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PUERTO RICO NUCLEAR CENTER

PROGRESS REPORT
MARINE BIOLOGY PROGRAM
FY-1965

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TABLE OF CONTENTS

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I. Title of Project: Marine Biology Program

2. Institution: Puerto Rico Nuclear Center

3. Project Abstract:

The research program outlined herein is a continuation of studies started at the Puerto Rico Nuclear Center in January, 1962 and continued to the present time. Although the program is composed of five major projects, its functions are integrated. The five original areas of research, although altered in some details to fit the aims of the program, are in progress at the present time. It is proposed that they be continued and that an additional area, Marine Ecology, be recognized.

The program was designed to provide measurements of the distribution and movement of selected trace elements in a restricted but complete ecological and biogeochemical system. It includes limited investigations of the lithosphere as well as detailed studies of the marine biosphere and hydrosphere.

In order to obtain information on interactions between the marine biosphere and hydrosphere, measurements are being made of biological productivity, amounts of trace elements in the organisms and the environment, biological half-lives of trace elements, characteristics of food webs, and the influence of physical and chemical oceanographic factors upon the distribution of trace elements in the marine waters, organism, and sediments offshore from the west coast of Puerto Rico. The latter studies include observations on the effects of varying rates of deposition of mineral-rich silt upon the distribution patterns of marine organisms. The research projects are as follows:

(1) Measurements of Biological Productivity.

The C^{14} method for measuring biological productivity is being used. The uptake of C^{14} is correlated with plankton volumes, amounts of chlorophyll, phosphate and nitrate content of the water, depth of water, distance from shore, amounts of suspended material in water, salinity, water temperature, and uptake of selected radioisotopes by phytoplankton. Productivity measurements have been made in water samples from the surface, 50 M and 300 meter depths in areas near and distant from the outflows of the Añasco and Culebrinas Rivers. Analyses have been started to determine specific activity of C^{14} in the total carbonate of sea water and in phytoplankton. The amounts of C^{14} in the samples are measured by β -counting and the total carbon content determined by a gas chromatographic technique.

(2) Analysis for Selected Trace Elements:

Trace element analyses have been continued in samples of marine organisms, sea water, marine sediments, river water, river sediments, and selected rocks, minerals, and soils of the Añasco River valley. The methods used to determine the amounts and forms of trace elements in the variety of samples include destructive and non-destructive neutron-activation analysis, atomic absorption spectrophotometry, flame spectrophotometry, colorimetric analysis, fluorometric analysis, X-ray emission spectrography, and X-ray diffraction analysis. In addition to the measurements of trace elements, analyses are being made for carbon, hydrogen, nitrogen, lithium, potassium, calcium, strontium, and magnesium in many of the samples. Until recently the amounts of elements were determined on the basis of ash, dry and wet weight of organism. The amounts of trace elements are now related also to the carbon, nitrogen, and hydrogen content of the samples.

(3) Measurements of Concentration Factors of Selected Organisms for Given Radioisotopes.

Uptake experiments have been started and will be continued using Mn^{54}, Cr^{51}, Fe^{59}, and Zn^{65} with *Tripneustes esculenta* (sea urchin); Mn^{54}, Cr^{51}, Fe^{59}, Zn^{65}, Rb^{86}, K^{42}, and Cs^{137} with *Sargassum lendigerum* and other selected algae; and Mn^{54}, Cr^{51}, Fe^{59}, Zn^{65}, and Ta^{182} with *Acanthopleura granulata*.

(4) Measurements of Radioactivity and Radioisotopes now Present in the Marine Organisms, Waters and Bottom Sediments off Puerto Rico.

Measurements of world-wide fallout in several large samples of marine sediment, algae, gorgonians, sponges, crustaceans, and fishes have been completed. The disintegration rates of the radioisotopes have been calculated on the basis of wet, dry, and ash weight. Co^{57}, to Co^{60} ratios have been measured in the samples and have been compared with the Co^{57}/Co^{60} ratio in samples from the Pacific Ocean. Determinations of specific activities for all of the samples are in progress (disintegration rate of radioisotope per gram of the corresponding stable element in the sample).

(5) Background Observations in Physical and Chemical Oceanography off the West Coast of Puerto Rico.

Measurements of bottom contours, salinities, temperatures, turbidities, dissolved oxygen contents, and current directions and velocities are in progress and will be continued. The work has been concentrated mainly in the area off the Añasco River and west of the Bonus site at Punta Higuero.

(6) Marine Ecology

The marine ecology project has been carried out on a limited scale as parts of projects two and three for the past two years. The ecological studies are concerned primarily with investigations of food web relationships