr-Nb, ^{106}Ru, ^{131}I, ^{137}Cs, ^{140}Ba, ^{144}Ce and the rare earths; and neutron activated radionuclides including ^{32}P, ^{46}Sc, ^{51}Cr, ^{54}Mn, ^{55}Fe, ^{59}Fe, ^{57}Co, ^{65}Zn, ^{64}Cu, ^{76}As, ^{24}Na, and others.

The abundance of the radionuclides from these sources, of course, is quite variable. In most cases, radioactive decay and dilution reduce the great majority to negligible amounts in our waters. A third source of radioactivity in the environment, and one getting much publicity now, is from releases from such sources as power reactors, experimental facilities, etc. The composition and abundance from this source obviously depends on the nature of the release.

The fourth source of radionuclides in water is from fallout from weapon testing detonations. The radionuclides produced include both fission products and neutron activation radioisotopes. The composition is dependent upon (1) the physical construction of the device, i.e. the materials it is made of, and (2) the environmental characteristics at the detonation site, i.e. underground, surface, air, or underwater detonation.

The relative distribution of radionuclides in the environment is governed, as would be expected, by many interrelated factors just as are the stable elements in an ecosystem. The nature of the particular water body, its biotic and abiotic constitutents, and the characteristics of the radionuclides all influence the fate of a given isotope.

Rigler (1956) found that ^{32}P added to a lake was very rapidly taken up by the bacteria and phytoplankton and in time was associated with the sediments. The degree of eutrophication of a water body will influence the distribution of a given radionuclide through isotope dilution. An added amount of ^{32}P is more likely to be rapidly taken up by algae in an oligotrophic lake low in nutrients than in an eutrophic one with an excess of phosphorus.

It must be kept in mind that there is basically no discrimination by an organism between radioactive and stable isotopes of the same element. The chemical state of a particular radionuclide is also important. Trivalent ^{51}Cr occurs in the dissolved state whereas hexavalent ^{51}Cr is present as a particulate.

Table 1, from Brungs (1967), shows the relative distribution of four radionuclides introduced into experimental ponds as measured over a time period of 80 days. Note how the great majority of the added material was eventually associated with the sediments.

Table 1. Percentage distribution of ^{60}Co, ^{65}Zn, ^{85}Sr and ^{137}Cs in the dissolved, particulate, biota, and substrate fractions of experimental ponds (day 2 - day 80). (after Brungs 1967).

	Dissolved	Particulate	Biota	Substrate
^{60}Co	15 - 0.7	43 - 0.3	0.2 - 0.05	41.8 - 98.9
^{65}Zn	16 - 0.1	25 - 0.5	0.5 - 1.0	58.5 - 98.4
^{85}Sr	83 - 23	1.0 - 0.1	0.1 - 0.4	15.9 - 76.5
^{137}Cs	13 - 0.3	5.4 - 0.3	0.2 - 0.03	81.4 - 99.4

MINERAL CYCLING IN AQUATIC ENVIRONMENT

Before proceeding with this subject, it might be useful at this point to explain some of the terms used in presenting radioecological data. Probably the most widely used expression is that of "activity density" which is the absolute concentration of a particular radionuclide per some unit of biomass, time, area, etc.

Examples of these would be disintegrations per minute/mg, pCi/ml (picocurie = 1×10^{-12} curie), μCi/fish, or, if a rate is involved, counts per minute/mg/hr. A second commonly used expression is the concentration factor, which is supposed to be an indication of the ability of the organism in question to concentrate a particular radionuclide over that of the ambient concentration.

It is the ratio of the radioactivity per gram wet weight of the organism to the radioactivity per ml of water. There is a good deal of discussion currently as to the validity of this measurement, as it has been widely used and misused in the literature. It is accurate only when the organism is in equilibrium with the water and is dependent upon the radionuclide concentration in the water. Concentration factors generally decrease from lower to higher trophic levels because of radioactive decay, mode of uptake, and turnover rates.

The third, and ecologically the best, method of expression is termed "specific activity", and is defined as the ratio of the radioactive to stable concentration of an element in an organism. Under certain assumptions, it is a true indication of an organism's demand from the environment and is useful in predicting the accumulation of an element by an organism.

The criteria for using specific activities are: (1) that the stable and radioactive isotopes must be completely mixed and the rate of biological movement the same; (2) the biological half-life of the element is known for the particular organism or tissue; (3) the organism is exposed to the same concentrations and is in equilibrium; (4) the concentration of the stable isotope in the environment is known; and (5) the chemical forms of the stable and radioactive isotopes must be similar.

For example, an uptake of 3 pCi of ^{65}Zn per gram by an organism containing 150 μg of zinc per gram would be ecologically equivalent to the uptake of 9 pCi of ^{65}Zn per gram by an organism containing 450 μg of zinc per gram. The use of activity densities alone would present a misleading interpretation. For a fuller discussion of this, see Nelson (1964).

The cycling of radionuclides in the aquatic environment is basically an interaction between the biological demand of the organisms and the mineral composition of the media, and differs from isotope to isotope. In this respect, it is no different from cycling of the stable isotopes of the same elements, but, in many cases, is much easier to measure.

In discussing radionuclide cycling, there are six factors or aspects, which we will consider: (1) the mode of uptake, (2) rates of uptake, (3) retention-elimination, (4) food-web relationships, (5) environmental effects, and (6) dispersal of radionuclides.

MODE OF UPTAKE

There are essentially, two principal modes of uptake of radionuclides by organisms: (1) absorption, which includes metabolic uptake or assimilation, and (2) adsorption, including ion-exchange or other physical phenomena taking place on the exterior surface of the organism.

Metabolic uptake by autotrophic organisms is related to photosynthesis and mineral assimilation for the elaboration of new organic material. The relative amount of metabolic uptake by zooplankton is related to the specific radionuclide. For instance, in zooplankton metabolic uptake is the principal mode for the accumulation of ^{85}Sr which is incorporated in the exoskeleton.

On the other hand, little ^{32}P is assimilated by zooplankton from food, most of it passing through in the feces and ending up in the sediments. Larger benthic invertebrates also exhibit a selective uptake irrespective of ambient concentrations.

The five most abundant radionuclides in Hydropsyche cockerelli larvae, in descending order, were ^{32}P, ^{64}Cu, ^{51}Cr, ^{65}Zn, and ^{24}Na. The five most abundant radionuclides in the water, in descending order, were: ^{64}Cu, ^{239}Np, ^{24}Na, ^{56}Mn, and ^{51}Cr (Davis 1965). Note that ^{32}P and ^{65}Zn were first and fourth highest in the larvae, but not in the highest five in the water. Kormondy (1965) studied the accumulation of radionuclides by larval Plathemis lydia and found that very little of the zinc accumulated was assimilated and most was adsorbed in the surfaces.

Adsorptive uptake by autotrophic organisms, phytoplankton and periphyton, is very important and is directly related to their large surface to volume ratio. Adsorption may be a first step followed by metabolic uptake through the cell walls. Cushing and Watson (1968) investigated the uptake of ^{32}P and ^{65}Zn by floating living and killed phytoplankton through the Columbia River in the vicinity of the Hanford effluents.

We surmised that if we subtracted the uptake of the killed plankton from that of the living, the difference should be metabolic uptake. Statistical analyses of the results, however, showed that killed plankton accumulated significantly more ^{65}Zn than did living plankton, and, conversely, living plankton accumulated more ^{32}P than did the killed.

After the initial shock wore off, we found that our results agreed with other workers who had found enhanced ^{65}Zn uptake by killed algae (Gutknecht 1963, Bachmann 1963). Our laboratory studies of ^{65}Zn uptake by natural periphyton communities show that there is little difference in uptake by living communities in continuous light or darkness or by killed communities - again emphasizing the importance of adsorptive uptake.

High levels of the biologically nonessential elements such as ^{51}Cr, ^{239}Np, and ^{46}Sc are accumulated by Columbia River plankton and periphyton. Zooplankton accumulate large amounts of ^{32}P by adsorption and may be related to epizootic bacteria on the animals integument (Rigler 1961). ^{85}Sr adsorption, however, is insignificant.

RATES OF UPTAKE

The rate of uptake of a particular radionuclide is a function of many factors. Body size (surface to mass) is generally inversely related to the rate of uptake. The biological demand for a given element is obviously important when comparing rates; consideration of the pre-nutritional history of the organism is important in this aspect.

The position of an organism in the food-web and its metabolic rate also govern the rate of uptake. In general, the further one proceeds through the trophic levels, the slower is the rate of uptake. Finally, a host of environmental factors,which will be discussed subsequently, play an important regulating role. The interplay of these factors must be considered, i.e. phytoplankton have a negligible demand for chromium, but exhibit a rapid uptake rate of it by virtue of adsorption to the large surface area present.

RETENTION - ELIMINATION

A knowledge of the retention of a particular radionuclide is fundamental to studies of food-web cycling and the construction of meaningful models to describe ecosystem dynamics. Retention studies involve estimates of elimination and turnover rates of the element in question. Radionuclides accumulated by an organism are lost by two ways: (1) biological turnover ($T_b 1/2$), and (2) physical decay ($T_p 1/2$).

The time it takes for the initial radionuclide burden to decrease by 50% by these two factors is known as the effective half-life, $T_e 1/2$. Using this information in conjunction with the activity density in the organism and its food at two successive sampling periods, good estimates of the amount of food eaten can be calculated. Some estimates of these measurements for rainbow trout are: ^{137}Cs $T_b 1/2$ = 25-80 days, (Häsänen et al. 1967), ^{65}Zn $T_e 1/2$ = 134 days (Nakatani 1966), and ^{32}P $T_e 1/2$ = 12 days (Watson et al. 1959).

FOOD-WEB RELATIONSHIPS

The definition of food-web relationships is one of the most effective uses of radionuclides by ecologists. With proper use, a knowledge of what element goes where and at what rates can be ascertained. One generalization which has been made is that the higher and faster the uptake by a particular organism, the greater is its response to changing environmental conditions.

Ball and Hooper (1963) spiked a stream with ^{32}P and found that uptake and cycling rates were faster in the periphyton, next in the filter feeders and algae scrapers, slower in the omnivores, and slowest in carnivores.

Other radionuclides, for instance ^{137}Cs, behave differently. Davis (1965) states that the location in the food-web affects the amount of radionuclides accumulated and that it is dependent upon: (1) the time required for the isotope to reach the organism from the water, (2) accumulation efficiency and transport time of radionuclides are, in turn, dependent upon the metabolic demand and the biological turnover rate ($T_b 1/2$) of the element for each component of the food-web, and (3) the degree to which transport time influences the efficiency of transfer depends upon the physical half-life of the radioisotope involved.

ENVIRONMENTAL EFFECTS

The influences of environmental factors on these processes are many and varied, and, obviously, are not unique to radioisotopes but pertain to stable elements as well. Responses, however, are usually easier and more accurately measured with tagged elements. Since there is a wealth of such data available, I would like to just present a few examples of data from studies using radionuclides to investigate physical, chemical, and seasonal phenomena.

Harvey (1969) found that non-lethal temperature increments up to 40 C. had no effect on the uptake of several radionuclides by a blue-green alga. Whitford and Schumacher (1961) used ^{32}P to show the enhanced uptake by lotic algae in flowing water as compared to standing water. Work in our laboratory and elsewhere has shown a stimulatory effect of light upon ^{65}Zn uptake by algae.

Bachmann and Odum (1960) thought this might be related to photosynthesis, but Gutknecht (1961, 1963) and we believe it is more directly related to pH changes; ^{65}Zn adsorption is highly pH dependent. The uptake of ^{85}Sr by algae has also been shown to be light related although the exact mechanism is not clear Patten and Iverson (1966). Kormondy (1965) showed that ^{65}Zn uptake by dragonflies is independent of temperature.

A temperature - dependent uptake of several radionuclides, however, has been shown for several organisms in the Columbia River.

Influences of the chemical constituents in the environment are, of course, very complex and highly dependent upon the element in question. Many workers have shown that there is a direct correlation between uptake of a radionuclide and its ambient concentration. We have found that decreasing the ambient concentration of ^{65}Zn by 50% decreases the uptake by periphyton by a corresponding amount.

The isotopic dilution, or ratio of stable to radioactive ions in the water, influences the rates and amount of uptake. Caddisfly larvae, diatoms, and juvenile suckers have been shown to take up more ^{32}P from water low in stable P than from one with a high stable P content (Davis 1965). Not only can there be isotopic dilution by the same ion, but also between similar stable and radioactive ions. We have found that uptake of ^{65}Zn by periphyton is decreased if the number of stable zinc ions in Columbia River water is doubled (0.036 ppm to 0.072 ppm), and that uptake of ^{65}Zn is drastically reduced if the number of stable magnesium ions is doubled (3.6 ppm to 7.2 ppm).

This is evidence of a competition for binding sites by divalent cations. Brungs (1965), studying bluegills, found that a 100 times increase in the calcium content of the water decreased the uptake of ^{85}Sr by a factor of about 20 times. The effect of pH varies among elements; ^{65}Zn uptake increases with an increase in pH, ^{90}Sr uptake increases with a decrease in pH, and ^{90}Y, a daughter isotope of ^{90}Sr, uptake decreases with a decrease in pH.

Seasonal influences of radionuclide cycling are essentially a reflection of physical and chemical changes interacting over a period of time, and we need not go into much detail.

An example of this can be seen in Fig. 1 (Cushing 1967). The upper graph shows the concentration of ^{32}P and ^{65}Zn in net plankton on a $_{n}Ci/g$ dry wt. basis and shows a marked decrease in summer when the reactor effluents are greatly diluted by the spring runoff. The lower graph shows that despite the low activity density in summer, more associated radioactivity is transported because of the high biomass levels.

DISPERSAL OF RADIONUCLIDES

Dispersal of radionuclides is important ecologically and from a health-safety view. The health-safety aspect is really a subject of its own and I do not have the competency to discuss it in full detail. Ecologically, radionuclides can provide us with a wealth of information, given the proper experimental design, whether they are "spiking" studies or ones using radionuclides already in the environment such as fallout or waste products.

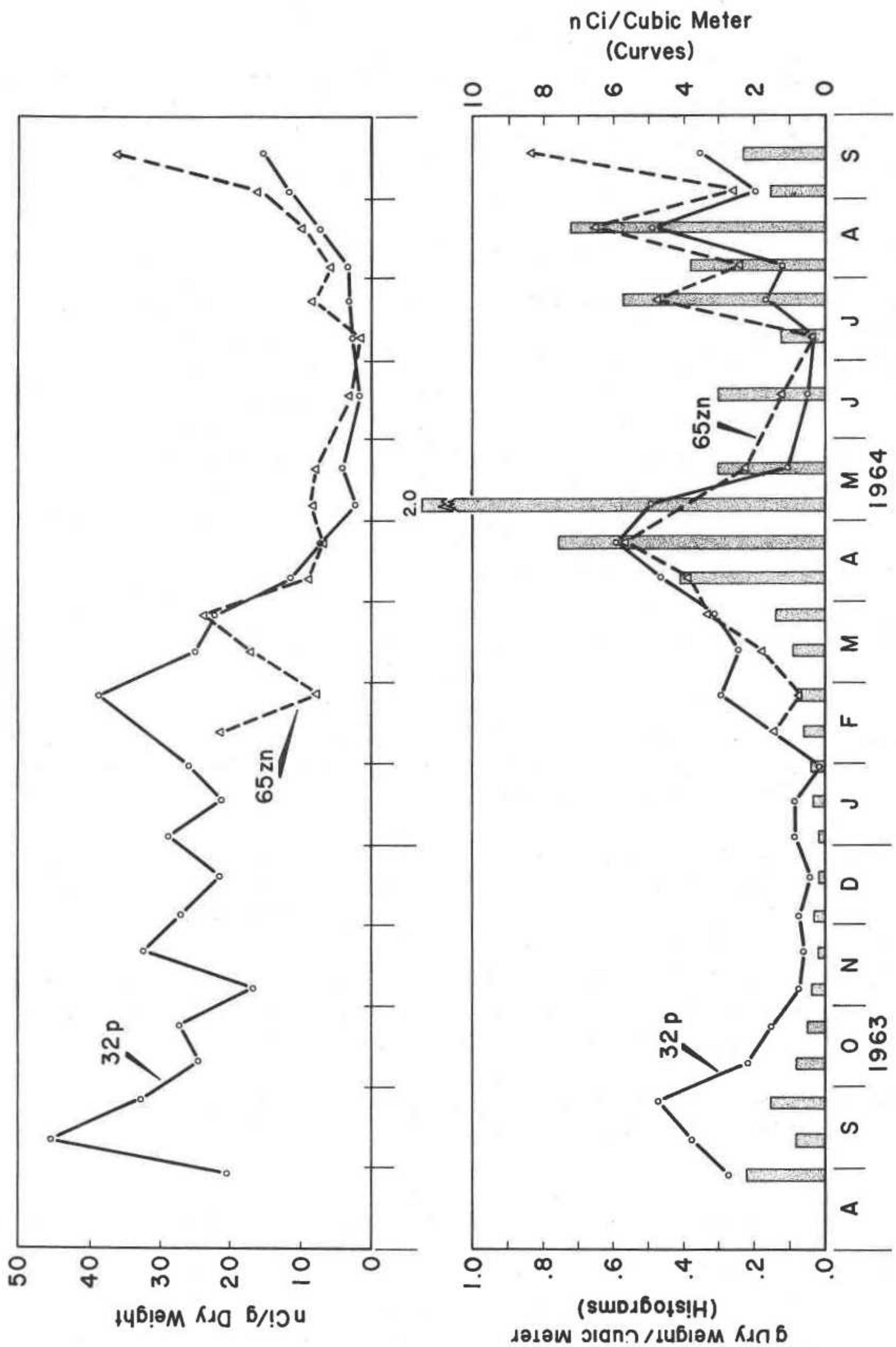
n Ci/Cubic Meter
(Curves)
n Ci/g Dry Weight
g Dry Weight/Cubic Meter
(Histograms)
32p
65zn
2.0
1963
1964

Figure 1.

Data on fish migration (Watson 1966), mineral translocation within the water mass, feeding habits (Kevern 1966), and migration of emergent insects with aquatic larval stages (Coutant 1967) are just a few of the many ecological studies performed with radioactive tracers.

SUMMARY

In conclusion, the presence of radioactive isotopes in the freshwater environment, disregarding their source, can provide us with a wealth of ecological data. Information ranging from the movement of a single element from one organism to another, or from one tissue to another, to data helping to unsort the complexities of entire aquatic foodwebs can be gained with properly designed experiments and treatment of the data. The dynamics of radionuclide cycling are basically no different from their stable counterparts, but their value lies in the increased precision of measurement, particularly at concentrations too low to measure by standard analytical procedures.

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Presented May 14, 1970 by DOUGLAS W. LARSON, Department of Fisheries and Wildlife, Oregon State University.

Cultural Impact on Lake Evolution

Many of the excellent lake environments in Oregon are being exploited for recreational use and, as a result, are becoming more productive biologically. The problems that are brought on by increased biological production have been well-documented in the literature (Hasler, 1969).

Man uses lakes for various purposes, all of which provide the algae with a source of essential primary nutrients. Unlimited use entails increased nutrient enrichment which in turn accelerates lake eutrophication. Thus, a lake that is used unconditionally will undergo an artificial enrichment that will shift it gradually (or perhaps abruptly) to a higher level of productivity. Ohle (1953, 1955) described the artificial (man-induced) process of lake evolution as "racing-aging" or "racing eutrophication" which contrasts with the slower-paced, natural course of eutrophication.

Several lakes in Oregon, including Crater, Odell, Waldo, and Woahink lakes, have been regarded by investigators as being oligotrophic (Kemmerer et al., 1924; Pettit, 1936; Griffiths and Yeoman, 1938; Newcomb, 1941; McGie and Breuser, 1962; Averett, 1966; Carter et al., 1966; Nelson, 1967; Hoffman, 1969; Gahler, 1969; Larson and Donaldson, in press). In theory, "oligotrophic" lakes are relatively unproductive biologically due to a poor supply of dissolved organic and inorganic plant nutrients. Consequently, the quality of water in lakes of this type is relatively high.

Crater, Odell, Waldo, and Woahink lakes are used differently. The excellent water quality of Crater Lake (National Park) is maintained by regulations that prohibit certain uses. Conversely, Odell and Woahink lakes are used intensively for recreation by various interest groups.

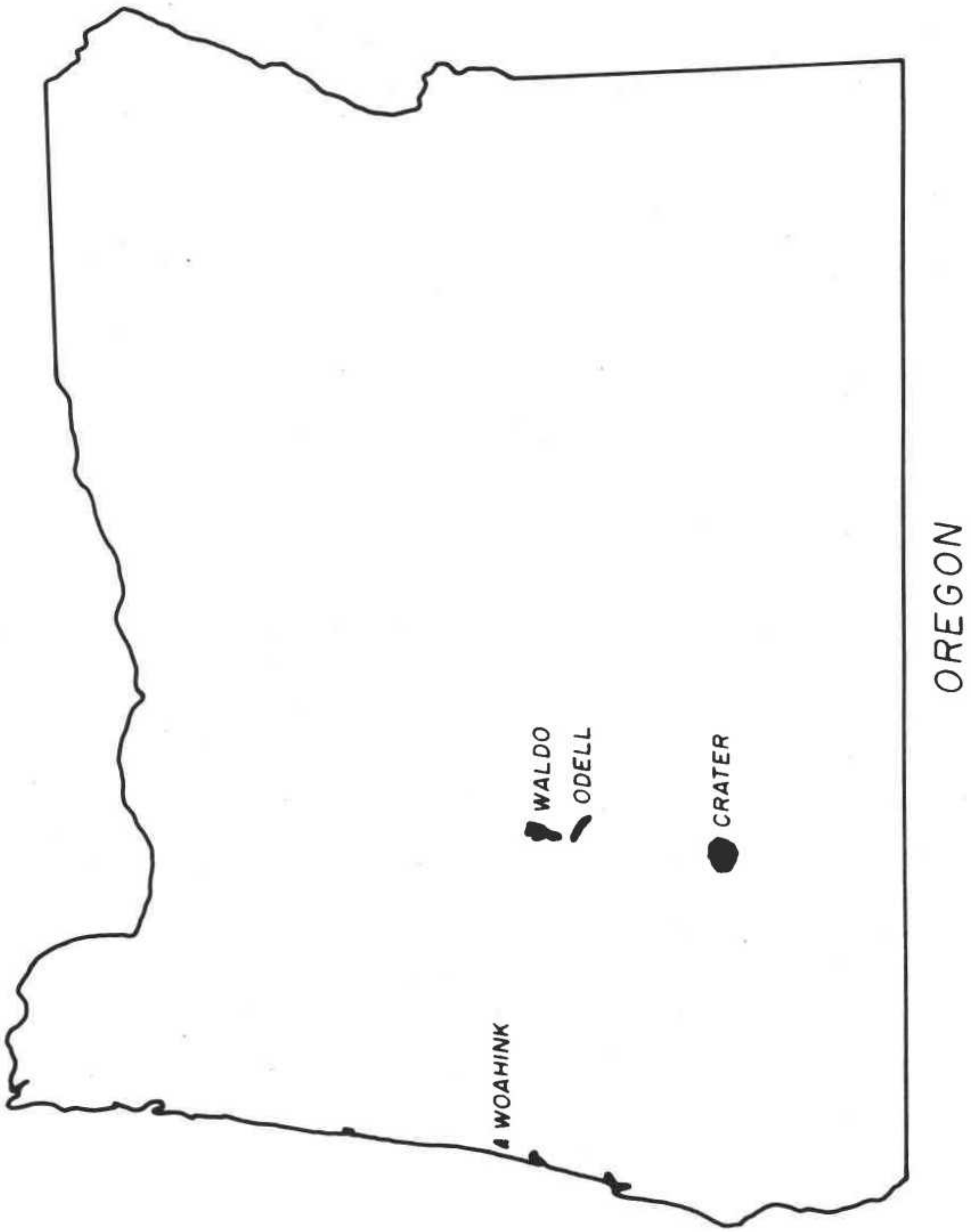

Figure 1. Relative locations of the four study lakes in Oregon.

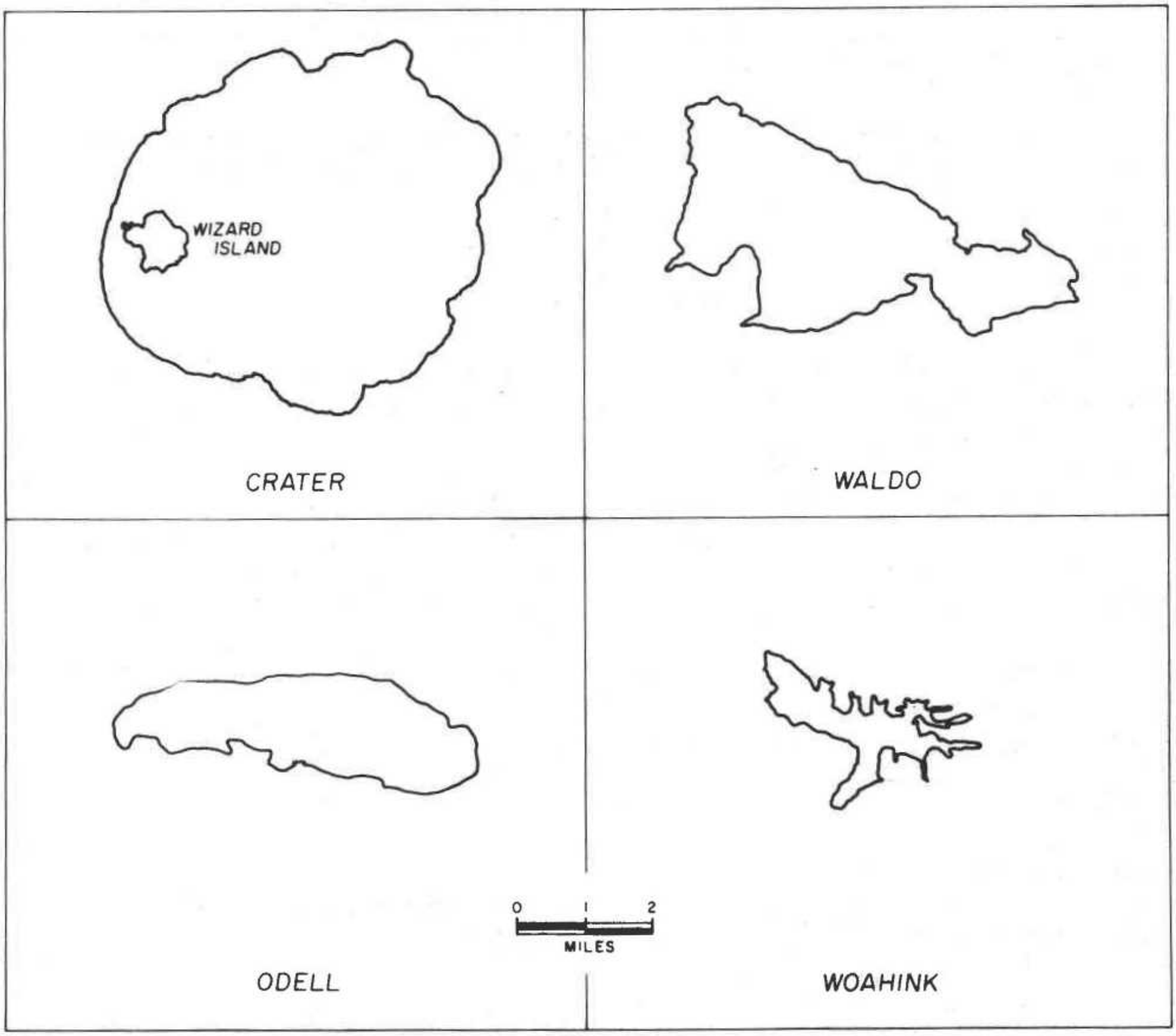

Figure 2. Size and shape relationships among the four study lakes.

Few, if any regulations exist which might restrict the type and amount of use either lake receives. Waldo Lake was, until recently, somewhat remote. Now, a newly-constructed highway makes this near-pristine environment easily accessible.

Specific objectives of my study were to (1) assess individual lake productivity and (2) determine to what extent each lake has evolved or "aged" in response to cultural impact.

THE LAKES

Relative locations, sizes and shapes of the four study lakes are illustrated in Figures 1 and 2. Morphometric data are given in Table 1.

Table 1. Lake Morphometry.

	Crater*	Odell	Waldo	Woahink
Elevation, surface (m)	1882	1459	1650	12
Area (km^2)	48.0	14.4	25.1	3.2
Volume (km^3)	16.0	0.59	0.95	0.04
Depth, maximum (m)	589	86	128	21
Depth, mean (m)	325	41	38	10.5
Shoreline length (km)	31.0	21.5	40.0	22.3
Shoreline development	1.27	1.59	2.25	3.50
Relative depth (%)	7.52	2.01	2.26	1.18
Mean depth: Max depth	0.55	0.48	0.30	0.50
Max depth: Surface	0.085	0.023	0.026	0.012

*Byrne (1965)

CRATER LAKE

Crater Lake is the deepest lake in the United States and the seventh deepest in the world (Edmondson, 1966). The lake is located in the south-western quarter of Oregon, approximately 104 km. north of the Oregon-California border, and 193 km. inland from the Pacific Ocean (Phillips and Van Denburgh, 1968). The lake occupies the collapse caldera of volcanic Mt. Mazama (Nelson, 1967).

The Crater Lake environment, by virtue of its being preserved in a national park, receives extremely limited use. Access to the lakeshore is along a precipitous trail that zig-zags for nearly 2 km. down the caldera wall. At the base of the trail, one finds a concession stand, rowboat rental service and two toilet facilities, all of which represent the total recreational development in the basin (i.e., along the lakeshore). Six excursion boats carry tourists on scenic trips around the lake. A boat storage and repair facility, property of the park concessionaire, is located on the southwest shore of Wizard Island.

ODELL LAKE

Odell Lake, situated at the summit of the Cascade Range in the Deschutes National Forest, is 65 km. directly north of Crater Lake. The basin is thought to be a glacial trough closed at the eastern end by a terminal moraine. The age of the basin is estimated at 10,000 to 12,000 years (E. Taylor, Department of Geology, OSU, personal comm.).

Odell Lake serves various interest groups, including those that fish, camp, boat, and waterski. The lake is easily reached by State Highway 58 which parallels, closely, the shoreline to the north and east.

The U.S. Forest Service maintains five campgrounds and three boating facilities in the Odell basin. The use of these has increased at a rate of about 9% per year (J. H. Nunan, U.S. Forest Service, Crescent, Oregon, personal comm.). All Forest Service toilet facilities are of the vault-type with one exception, this being at the Pebble Bay campground. The vaults are pumped two or three times during the summer and fall and the contents are removed from the basin (J. H. Nunan, personal comm.).

Included in the total development of the lake are two privately-owned resorts, a marina, and 67 summer homes, most of which are situated at the western end of the lake. The homes are occupied usually from May until September. Sewage wastes are removed by drainage-field or pit-type systems. These are located, as a rule, at least 60 m. back from the shoreline and 30 m. from any water course (J. H. Nunan, personal comm.).

Since 1965, angler use of Odell Lake has nearly doubled. Creel census data, collected by the State of Oregon Game Commission, show that the number of boat hours spent on Odell Lake increased from 46,000 in 1965 (Averett, 1966) to over 69,000 in 1968 (S. Lewis, Oregon Game Comm., personal comm.).

The overall use of Odell Lake has grown rapidly, especially within the last 10 years (J. T. Atkinson, Odell Lake marina owner, personal comm.). Lake users have brought a substantial load of nutrients into the basin that otherwise would not have been available. As expected, the algae responded positively. Now, frequent pulses by phytoplankton populations and a relatively high rate of primary production throughout the growing season are features of the lake's biology. Algal blooms were never observed in the years prior to 1960 (J. T. Atkinson, personal comm.).

In 1940, the State of Oregon Game Commission conducted a biological survey of 40 lakes, including Odell Lake, in the Upper Deschutes River Watershed (at that time, construction of Willamette Highway no. 58 had just been completed; Newcomb, 1941). Part of the task was to quantify the benthic and planktonic communities and to classify the lakes accordingly.

Each lake was assigned a numerical grade (or index value) that ranged between 1.0 and 2.5. The magnitude of the number depended upon the degree of eutrophy (i.e., the more eutrophic the lake, the larger the number). The number itself was based on a set of limnological conditions that were common to each lake.

If a lake received a number between 1.0 and 1.5, it was classified as oligotrophic (implying that the value 1.0 represented ultra-oligotrophy). The ensuing ranges of values from 1.6 to 2.0 and 2.1 to 2.5, designated lakes that were eutrophic and advanced eutrophic, respectively. Interestingly enough, Odell Lake was graded 1.4.

WALDO LAKE

Waldo Lake is located in the Willamette National Forest, approximately 89 km. southeast of Eugene, Oregon, and 14 to 16 km. north of Odell Lake. The lake basin, estimated to be 10,000 to 12,000 years old, is a glaciated depression enclosed by end and lateral moraines (E. Taylor, personal comm.).

The extreme oligotrophic nature of Waldo Lake, Oregon, was first reported in a document prepared by the State of Oregon Sanitary Authority (presently the State of Oregon Department of Environmental Quality) and the U.S. Forest Service (Carter et al., 1966). Data reported from the study suggested that Waldo Lake may be one of the most oligotrophic lakes in the world. Subsequent research as a part of this study verified the 1966 report.

Before 1969, Waldo Lake was nearly inaccessible to vehicular traffic. Use estimates by the U. S. Forest Service for the period 1966-1968 showed a yearly average of 33,000 visitor days (i.e., one person visiting the lake for 12 hours equals one visitor-day). In June, 1969, a paved highway was opened leading to several newly constructed campsites situated along the east shore of the lake. Consequently, visitor-day estimates for 1969 and future years were expected to rise dramatically.

The lake changed little, if at all, during the time before 1969 when the number of users was limited. Now that the lake is easily accessible and construction projects are disturbing the watershed, continuous limnological monitoring is essential. This research will hopefully provide a reference point, allowing responsible agencies to estimate periodically the effects of population impact on the Waldo Lake basin.

WOAHINK LAKE

Woahink Lake is situated on the central coast of Oregon, approximately 165 km. west-northwest of Waldo Lake. The lake basin, typical of nearly all the coastal lakes in the state, is a former stream valley obstructed at its mouth by alluviation and sand dune encroachment (Baldwin, 1964). The movement of sand is generally in an easterly-northeasterly direction. In places along the west shoreline, the lake is adjoined by dune complexes.

Among the study lakes, Woahink Lake probably receives the widest variety of uses. And, the lake is used continually throughout the year.

Use-estimates for Woahink Lake were not available. As one would expect, recreation ranks highest among all uses received. The number of persons who visit the lake for this purpose has increased noticeably over the last 5 to 10 years (C. Mulvey, Woahink Lake resort owner, Florence, Oregon, personal comm.).

More than 150 summer cabins and permanent residences line the shore of Woahink Lake. Nearly 20% of these have been constructed since 1964. (C. Mulvey, personal comm.). Domestic sewage is handled by septic tanks and drainfields.

Water is pumped from the lake and, sans treatment, is used for drinking and other domestic purposes. This is approved by the Lane County Health Department which periodically examines the water to see that it conforms with accepted bacteriological standards of purity. They have insured that domestic wastes will not be discharged directly into the lake. Samples of water tested for coliform bacteria resulted in MPN values ranging from 2 (June, 1964) to 22 (July, 1969) (R. Burns, Lane County Health Dept., Eugene, Oregon, personal comm.).

During the tourist season (June-August), weather and daylight permitting, a commercial floatplane makes, on the average, four take-offs and landings per hour. The quantity of oil that is put into the water by this operation is indeterminable. In places along the shoreline, an oil scum will develop, usually following a period of intensive floatplane use.

Several land-development projects have denuded large watershed areas that adjoin the lake. Most notable among these is an extensive recreational facility situated on the terminus of the north-central peninsula. The work has generated a considerable amount of exposed, unconsolidated material, much of which has been consumed by erosion and discharged into the lake. Consequently, the water in the vicinity of the peninsula has become extremely turbid (D. W. Larson and J. G. Malick, aerial observation, August, 1969).

PHYTOPLANKTON PRODUCTIVITY ESTIMATES

Biological productivity in a lake environment begins with the phytoplankton. These are the primary producers, the productivities of which are controlled by temperature, light, and nutrients. The productivity or trophy of a lake is determined at this first trophic level, then, by the response of the phytoplankton to its environment.

The net primary productivity of the phytoplankton was estimated periodically for each of the four study lakes. Production was measured *in situ* with carbon-14.

Detectable concentrations of chlorophyll a provided a partial estimate of phytoplankton biomass. Analyses for chlorophyll a were conducted in accordance with Strickland and Parsons (1965).

Net phytoplankton productivities (in $mgC/m^2/hr$) among the four study lakes for 1968 and 1969 are compared in Figure 3. The values for 1969 are related to concentrations of chlorophyll a per square meter (Figure 3).

CRATER LAKE

Net productivity for Crater Lake--often regarded as being extremely low in biological production (Nelson, 1967)--averaged 6.70 $g\ C/m^2$/month (June-August, 1968) and 6.61 $g\ C/m^2$/month (July-August, 1969). Concentrations of chlorophyll a ranged from 8.4 to 60.0 mg/m^2.

ODELL LAKE

At all times, primary productivity in Odell Lake greatly exceeded that of any other study lake (Figure 3). Productivity was generally higher in 1968 (averaging 67.8 $g\,C/m^2$/month, July-September) than in 1969 (averaging 40.7 $g\,C/m^2$/month, July-September). Concentrations of chlorophyll a ranged from 52.7 to 150.7 mg/m^2.

The average volume of plankton collected in Odell Lake in September, 1940, was 1.8 mg/m^3 of water (Newcomb, 1941). Thereafter, the production of plankton increased considerably. In 1968 and 1969, the September hauls yielded 15 to 25 mg of plankton/m^3 (very rough estimate by the author).

WALDO LAKE

Waldo Lake certainly ranks as one of the most oligotrophic and consequently, the least productive, freshwater temperate lakes ever encountered. The total production estimate for a 103-day sampling period (21 June to 3 October, 1969) was only 4.225 $g\,C/m^2$. Concentrations of chlorophyll a were similarly low, ranging from 0.263 to 9.4 mg/m^2.

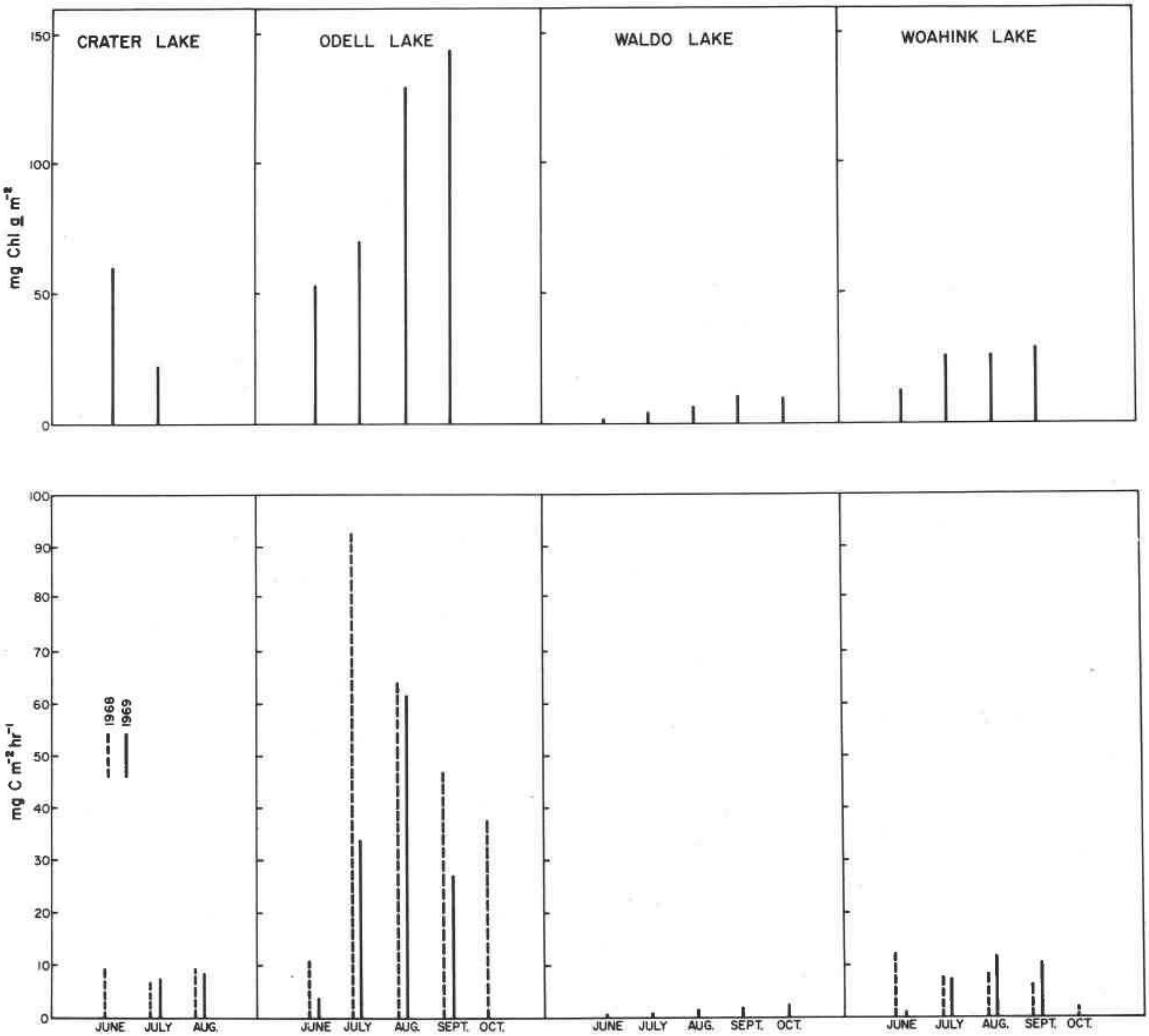

Figure 3. The monthly average rates of production (lower panel) and concentrations of chlorophyll a per meter squared. Chlorophyll data taken only in 1969.

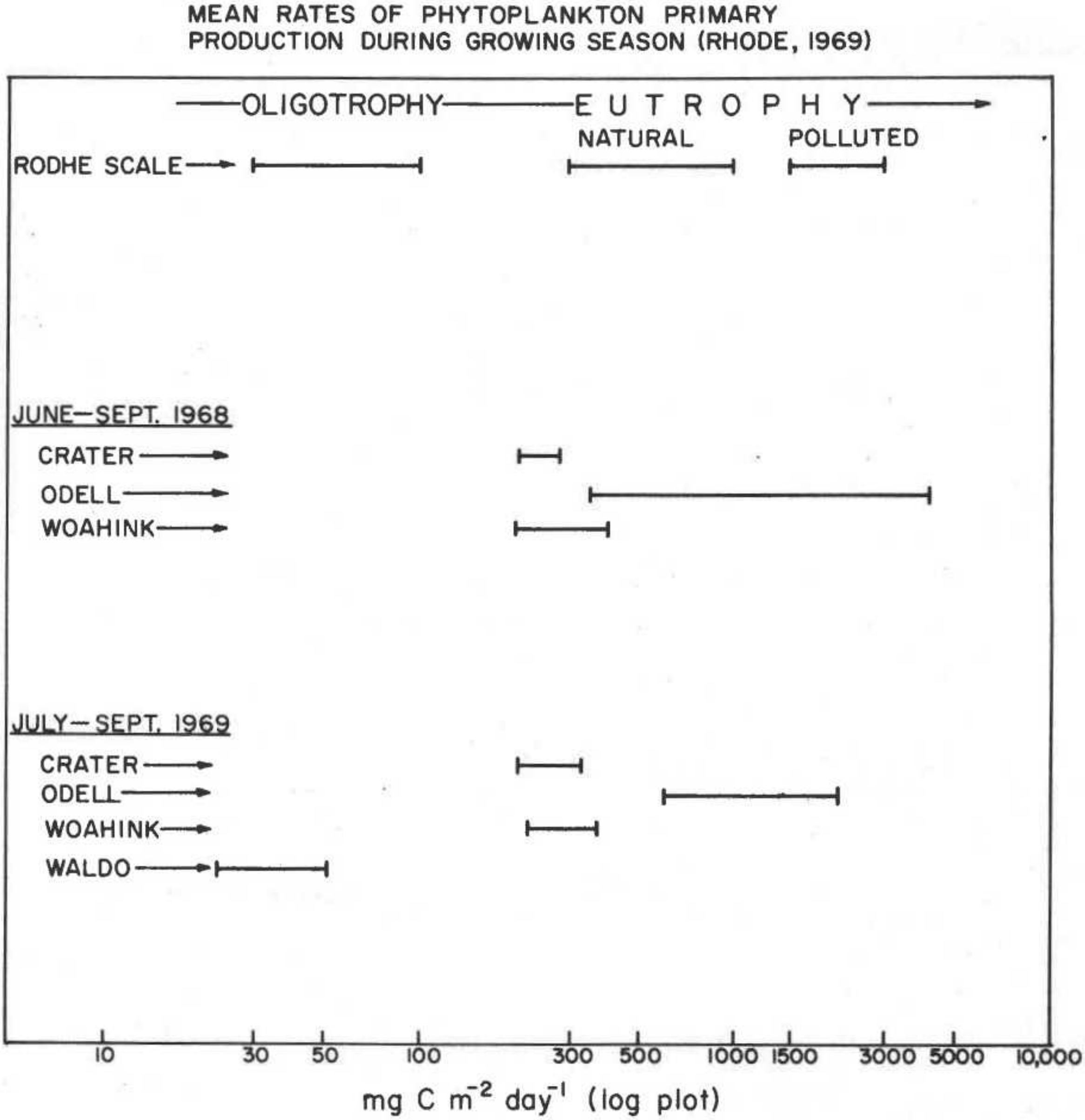

Figure 4. Approximate ranges of phytoplankton primary productivities for the study lakes compared with the Rodhe (1969) scale for oligotrophic and eutrophic lakes.

WOAHINK LAKE

In terms of phytoplankton production per unit area, Woahink and Crater lakes closely resembled one another (Figure 3). Net productivity for Woahink Lake averaged 7.9 g C/m^2/month (July-August, 1968) and 9.4 g C/m^2/month (July-August, 1969). Total annual productivity (June 27, 1968 to June 13, 1969) was calculated to be 37.2 g C/m^2/ year. Concentrations of chlorophyll a were reasonably uniform from July to September, 1969 (Figure 3), ranging from 24.5 to 29.8 mg/m^2.

CULTURAL EUTROPHICATION

The use to which each of the study lakes is being put has been discussed. Where human activities are restricted, eutrophication will proceed at a rate that is determined primarily by the natural factors of the basin environment. On the other hand, where the lake is used for any number of purposes, eutrophication is likely to accelerate beyond natural limits.

Rodhe (1969) established rather precise boundaries in graphically depicting the various stages in lake evolution (Figure 4). The relative positions of the study lakes in Figure 4 are most interesting in view of how each is being used. Waldo Lake is certainly where one would expect it to be--as is Woahink Lake. The degree to which Odell Lake has approached eutrophication on Rodhe's scale is somewhat alarming. The position of Crater Lake is the most surprising, being as far up the scale as it is.

Lakes are undergoing continuous physical, chemical, and biological changes in response to natural and, especially, cultural impositions. As a result, lakes will evolve or age by advancing to a higher level of productivity. For example, consider the trophy change that has taken place in Odell Lake over the past 30 years in spite of its "oligotrophy" classification. What is needed, then, is a periodic re-assessment of lake productivity and, if possible, a re-assignment of respondent lakes to an advanced trophy category. Certainly this will be needed, considering that most of our valuable water resources are being threatened by man's involvemnt with nature.

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Presented May 21, 1970 by DR. WILLIAM J. MC NEIL, Marine Science Center, Oregon State University.

Future Opportunities for Aquiculture

The appearance of Russian fishing vessels off Oregon was headline news in 1966. Plans for a nuclear steam-electric power station on the coast near Florence were announced this spring. These events, though unrelated, may portend new opportunities for farming in Oregon.

The coming of Soviet fishermen was anticipated by fisheries experts. Soviet research vessels had earlier located quantities of Pacific hake, rock fishes, sablefish, and Dover sole in Northwest waters. Since 1966, the annual harvest by this Russian fleet has included between 250 and 300 million pounds of hake and lesser quantities of other species.

The standing stock of hake off the Pacific Northwest has been estimated by Alverson (1958) to be about 1,500 million pounds. Alverson predicts that this stock can sustain an annual harvest of between 300 and 540 million pounds. Species of food fish off Oregon which remain relatively untapped by either domestic or foreign fisheries probably exceed the standing stock of hake; hence, large reservoirs of animal protein exist off the Oregon coast.

The ocean is an important source of animal protein for the dietary of poultry, swine, cattle, and freshwater fish (catfish and trout). Large quantities of fish meal and oil are imported into the U.S. from Peru and other countries. Increasing world demand for meal and oil should soon direct our attention to stocks in Northwest waters. Hake and other species could become important to the growth of Oregon's agriculture in the 1970's.

The waste heat from steam-electric power stations might also contribute to Oregon's economy through uses in agriculture (Boersma, 1970) and through the development of a new aquiculture industry. The Northwest has traditionally depended upon hydroelectric power, but the capacity of streams to generate electrical energy has largely been developed. The demand for electrical energy in the Northwest is expected to treble over the next 20 years, and large steam-electric stations will need to be constructed. Because fossil fuels are in short supply, it appears that the Northwest will make use of nuclear energy.

Utilities are examining coastal sites for future steam-electric stations because of the availability of cold ocean water for once-through cooling. Nuclear steam-electric stations now in planning will generate at least 1,000 megawatts of electrical power and will release at least 2,000 megawatts of thermal power as a waste by-product. This compares with about 500 megawatts produced at Bonneville Dam on the Columbia River. Where once-through cooling is employed, the coolant water released from a 1,000 megawatt plant would ideally be about 700,000 gallons per minute and would have a temperature about 8°C warmer than the incoming water. By using a substantial portion of this heated water in aquiculture, it is conceivable that several million pounds of fish and shellfish could be produced annually at individual stations.

PRINCIPLES IN AQUICULTURE

One premise of aquiculture is that higher levels of animal production are possible in water than on land. There are a number of explanations why this should be true:

(1) Aquatic animals require less skeletal support than terrestrial animals since they live in a medium of approximately their own density. A higher percentage of their assimilated energy can therefore be devoted to production of edible musculature.

(2) Fish and shellfish are cold-blooded and do not expend a significant portion of their caloric intake to maintain a constant body temperature.

(3) When reared in brackish water approximately isotonic to their body fluids, fish and shellfish expend relatively little energy in osmoregulation.

(4) Sessile forms, such as oysters, expend relatively little energy in searching for food.

The more advanced systems in aquiculture employ hatcheries to provide seed stock; whereas, the least advanced systems rely upon natural populations to supply juveniles to be raised under semi-controlled conditions. Before a food fish or shellfish can be raised successfully under the more advanced systems, the animal must exhibit certain characteristics (Bardach, 1968).

(1) Adults should reproduce in captivity or semi-confinement or yield easily to manipulations that result in the production of their offspring;

(2) eggs and larvae should be hardy and capable of being hatched or reared under artificial conditions;

(3) food habits of larvae and young should be satisfied by operations which can increase natural food, or they should be able to take prepared feeds beginning with their early stages;

(4) juveniles should gain weight rapidly and show a high conversion efficiency.

PROBLEMS IN AQUICULTURE

Aquiculture requires substantial investments in equipment and facilities and much labor must be expended to maintain healthy stocks of fish or shellfish and to harvest and process animals. The market value of products of aquiculture must compare with the better cuts of beef if the producer is to realize a profit with present technology. Because aquiculture is still in an early stage of technological advancement, we can anticipate innovations which will reduce the cost of production as science and technology begin to attack the problems. There is already speculation that the catfish farming industry in southern states will follow a pattern similar to that of the broiler industry.

Most of us can recall when broilers were a high-cost luxury food favored primarily for an occasional Sunday dinner. This changed in the 1950's and 1960's: The average price of broilers dropped 50 percent in the 15-year period 1949-64.

The break in price was made possible only after serious disease problems and nutritional deficiencies were understood and methods of control were devised. Fast growing breeds of chickens were developed through selective breeding, and "factory" methods of production were adopted. The outcome is obvious in the market today where poultry ranks among the least expensive of our meats.

We are still attempting to lay the biological groundwork in aquiculture which someday could provide the foundation for technological innovations necessary for commercial production of food fish and shellfish. The important biological problems can best be described as primary and secondary limiting factors (Shelbourne, 1970):

(1) Primary limiting factors
  (a) The provision of high-quality "seed stock".
  (b) Food supplies for captive stock at different stages of development.

(2) Secondary limiting factors
  (a) Physico-chemical conditions.
  (b) Stock/space relationships.
  (c) Disease.
  (d) Predation and cannibalism.
  (e) Competition

YIELDS IN AQUICULTURE

If the important biological problems can be resolved, aquiculture holds the promise of high yields from small bodies of water. Production of wild fish stocks in the more productive marine waters compares favorably with cattle on pasturelands (20 to 300 pounds per acre per year) (Ryther and Matthiessen, 1969). By contrast, the culture of oysters in Japan has produced 46,000 pounds of meat per acre per year and of mussels in Spain 240,000 pounds. Such high yields are made possible by suspending shellfish from rafts and growing them in vertical columns where currents deliver a continuous supply of algae to the feeding animals.

High yields can also be obtained by raising fish in ponds and raceways on artificial diets. Raceways with flowing water are the most productive, with yields up to one million pounds per acre per year reported for carp and 70,000 pounds for trout (Anon, 1967). The yield of catfish raised in static ponds may be two thousand pounds per acre per year, but this can be increased 50 percent or more by introducing small volumes of flowing water (Anon, 1970).

The passage of heated discharge water from steam-electric stations through raceways may afford aquiculture opportunities for significant expansion in this decade. One analyst (Gaucher, 1970) concludes that the projected volume of heated water from U.S. thermal power plants will be sufficient by 1980 to raise between 1.3 and 2.6 billion pounds of fish and shellfish annually. An aquiculture industry producing this poundage would require only about 10 percent of the total discharge water from power plants.

The development of aquiculture at steam-electric stations could introduce a new opportunity for growth of the domestic commercial fishing industry. The total U.S. commercial catch has remained static at about five billion pounds annually for the past 30 years. The increased demand for fishery products in the United States has been satisfied by increasing imports which now supply over 75 percent of the total market.

RESEARCH AT OREGON STATE UNIVERSITY

Development of an aquiculture industry at coastal steam-electric stations is an important goal of aquiculture research at OSU. Our program currently places emphasis on Pacific salmon and oysters.

Salmon and oysters enjoy a strong market demand and bring high prices. Knowledge of their life histories and ecological requirements is fairly complete. Both have been raised in hatcheries.

Pacific Salmon

Of five species of salmon which spawn in Northwest streams, three species (chinook, coho, and sockeye) feed in fresh water as juveniles and two species (pink and chum) enter the ocean as unfed fry. When young salmon enter the sea, they must be able to maintain a proper balance of water and salts in their body tissues. To avoid dehydration while at sea, salmon drink water and excrete excess salts. Pink and chum salmon are able to excrete excess salts as young fry, but the other species grow to a larger size before they are prepared physiologically to live in the ocean.

OSU has constructed an experimental hatchery at Netarts Bay, Tillamook County, to produce young salmon for release directly into salt water. Land for the hatchery was a gift of Mr. and Mrs. Victor A. Swanson. The Fish Commission of Oregon, the Bureau of Commercial Fisheries, and the Sea Grant Program have provided financial support for the project.

Three species of salmon were released from the hatchery this past winter and spring in an effort to develop a source of seed stock for future salmon aquiculture: 393,000 pink salmon, 220,000 chum salmon, and 75,000 chinook salmon. Success of these releases will be judged by the number of spawners returning in later years. Surviving pink salmon are expected in summer 1971: chum and chinook salmon are expected in autumn 1972.

Other experiments on salmon culture are underway at Port Orford, Curry County, where we have converted a former Coast Guard Station into a marine research laboratory. Young chinook and hybrid salmon (chinook X pink and chinook X chum) are being acclimated to sea water at an early age. We find for example, that the pre-migratory young of chinook salmon can be acclimated to live in ocean water by first raising them for six weeks in water of low (16‰) salinity. Chinook salmon released at Netarts Bay in spring 1970 were acclimated to live in ocean water by this method.

Further studies are being planned jointly by OSU and the Bureau of Commercial Fisheries to determine the effects of temperature and ration on growth of juvenile salmon in salt water. Under favorable conditions in nature, salmon will increase their body weight by two percent per day. A growth of 2.4 percent of body weight per day has been achieved in a Canadian laboratory (Brett and Sutherland, 1970). If we knew how to achieve this rate of growth in thermally regulated sea water, we could produce a one-pound fish in 21 weeks.

Our preliminary goals with salmon, then, are:

(1) To develop a source of salmon seed stock to serve an aquiculture industry.

(2) To understand the role of temperature and ration on growth of salmon in thermally-regulated sea water.

Attainment of these goals is essential if we are to progress to the next important objective -- viz. pilot production at a coastal steam-electric station. Pilot production should begin in the mid 1970's when the first coastal nuclear power plant in Oregon is scheduled to go on line.

Oysters

Oyster culture dates back at least to the days of the Roman Empire. Oyster seed is usually collected from natural waters and raised under semi-controlled conditions. Considerable attention has been given recently to the production of oyster seed in hatcheries, and the OSU pilot oyster hatchery is the first facility of this type in the Pacific Northwest.

The pilot oyster hatchery was constructed with funds from the University and the Oregon Cooperative Oyster Marketing Association. The Association was organized by Oregon oystermen and the Lincoln Development Corporation to work cooperatively with OSU to determine the feasibility of constructing a commercial hatchery. We are now entering our second year of production of oyster seed from the hatchery. Several operational problems have been identified, and some have been solved. We hope soon to approach our target production of 20-25 bushels of oyster seed per week (one bushel contains about 10,000 juvenile oysters attached to shell).

The hatchery has already proven to be a valuable asset to other research. Our study of oyster genetics, financed by the Hill Foundation, is made possible by the fact that we can crossbreed selected adult oysters with reasonable assurance that a substantial quantity of juvenile oysters will result. We also have experiments underway on physiology, feeding behavior, and settlement of oyster larvae. These experiments require substantial quantities of oyster larvae which are readily available from the hatchery throughout the year.

Juvenile oysters from a hatchery need to obtain early growth before they are transferred to growing grounds. This is especially important in autumn, winter and spring, when the environmental conditions are apt to be most severe. The operation of a commercial oyster hatchery will require that juvenile oysters be held for several weeks in water having a temperature suitable for rapid growth. Heated discharge water from coastal steam-electric stations might be ideally suited for this purpose.

There might also be opportunities to link together the growing of salmon and oysters in a symbiotic "factory type" aquafarming system. Nitrogenous wastes and carbon dioxide from the salmon would enrich water for phytoplankton. Perhaps other trace elements could be added along with an innoculum of plant cells to stimulate a rapid "bloom." Water would then be "filtered" through a bed of oysters which would feed on the phytoplankton.

SUMMARY

The ocean enriches our lives with high-quality animal protein. Heavy world use is being made of marine fish in agriculture and aquiculture, and the demand for "industrial" fishery products continues to increase at a rapid rate.

Oregon fishermen have access to large stocks of industrial fish, but these fish do not enter the domestic fishery in any substantial quantity. Efforts are underway to develop the biological background for aquiculture at coastal steam-electric stations. Production of poultry and other farm animals might also expand in Oregon to make fuller use of fish protein from our coastal waters.

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Presented May 28, 1970 by DR. JEFFERSON J. GONOR, Marine Science Center, Oregon State University.

Oregon Coastal Marine Animals

During the summer of 1967, we began a research program at the Marine Science Center on a basic, if somewhat obscure, problem in marine biology which since then has become of immediate practical significance for coastal water quality and its management. Because of accelerated use of Oregon coastal and estuarine waters and the growing national interest in maintenance of high quality for all water uses, there is a pressing need for a capability for prediction of the biological effects of human use of these resources.

The long range scientific objective we set for our program was to develop the capability to predict what effects fluctuations in the physical environment have on the marine biota. This objective is relevant to oceanography's goal of understanding long-term pervasive biological and physical changes in the sea and the relation between large-scale physical and biological oceanic processes. We set out to achieve our objective by studies designed to determine how environmental factors affect the occurrence, distribution, and population density of marine littoral species.

The marine intertidal habitat and its biota was chosen for detailed study because of a number of characteristics which have long attracted marine biologists, and has made the biology of intertidal organisms better known than most other marine forms. The major ones are:

1. It is represented in some variation in all oceans.

Note:

Full title is "Oregon Coastal Marine Animals, Their Environmental Temperatures and Man's Impact."

2. It is essentially a two dimensional habitat for the permanent biota, with its vertical range greatly restricted in space, making it feasible to examine this dimension in its entirety at any one place.

3. It is directly accessible throughout the year.

4. The biotic community is characterized by a rather high species diversity and a high density of many species, providing a suitable range of types of organisms in adequate numbers for study.

5. Most of this biota is sessile or sedentary and their occurrence and distribution is not affected over short periods by migrations or currents.

6. Many of the most abundant species are long lived; this and their sedentary nature make these populations relatively stable. The state of the population may be assessed and then later re-studied to detect changes due to long-term environmental fluctuations.

7. The vertical range of the tides impose a major environmental gradient of fixed direction and known periodicity.

These distinctive characteristics make the intertidal community appear to be a closed, independent system but instead it is an integral part of the larger coastal ecosystem, and can reflect changes in the coastal water mass as well as any shallow water subtidal component of the system. At high tide, the physical environment of the intertidal biota is the sea itself. While the majority of the resident species are sedentary as adults, some of the browsing and predatory fish of this community move in and out with the tides and are free to range horizontally along the shore.

Of more importance is the link the intertidal community has to the larger inshore marine system through its energy relationships and the role inshore water movements have in dispersal ofits larvae. Suspended debris and plankton form the entire food source of many of the intertidal animals. Some of these filter feeders, such as barnacles and mussels, form the greatest part of the intertidal animal biomass, and their nutrition is dependent on the productivity of the inshore water mass.

Reproductive success of most intertidal species is dependent upon the survival of larvae released into the sea, to become part of the inshore planktonic community and subject to its environmental pressures such as predation, temperature and food production.

GENERAL UNDERSTANDING NECESSARY

The complexity of the intertidal community is so great that it is impossible to simultaneously measure all interaction of the organisms with each other and with all physical factors of the environment. The only feasible approach to a direct analysis has been to describe the general community at reference stations and begin to follow these populations with time while searching for mechanisms through which the more abundant species are affected by the environment.

Because of year around cold oceanic water conditions along the Oregon coast, the possible range of temperatures experienced by intertidal animals as they are alternatively exposed and covered by the tides is great. We accordingly placed early emphasis on studying temperature as a possible critical environmental factor controlling the activities of the organisms under study.

In order to understand the significance of our findings they must be related to the oceanographic regime in Oregon coastal waters, for this is the context within which comparisons must be made. A general understanding of coastal oceanic features is also necessary in evaluating the possible effects of human alteration of coastal waters, and in comparing the local situation with that elsewhere. Especially in regard to temperature. Pacific Northwest coastal waters are unique and resultsfrom elsewhere will not necessarily apply here. The reason for this is best understood by first examining the large-scale oceanographic features of the area.

The general oceanic climate of the Eastern North Pacific has a controlling effect on inshore sea surface temperatures along the Oregon coast. The major oceanographic feature dominating the marine climate off Oregon and California is the California Current, a great offshore oceanic surface stream about 350 miles wide.

It originates in the North Pacific Ocean as an eastward flow, influenced by the strong westerly wind of that latitude. After going across the Gulf of Alaska, it turns south along the coast, moving slowly at about half a knot. This southward flow of surface water is about 200 meters deep and is cooler and less soline than the Ocean surface waters west of it.

The deep oceanic water underlying the California Current is colder and more soline than the Current. Such deep oceanic water off Oregon is located rather close inshore because the Continental Shelf here is only 9 to 30 nautical miles wide (Byrne, 1963a, b). The cool temperature of the Current is the basis for the generally cool Pacific coastal climate of both the land and the inshore surface waters derived in part from the Current, and the area it dominates along the Pacific Coast is inhabited by a cold water biota mostly of northern origin as far south as Pt. Conception, California.

COMPLEX AND VARIABLE CHARACTERISTICS

Between the California Current and the coast is a narrow region in which occur complex water movements showing great seasonal variation compared to the steady southward flow of the Current. The environmental water temperature of the coastal oceanic biota is dependent upon the complex and variable temperature characteristics of this inshore region. And since any possible influence of man on this water temperature regime could be of importance, we will now examine what is known about it.

In the summer, even close inshore the currents move in the same southward direction as the California Current offshore. However, at this period of the year coastal water temperature are not those of the California Current. Strong northwest winds from the prevailing North Pacific high pressure system blow parallel to the coast during the spring and summer in the same southerly direction as the flow of the Current.

This wind and the rotation of the earth causes inshore surface water to be transported west, offshore and away from the coast. Because of the narrow Oregon Continental Shelf, this displaced surface water is replaced from below rather close inshore by upwelling of the deeper, colder water. This effect can be measured within 5 to 10 miles of the shore. The occurrence of upwelling and the resulting low summer inshore water temperature is a major influence on the annual environmental temperatures experienced by the coastal organisms.

Along the Oregon coast upwelling occurs from May to September and is most intense during the spring and summer. It lengthens the cold water period of the year and reduces the range of seasonal coastal water temperatures well below that of the offshore wat er which would otherwise approach the coast.

The largest Pacific coast upwelling area extends from just north of San Francisco Bay to Central Oregon and centers on the Cape Mendocino and Cape Blanco areas, because upwelling is greatest on the southern sides of large projecting points. Along the shore where upwelling takes place, surface water temperature throughout the year is lower than that of more southerly areas still within the California Current influence but where little or no upwelling takes place.

Even at times of the year when the northwest wind is weak, it may still cause some upwelling, adding to the stability of the low inshore temperature of coastal Oregon.

Northwest winds along the coast diminish during the fall and after a transition period are replaced by variable winds mainly from the south and southwest. A seasonally occurring surface current flowing from the south, the Davidson Current, appears in the inshore region between the Oregon coast and the California Current.

It can be detected off Oregon from October through March (Burt and Wyatt, 1964) along coastal Oregon and Washington. The flow of this countercurrent is quite variable and is increased by the southerly winter gales. More saline and warmer water from the south is brought by the counter current close inshore where the eddys and currents of the nearshore region intensively mixes it with cooler water.

The Davidson Current has the effect of prolonging the warm period of the year, since it occurs in the period just following the summer when atmospheric warming of the surface waters is greatest. The highest surface temperatures of the year may occur during the early fall at Oregon shore stations. Surface temperatures along the Pacific Coast in the early winter characteristically show an abrupt drop. Bolin and Abbott (1962) attribute this to the sinking of heavy Davidson Current water and its replacement by an onshore flow of cold offshore surface water in Monterey Bay, California. But farther north, insolation is also sharply reduced by cloud cover in the fall and the abrupt drop in Oregon waters may also be related to seasonal cooling at a rate faster than the Davidson Current water can bring heat into the area.

TEMPERATURE AND SALINITY

Coastal surface temperatures reach their annual minimum during the winter as cooling and mixing continue. Subtidal coastal organisms experience low sea temperatures of a narrow range at this time of the year. The intertidal biota is exposed by the tidal excursion to even lower air temperatures and so experience a slightly greater but lower winter temperature range.

Fig 1

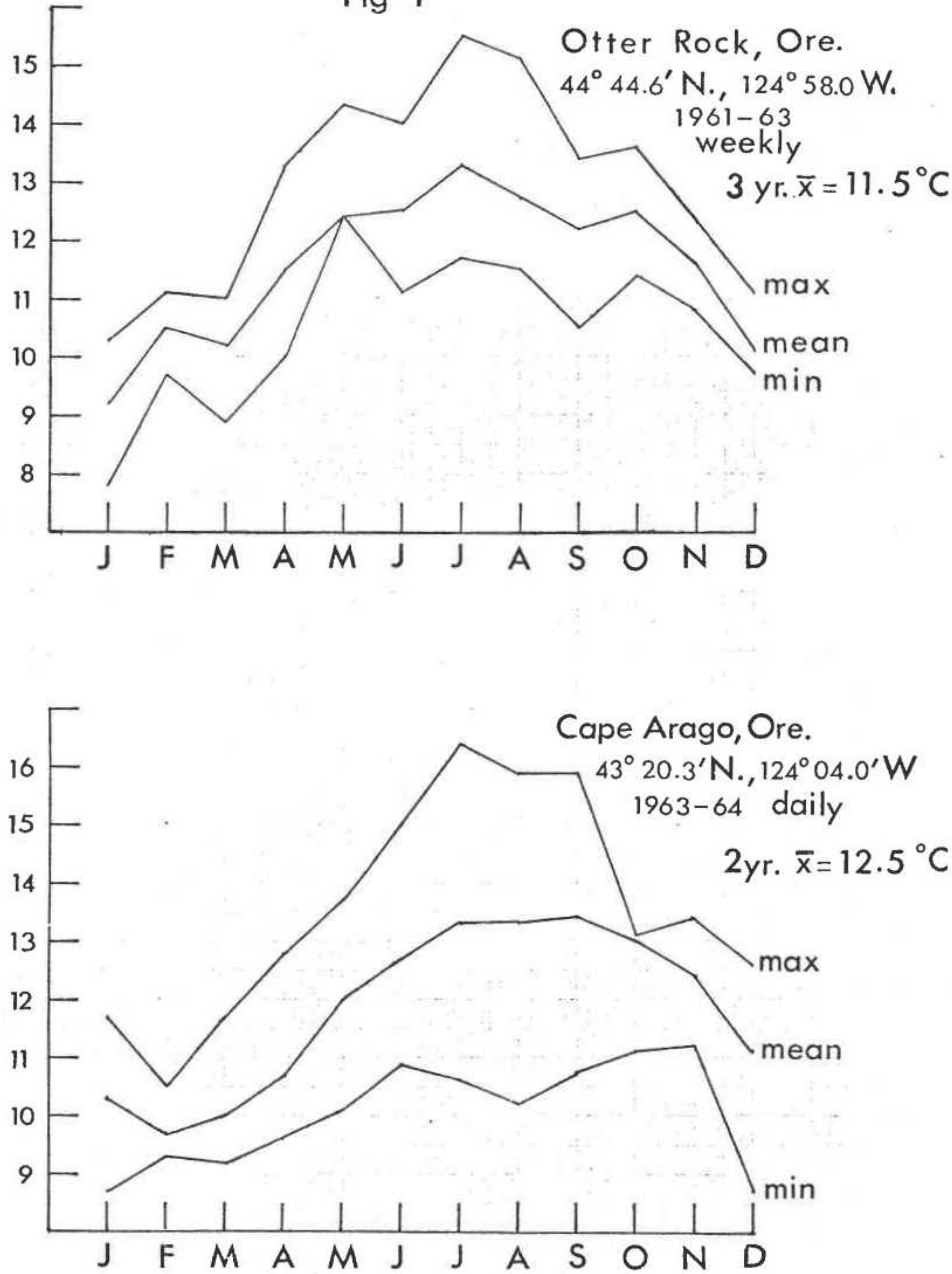

Figure 1. Temperature curves for Oregon Coastal Sea Surface Temperature Stations.

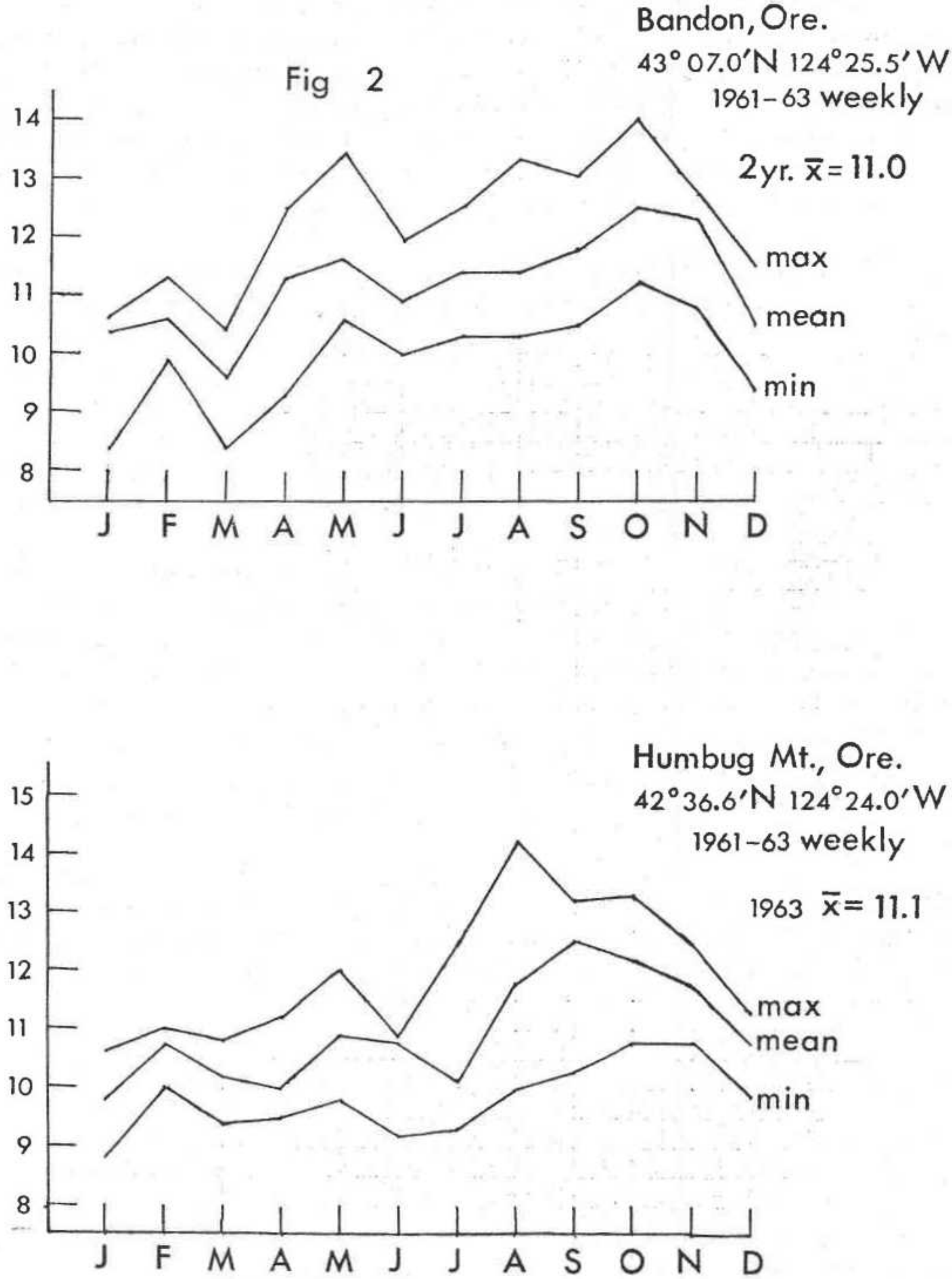

Figure 2. Temperature curves for Oregon Coastal Sea Surface Temperature Stations.

Temperature and salinity observations at shore stations on the Oregon coast have been made at weekly intervals by the Department of Oceanography of Oregon State University for several years. These observations make possible a more specific description of oceanic water temperatures along the Oregon coast. Average monthly maximum and minimum and monthly mean temperatures derived from these measurements for several stations are given in Figures 1 and 2.

The annual mean surface temperature at these beach stations is between 11° and 12.5°C, with a range of from 5 to 7 degrees. At all stations the yearly low of 8°C is reached in December and January which is also a period of narrow temperature range. Increasing temperatures of greater range in the earl y spring is followed by a drop and narrowing of range in June, as upwelling commences. Differences in the summer temperatures of these stations is largely due to local variations in the intensity of this upwelling.

Increased insolation begins to warm the upwelled water faster than it is displaced and a slow increase in summer temperature and a more rapid increase in its range is evident. The annual maximum of about 16°C occurs in August and September at most stations while the minimum is about 10°C. An unexplained drop in September is followed by a slightly warmer October with a mean of about 12.5, and a narrow range, marking the onset of the Davidson Current period. This is followed by a steep decline to the annual low range of late winter.

While the weekly measurements made at the shore stations permit a general description of the nature of the annual cycle in inshore sea surface temperatures, they are inadequate for assessing short term variations in this complex region. Sampling frequency has a strong effect on shore station sea surface temperature curves.

Daily or twice daily measurements begin to reveal the very variable nature of these temperatures, and indicate the fallacy of using 'average' temperatures in making biological correlations or in calculating temperature differences for thermal discharges into coastal waters. We have been making daily measurements at Agate Beach, Oregon during the fall and winter periods and twice daily measurements during the upwelling season for several years. Figure 3 summarizes some of this data. Within a single year, intermitten upwelling during the summer months can considerably modify seasonal temperature cycles.

Fig 3

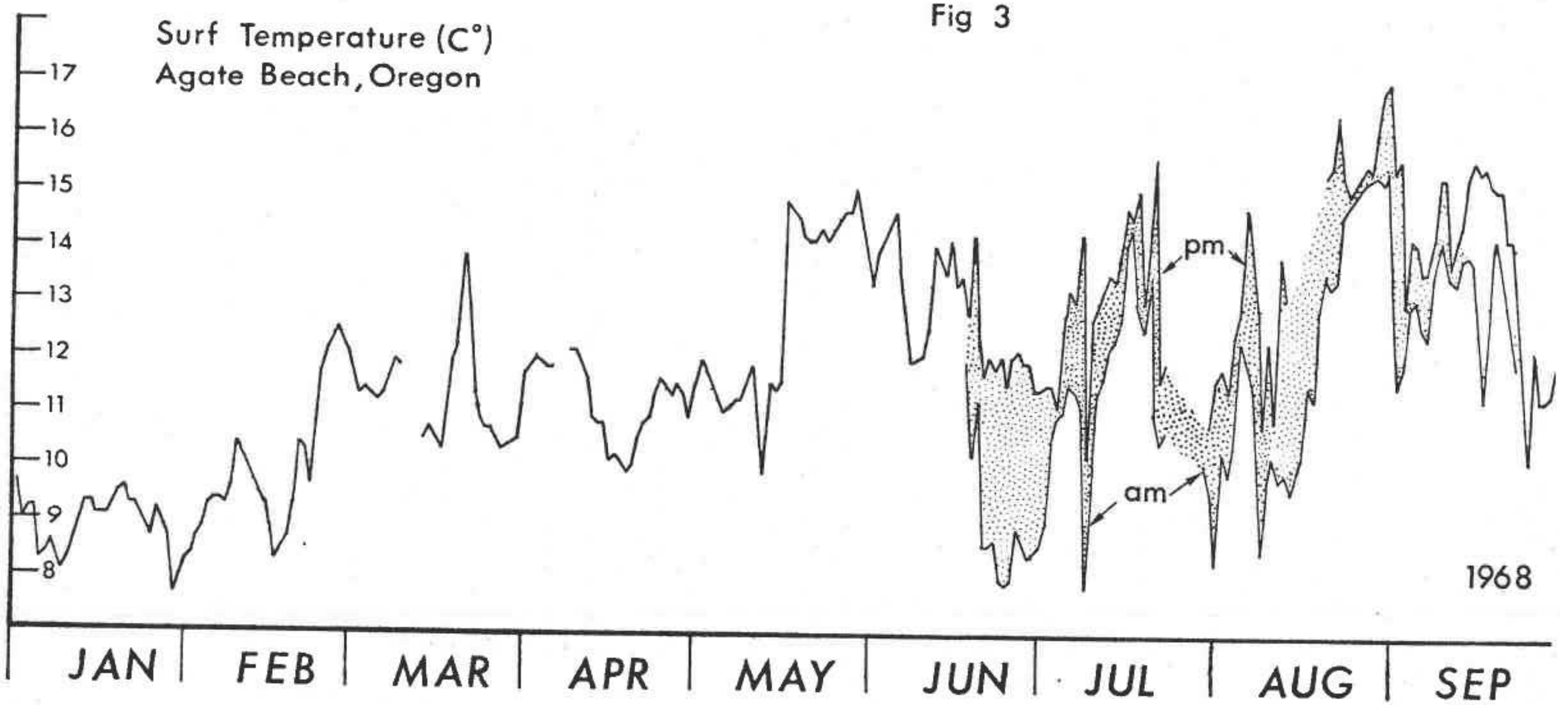

Figure 3. Daily Sea Surface Temperature at Agate Beach, Oregon for 1968. AM and PM measurments indicated for summer months.

The nature of this variability is exemplified by data taken during June, 1968, when temperatures ranging between 7.8°C and 14.6°C were measured. These temperatures span the entire annual range for this locality and the differences between morning and afternoon were often as great as the differences between some monthly averages. Temperature adaptations in organisms experiencing this type of temperature regime cannot be expected to be to some simple upper or lower level, but to some complex function of time duration and temperature level.

It is clear that variations in the wind regime produce correlated changes in the pattern and intensity of upwelling along this coast, and this results in many other changes in the inshore waters. Such perturbations affect all components of the ecosystem of the inshore waters in a complex, interrelated fashion.

The most important of these long-term fluctuations in environmental factors seem to be those of temperature. Anomalous, non-seasonal variations of inshore water temperature along the Pacific coast, usually lasting several months, have been detected when the monthly averages for each year are compared with the monthly averages derived from many years measurements. These relatively small variations in oceanic temperatures and associated changes in the seasonal current systems are believed to be a major cause of large scale biological changes along the Pacific coast.

These changes have been detected through studies designed to investigate changes in the commercial fisheries, especially that of sardines off California because the most notable biological effect of these variations has been large fluctuations in the abundance of fish taken in the fishery. Periods of unusually intense upwelling and low temperatures in the early months of the year occurred during the spawning season of the sardine in the past and the anomalously low temperatures apparently reduced breeding success in this fish below the level necessary to sustain the populations subjected to intense fishing pressure.

These California Cooperative Fisheries investigations also discovered changes in the distribution and abundance of other organisms. Since these studies emphasized the pelagic fisheries resources and associated organisms, only the effects on pelagic and planktonic animal populations have been detected. If these fluctuations from long term averages in oceanic climatic conditions affect the benthic intertidal and subtidal fishes and invertebrates, they have gone unnoticed in the past because no long term studies were in effect which would have detected them.

MORE INFORMATION NEEDED

The foregoing summary of Oregon coastal oceanography shows that we have a general picture available of the annual water temperature regime, but do not have very much information about the extent of small deviations from the average annual cycle or their biological effects.

When we examined what was known about the other component of environmental temperature of the intertidal biota, the temperature experienced at low tide, we found that even less information was available (Hedgpeth and Gonor, 1969). Because of their ease of study and proximity to coastal discharge sites, intertidal forms are often picked for ecological monitoring for pollution effects, including temperature, making the study of their normal temperature experiences of practical importance.

With the aid of an electronic thermometer and probes constructed of thermistors mounted in the tips of hypodermic needles, we have studied the temperatures experienced by intertidal animals at low tide, and the rate of change in these temperatures. Experiments on temperature tolerances based on these field measurements have also been conducted so that we have tolerance data based on realistic estimates of duration, levels and rates of temperature exposures.

Our first results showed that in spring and summer, intertidal animals along our coast commonly experience at low tide temperatures 10 to 15°C above the sea temperatures they experience the same day at high tide.

For the mussel, *Mytilus californianus*, we found that in June, 1968, the mean internal temperature of the population exposed by morning low tides was commonly between 19 and 24°C, and occasionally between 27 and 31°C, while the sea surface ranged between 9 and 14°C. Individual internal temperatures as high as 34°C were recorded. The rate of heating at low tide during this period proved to be rather rapid (Fig. 4).

Observed rates of increase were on the order of 1° C per 20 minutes. Other animals, such as barnacles, turban snails, limpets, and chitons, from the same higher intertidal habitat showed similar elevated temperatures upon exposure. Conversely, in winter rapid cooling below ambient sea surface temperatures takes place at low tide, when the animals experience near 0° C temperatures in December.

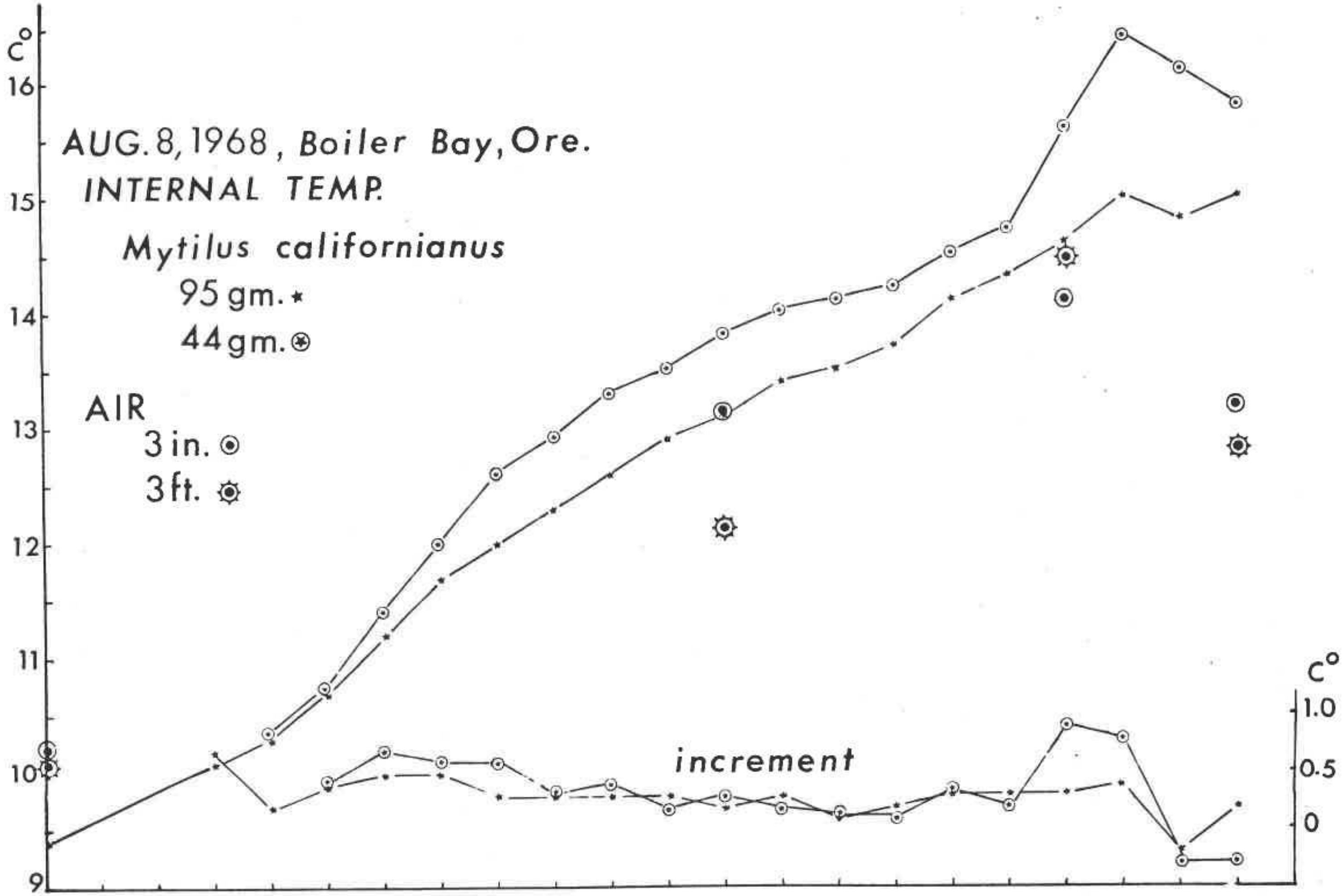

Figure 4. Internal Temperatures of two *Mytilus californianus* measured at five minute intervals at low tide.

During the 1968 field work, a fortuitous opportunity arose to study the limiting effect on an intertidal population of elevated temperature at low tide. While we were making measurements of low tide internal temperatures in the sea urchin, Strongylocentrotus purpuratus, an animal which inhabits the lower part of the intertidal zone, we observed that the urchins were showing signs of extensive damage and mortality.

We were able to demonstrate that a naturally occurring heat kill, resulting from solar thermal radiation, was happening in the population that we were studying. This was the first such observation outside of tropical areas, and is of practical importance because this sea urchin is known to be very sensitive to physical environmental factors, and has been proposed as an indicator of chemical and thermal pollution along the Pacific Coast. They inhabit hemispherical burrows in rock and are thus kept cool on the bottom side, but at low tides on early summer mornings commonly show a population mean internal temperature of from 15 to 23°C along the Oregon coast.

In May, 1968, mean internal temperatures of 26°C were recorded on several successive days at low tide in beds of urchins exposed to the sun. Some urchins had internal temperatures of 27°C to 30°C. On successive days the population along the coast were exposed to this level of heating for periods of three to five hours, after which damaged, and dead and dying individuals were numerous on many beaches along the central Oregon coast.

We were able to demonstrate that heating to 26°C was critical in this animal, and that individuals which experienced in the field temperatures above this were injured irreversibly and would die within 24 hours.

MORTALITY MEASUREMENTS

These sea urchins are oblately spheroidal in shape, about three inches in diameter, and a dark purple color. At least half of their dark body surface is thus exposed from above. By both repeatedly measuring the internal temperatures of a sample of the population after tidal exposure and following continueously the change in internal temperature of individuals, we were able to monitor natural rates of heating.

We found that these animals behaved thermally like a water-filled black body, warming at nearly linear rates approaching 5°C per hour under suitable climatological conditions in 1969, a year when no heat kills were observed. On succeeding mornings, as the time of low

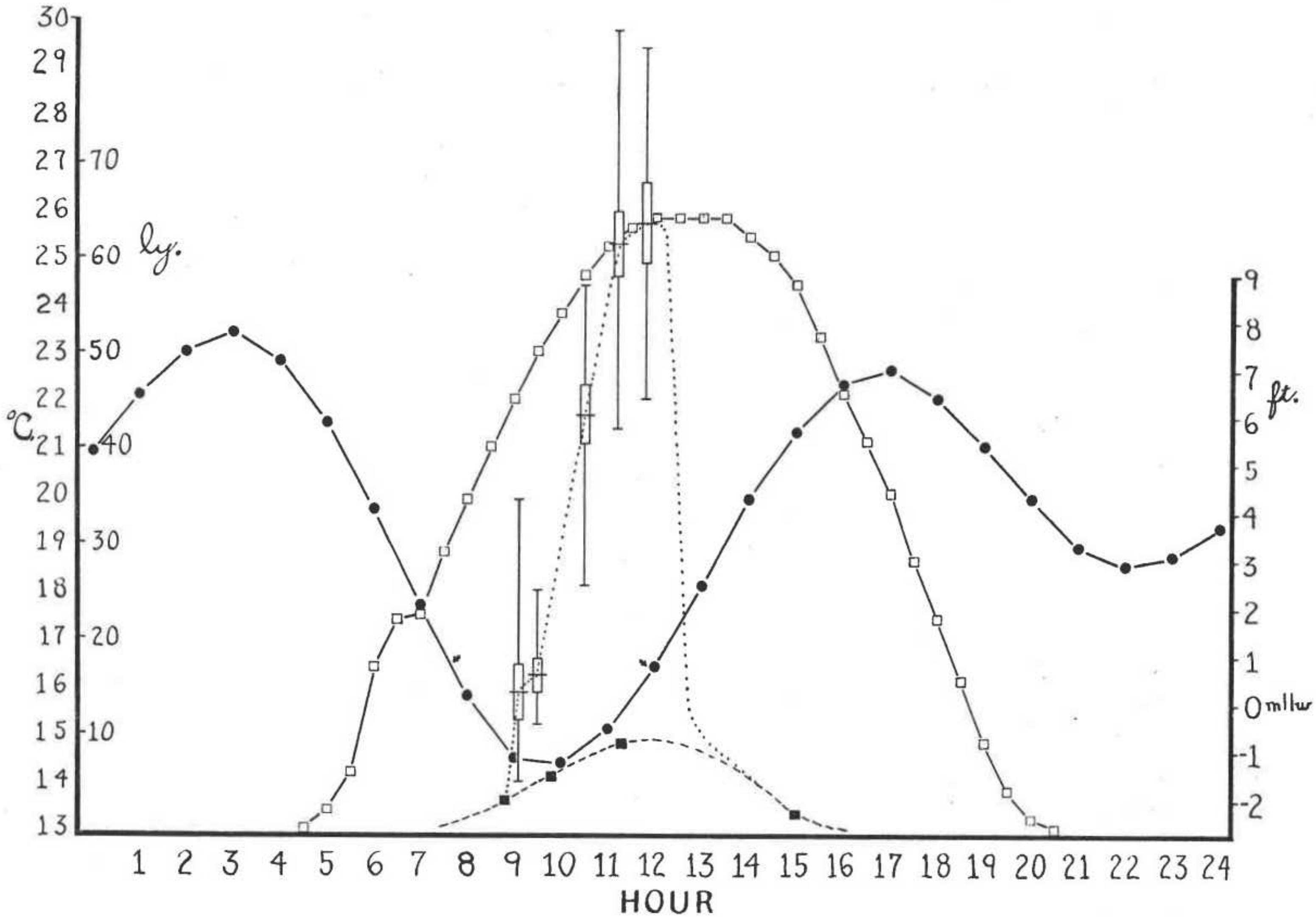

Figure 5. Lethal Heating in the Boiler Bay population of the sea urchin, Strongylocentrotus purpuratus at low tide on June 16, 1968. Urchin measurments (dotted line) given as range, mean and ± 2X standard error of sample of 30. Solid circles, tide levels; solid squares, sea surface temperature at Boiler Bay; Open squares, total radiation in Langleys, cumulative for half hour intervals. Urchins exposed and covered by the tide at points indicated by arrows.

tide occurred an hour later each day, the animals were exposed to the sun at higher angles of elevation and the maximum temperature measured increased by about one degree per day. With some total incident radiation measurements available, we were able to begin to define the conditions of time of tidal exposure, climatological and meteorological conditions which would bring about mortality in the populations.

Laboratory experiments on the role of desiccation in this mortality permitted us to estimate the lethal effect of different temperature and humidity combinations at different air speeds, for animals adapted to both winter and summer conditions. Winter adapted animals have a lower tolerance to both desiccation and temperature than do summer adapted ones. It is for this reason that the species experiences occasional natural mortality in the spring when conditions at low tide exceed their winter upper limit of heat tolerance which they normally approach during tidal exposure in spring and summer.

From laboratory experiments we determined that 50% mortality occurs in groups of animals which have experienced an internal temperature of 25°C for one hour while submerged in water. The lethal effect of this treatment is not immediately apparent; those individuals which will not survive the heat damage die over a period of 4 to 5 days after being returned to ambient sea temperature. This is similar to the continued, gradual mortality observed after the heat kill conditions occurred.

During the heat kill period in 1968, an unshielded recording pyrheliometer was in operation at the Marine Science Center, as well as a recording tide gauge. The tidal level of occurrence of the urchin beds was measured, and the tide gauge record indicates the period of time this level, +1 ft. above MLLW, was exposed. In Fig. 5 the tidal curve for the day and the radiation curve for the same period are plotted. During the period of tidal exposure, the internal temperature of the urchin population was measured five times, at hourly intervals.

The mean, standard deviation and range of these measurements (n=30) is also plotted in the same figure. The urchin internal temperatures rose rapidly after they were exposed at 9:00 A.M., coincident with the rapid and steady rise in radiation. During the third and last hour of tidal exposure, the population was exposed to the highest thermal radiation intensity of that day, and the mean population internal temperature was above the critical level of 25°C for almost an hour. The population range went well above this, and the experimental results described above indicate that it was those individuals whose internal temperature was above 25°C that died on subsequent days.

Another dark colored animal, the turban snail, Tegula funebralis, appears to represent the other extreme of temperature adaptation for intertidal life. This animal occurs in the high intertidal, up to +7 feet above MLLW, is exposed for long periods of time and regularly experiences in nature internal temperatures as high as 33°C, attained at heating rates as fast as 7°C per hour without mortality. We have shown by temperature tolerance experiments that this snail can tolerate heating in water at the maximum rate observed in the field to the highest levels observed with no mortality.

They can survive being maintained at 30°C for 9 hours, the maximum tidal exposure possible in Oregon at the upper limit of their intertidal range. This animal, in contrast to urchins, does not live near its maximum "time/temperature/desiccation" limits. An internal temperature of 37 to 39°C, experienced for more than three hours, is required to produce 50% mortality in Tegula, conditions which do not appear to ever occur naturally in Oregon.

The dark color of the urchin probably contributes to the effect that solar radiation has on that species and consequently might appear to be a disadvantageous characteristic for intertidal animals so far as their heat budget is concerned. Examination of the thermal characteristics of the mussel, the turban snail, and of a black chiton from the same habitat indicate that this cannot be true.

In the case of the turban snail, we demonstrated experimentally that the dark color increases the heat absorbed at low tide (Fig. 6), but this does not raise the temperature to levels of practical significance to this thermally resistant species and so the black color is not disadvantageous. The mussels are also black and while they heat to surprisingly high levels, are also resistant and the color seems irrelevant to their thermal biology. The chiton, Katharina tunicata, has low tide internal temperatures 10°C to 15°C higher than the sea surface in June, but is also a thermally resistant species showing no mortality from this heating.

It is also a herbivore and its gut is filled with digesting algae at low tide. It is possible that the increase in temperature facilitates digestion and increases the rate at which the animal can process and use food. In this case dark color and high temperatures at low tide may be an advantage as they are in the marine iguana (Bartholomew 1966).

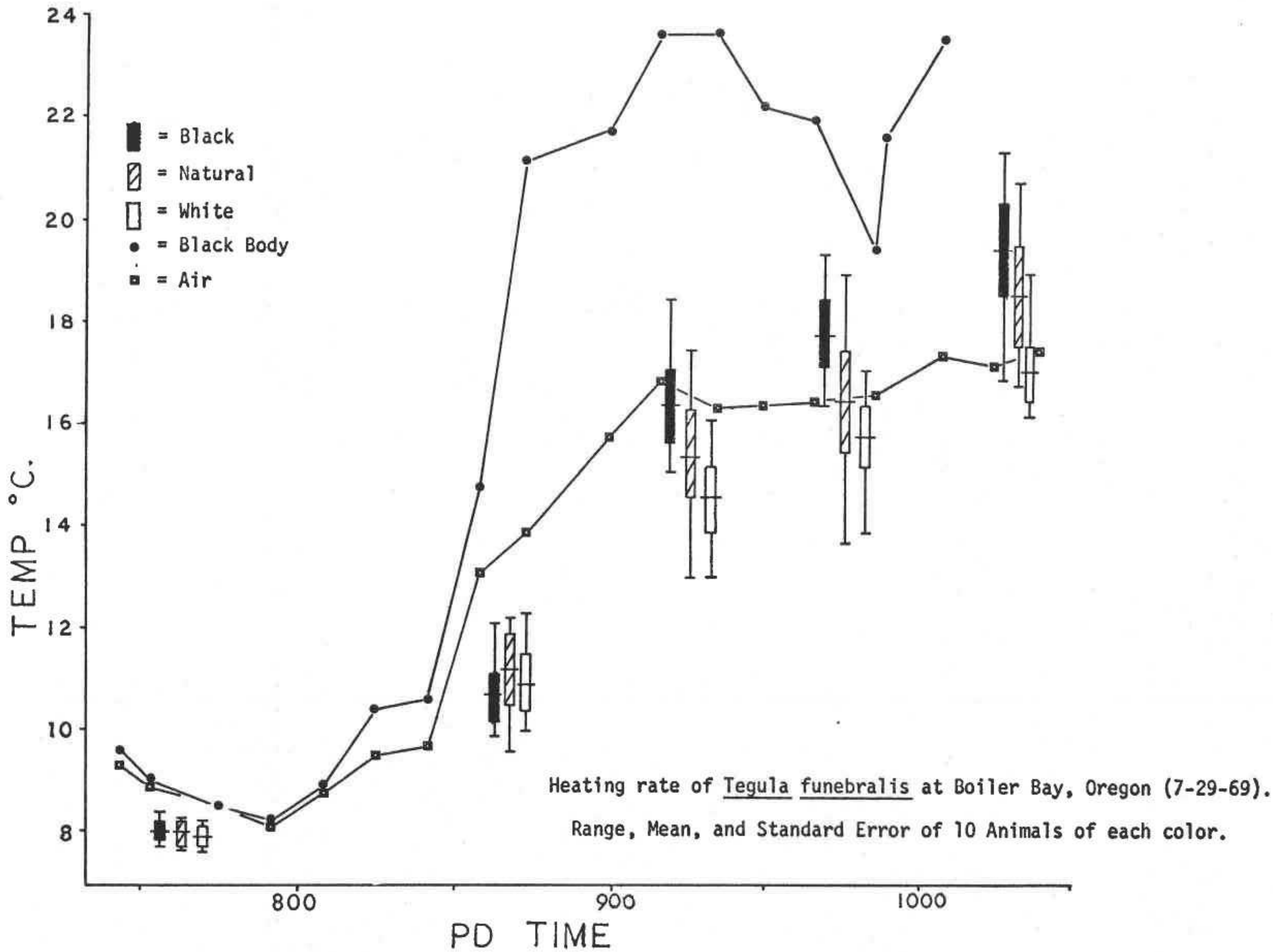

Figure 6. Mean, range and ± 2X standard error given for natural colored, black painted and white painted animals. Squares, air temperature in shade; solid circles, black body temperature.

VARIABLE THERMAL DISCHARGES

Our work to date shows that marine intertidal animals experience a much greater range of temperature than has been previously known, and that data now available on inshore sea and air temperature is not adequate to predict either the range or levels of temperature they normally experience. There is no accumulation of data on the actual temperatures they experience to compare with possible alterations of inshore sea temperatures by thermal effluents. Some effluents may produce temperatures normally tolerated at least for short periods. But, intertidal animals differ in their temperature characteristics, even though most have a rather high tolerance as adults.

Others, like the purple sea urchin, are so sensitive that natural variations in environmental temperatures can lead to significant mortality in the populations. Fluctuations in abundance caused by such sporadic natural events can only be recognized if long term population monitoring studies are conducted. Experimental work on the thermal tolerance of these and other marine animals must be based on measurements of naturally experienced levels, rates, durations, etc. and their seasonal differences if such work is to have any ecological relevance.

A great deal could be learned about possible effects of variable thermal discharges into coastal waters by comparing intertidal and subtidal animals in thermal tolerance and acclimation experiments with simulated natural and altered daily and seasonal thermal curves for the two types of habitat. Such experiments would permit examination of the effect of normal as well as altered ranges of environmental temperature on survival, growth, and reproduction.

Despite the convenience of their use, intertidal animals should not be the only forms used to determine typical tolerance levels upon which permissible limits for alteration of coastal water temperatures would be based. The subtidal, planktonic and nektonic coastal biota are adapted to a narrower range of water temperatures, a range which ends more than 10°C below that of the intertidal biota. This component of the coastal biotic community must be considered to be the most sensitive when seeking limits on man's warming of coastal waters.

The most significant source of man-caused warming of coastal waters now is steam generating plants producing electrical power. This will grow rapidly in the future if the electrical power industry predictions and plans are realized. Other industrial uses of coastal and estuarine water for cooling seem minor when compared to the projected number and size of coastally located power plants using nuclear reactors as the energy source and requiring large amounts of sea water for cooling. Very little can be accurately predicted about the effects of these plants on Oregon coastal envirnomental temperatures and biota, but the problem can be reviewed with information we have now.

The smallest nuclear thermal plant being considered for a coastal location is one of 1100 MW capacity, using something like 1.3 billion gallons of once-through cooling water a day with an average Delta T of about 11°C and a dwell time inside the system of some 10 minutes. The mass of water affected is far greater than the billion gallons a day as currents exchange the water in the intake and mixing areas. Only benthic organisms in the vicinity of the outfall will be under its constant influence and these can be studied for possible changes in their species composition, numbers, growth, etc. relatively easily.

While increased temperature may make possible increased growth, a net increase in production may not result from a sub-lethal increase in coastal sea temperature by power plant effluent. Ansell (1969) found that the growth of clams from an area warmed by power station effluent did not result in increased production throughout the year because while the temperature caused increased metabolic rate, food was limiting at most seasons.

The seasonal cycle of spring phytoplankton was not affected so that food in excess of normal use was present only for short periods, during which an accelerated growth rate was made possible by the temperature increase. During other times of the year, the warming increased metabolic needs beyond the naturally available supply of food and body weight fell. But what of the effect on the whole inshore ecosystem as plant after plant is added along the coast?

The vastly more abundant planktonic species which vary seasonally will be affected in a different way from the benthic biota. The mass of water in the vicinity of the intake and outfall will be ever changing, so that the potential effect is spread beyond the confines of the immediate vicinity, and this sort of effect is seldom mentioned let alone studied. Because of the great abundance and diversity of oceanic plankton, potential effects are far greater than that in a river or lake with a much less diversified planktonic biota.

EFFECT ON PLANKTON

What will be the effect on planktonic populations which will be carried into the area as their water mass is entrained and mixed with the warm effluent water? At present all that can be offered are some guesses as to the possible temperature effects. Two of these are:

1. Faster growth of producers during seasons when nutrients are not limiting, faster feeding and metabolism of the grazers and carnivores, resulting in a change in the net production at each level, the direction and amount depending on how increased temperature affect different species. A water mass so affected is very different as it moves past the area of temperature influence. How would such a change affect the general inshore balance over larger areas? Will it be of a magnitude to be of any significance to overall production? These questions are presently beyond our predictive capability.

2. Differential mortality, changing community interrelationships throughout the food web, so that a community of different structure is formed in the water as it moves away and gradually mixes elsewhere. Again, if this happened, would the magnitude be of any significance?

Another question that arises is what would be the effect on the plankters taken into the condenser cooling water? Because of the abrupt temperature change, a lethal effect is the first to be anticipated since boreal marine plankters have a narrow range of temperature tolerance in keeping with their stenothermic habitat.

If questions such as these appear to be merely academic, consider only the calculations of Morgan and Stross (1969). Phytoplankton in cooling water in the Patuxent River estuary, Maryland, is destroyed by passage through the condensers of a thermal plant, both by heat and chlorination and some other factor of passage, possibly turbulence or abrasion.

Their calculations based on minimum estimates indicate a reduction 424 TONS of dry weight phytoplankton a season (ca. 120 days) to the system they study. Near the same plant, Anderson (1969) demonstrated a disappearance of one abundant rooted plant due to thermal effects, and its partial replacement. Wood and Zieman (1969) have also noted the destruction of macro-algal and rooted plants at Miami by a thermal effluent. These plants are imprtant sources of primary production in shallow waters.

The change in primary productivity of the Patuxent estuary system has also been estimated by Hamilton, et. al. (1970). Their work indicated that the station reduces the primary production of the cooling water by 91%, and cause a calculated maximum loss of primary production of 6.6% for the adjacent tidal segment of the Patuxent River.

Adult copepods received fatal injury from a trip through the same system (Heinle, 1969). The quantity of estuarine copepods killed did not apparently alter the seasonal patterns of distribution and production, but what of the whole system? Quantitative information is lacking, as is information on latent effects of passage. Possibly the only effect of the death of some adult plant and animal plankton would be to increase the detrital supply available to detritus feeders in the outfall vicinity. This might be called the hot cooked meal effect.

We urgently need a start on studies of the coastal marine biota conducted over long periods of time so that normal fluctuations in abundance can be recognized and considered when the effects of thermal additons are under evaluation. For both the organisms in the water mass affected by the warm effluent flow and those in the water passing through the condensers, differences in sensitivity between species and seasons should be expected, but we do not have sufficient information now on thermal tolerances and seasonal acclimations of sufficient numbers of species in our coastal biota to begin to speculate about such effects.

MORE WORK ON BASIC QUESTIONS

An ecological effect potentially more serious than cooked copepods and algae, is the possible killing of the pelagic larvae of ecologically and economically important animals such as fish, crustaceans, and molluscs that would be pumped through condenser cooling systems and entrained in effluent flows. Many marine species have rather short life spans and regular recruitment to the adult populations from the larval stock produced during short annual breeding seasons is critical to the survival of such species.

Breeding periods of different species are scattered throughout the year. Planktonic crustacean larvae for example are always present in shallow inshore areas along the Oregon coast, but reach peak abundance during winter and spring. Larvae are very much more temperature sensitive than adults of the same species. The thermal tolerance of larvae of West Coast species is not well know; especially do we lack information on the effects of thermal shock. Fragmentary and anecdotal accounts of apparent passage alive through condenser cooling systems have been given for oyster and shad larvae, but what was the Delta T at the time and what was the quantitative effect?

Again, if lethal effects on some individual planktonic larvae coming under the influence of a thermal power station were to be demonstrated, what is the magnitude of this for the inshore adult populations? Would the added larval mortality from being passed through the condenser system or swept into the effluent water by entrainment be of a magnitude to be significant compared to natural mortality, which we know must be enormous? And what of the times marine biologists call 'bad larval years', when survival is suppressed through natural environmental perturbations?

We have neither the data on annual differences in larval production and mortality, nor the data on acute and long term temperature tolerances to make scientifically responsible predictions for the Pacific Coast, and scanty data from elsewhere is useless to us. Practical evaluations of the effects of thermal power plants and how much overall warming of the coastal zone is tolerable will be inconclusive without further work on such basic questions as what natural factors affect survival of marine larvae and determine their seasonal and spatial distribution.

Some experiments in England (Barnett and Hardy, 1969) indicate that the larvae of the clam, Tellina tenuis, could possibly survive the temperature experience of passing through the cooling system if no other lethal agent was present. Larvae grown at 14 - 15°C, the local sea temperature maximum, have an L.D. 50 of 32.6°C, and could only be subjected to 24°C in the condensers.

Other types of experiments on larval temperature responses can produce information with valuable predictive uses. As a part of a recently completed study (Lough, 1969) on the effect of temperature and salinity on the survival in culture of the larvae of the clam, Adula californiensis, response surface curves were generated for survival after three and fifteen days at different temperature and salinity combinations. This has permitted us to predict survival under many sets of temperature/salinity combinations not directly tested in the laboratory, and to project the results to the natural system. Adult populations, living permanently in the Yaquina Bay estuary, withstand a wide range of seasonal temperature and salinity conditions.

Comparison of the experimental results with the annual hydrographic regime of the Bay indicated, however, that larval survival is possible in the Bay for only a very restricted part of the summer. We could use the curves generated from the factoral experiment data to predict what maximum survival would be if this regime were altered permanently, or for three or fifteen day periods during the larval season. As comparable information is accumulated for developmental and larval stages of the more abundant and important coastal invertebrate and fish species, our ability to estimate the effect of thermal alterations on the coastal ecosystem will be greatly improved.

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Private Fish Ponds in Oregon

Privately owned impoundments with suitable habitat for fish have been built in every county of the State. There are over 1100 of them, ranging in size from 1/4 acre to 55 acres and they total 3000 surface acres. Washington, Clackamas, Yamhill, Polk, Marion, Linn and Lane counties have the majority of ponds. Polk County alone has well over a hundred.

The private pond owner's interest, background and willingness to manage his fish is the key to the production of fish and fishing in Oregon's private impoundments. He can buy fingerling trout from a number of private hatcheries in the state and several places in Washington. Each year county Extension agents coordinate the purchasing and stocking of about 125,000 trout in private ponds and some pond owners raise their own trout from purchased fertile eggs.

Largemouth bass, bluegill sunfish, black crappies, white crappies, yellow perch, pumpkinseed sunfish, warm mouth bass, bullhead catfish, and trout--particularly rainbow trout--all are living and growing in suitable Oregon ponds. In addition, the bullfrog has found a niche in privately owned impoundments and can provide excellent recreation and food. As a general rule, private ponds are very rich in chemicals and can produce an abundance of fish food.

The warm water game fish are able to spawn successfully in most ponds while the trout rarely spawn in them. Only two ponds in the last ten years have been observed where trout were able to reproduce. In both instances, cool, clean ground water entered the ponds through a layer of gravel joining a nearby river.

At present, trout spawning in tributaries to ponds is seldom successful. The stocked trout do not seem to find tributaries of ponds and use them for spawning. However, planting fingerling trout directly into the tributaries has resulted in the fish returning to the stream to spawn. This practice shows promise of producing sustained populations of trout and contributing to longevity of trout in farm ponds. Trout stocked in the ponds and not spawning do not live more than two or three years.

COOL RUNNING WATER

An excellent warm water game fishery can be produced in warm water ponds in Oregon. Temperatures have reached 75° F. at 6 foot depths in the Willamette Valley and southern Oregon ponds. Surface waters are frequently in the 80's. Ponds do not need a large flow of water during the warm summer months to provide suitable living environment for the warm water game species. Enough flow to compensate for evaporation or seepage is adequate. It keeps the water level constant, favors full utilization of chemicals for food production and enhances the warming of the water. A water temperature of 70° F. is ideal for bass growth and production. The bluegill prefers warmer temperatures.

On the other hand, trout in the smaller ponds need a dependable flow of cool running water during the months of June, July, August and early September. The time from July 20 to August 7 is the most critical period for water becoming too warm for trout in Oregon ponds.

A quantity of water equivalent to the flow of a 2 inch plastic pipe has provided the cool water and living conditions for trout in one and two acre ponds in the Willamette Valley during the critical warm weather summer days. In numerous instances, cold springs at the bottom of the ponds have provided the cool water. Even when surface temperatures have warmed to the 80's, the bottom temperature at 10 foot depths has remained in the 60's.

I do not recommend stocking trout in any small Oregon pond that does not have a dependable source of enough cool running water in the summer months.

Stocking rates and combinations to get the best fishing possible vary throughout the State for warm water game fish. However, ponds stocked with fingerling bass alone, at the rate of 400 fish per surface acre, have produced excellent fishing for 9-inch bass by September of the second summer in all areas of the State. Most warm water game fish ponds will grow 400 bass to catchable size. However, to insure continued growth of bass when stocking at this rate, at least a hundred of the fish should be caught and used when they have grown to 8 and 9 inches in length.

EXCELLENT TROUT FISHING

After the bass have spawned for the first time, stock 100 black crappies and 200 adult bluegills per surface acre in the pond. This stocking method indicates that the black crappie and largemouth bass are capable of foraging on small bluegills sufficiently to keep the pond in balance. In ponds stocked with only bass and bluegill the prolific and hardy bluegills have overpopulated the pond and destroyed the good fishing in three to four years.

The stocking of 1000 two to four inch fingerling trout per surface acre in ponds up to 2 acres in size has produced excellent trout fishing in suitable ponds all over the State. The trout need to be caught by the time they reach two years of age or are old enough to spawn. When trout are unable to spawn in ponds they have consistently died with unspawned eggs retained in their abdomens.

Occasionally, natural spawning does occur in ponds. When it does, the hook and line fishing from natural spawning is not as good as that provided by stocking. However, it has been good enough for family use in one acre ponds, and trout live longer and get bigger when they are able to spawn. To many pond owners, the knowledge of having a few "lunkers" in the bottom of the pond is better than catching ten to twelve inch trout on every third cast.

A number of private trout hatcheries operate in the State. They sell their trout to pond owners, U-Catch-Em enterprises, and market some directly to special eating places. Trout pond owners buy trout for several reasons. One is to have the fun and recreation of fishing and sharing it with friends. Another is to dependably produce fish for the table, and a number of people have trout for the feeling of ownership and the joy of watching them feed on the surface.

The news of producing channel catfish in the southern states has reached the ears of many Oregonians. Our Department of Fisheries and Wildlife anticipated local interest, and under the direction of Dr. Carl E. Bond, conducted a number of experiments with growth of channel catfish in our Oregon ponds. The fish did not demonstrate a growth under our pond conditions that would make it profitable. The growing season in optimum water temperatures is too short.

MANY QUESTIONS ARE POSED

The acclimated bullhead catfish (introduced in about 1870) readily reproduces and grows to two pounds in many Oregon ponds. These characteristics plus a ready market for catfish suggest their potential as a market fish. Again, the Department of Fisheries and Wildlife is experimenting with the brown bullheads to see if this fish has market possibilities.

Questions regarding fundamental husbandry need to be answered with this species. For instance, "How much artificial feed does it take to produce a pound of catfish?" "Will the fish grow to a pound weight in two years?" "How many fingerlings can one stock per acre?" A pond observation on yield in Jackson County several years ago, suggested a production of 500 pounds of live catfish per surface acre. These one to two pound catfish had been supplementally fed with trout pellets. Their age in relation to size was not known.

At this time, graduate student Jim Nielson and Dr. C.E. Bond, Department of Fisheries and Wildlife, are losing bullheads to Columnaris, a common fish disease, in our Oregon water. The disease is killing the bullheads at a rate fast enough to prompt serious thoughts about the success of the present research efforts and the feasibility of raising bullhead catfish commercially.

A thermocline usually associated with larger lakes, does occur in many one and two acre ponds. It is prevalent in rich ponds without a source of water or method of circulation during the summer months. An extensive thermocline can reduce the pond's food producing ability during the summer months.

Bullfrogs live and reproduce in farm ponds and swamps. However, even under favorable conditions, it takes three or four years to grow an edible sized frog. Therefore, it is impractical to grow bullfrogs commercially in Oregon, but there are enough of them to provide genuine sport in bullfrog fishing.

Recreationally, the bullfrogs are one of our finest game animals. To catch them with hook and line requires a good eye, knowledge of habitat, stalking, patience and skill in accuracy in casting, and self control in setting the hook and landing the frog. Field dressing is recommended and both bront legs and hind legs are used. They are a gourmet's dish when fricasseed like chicken.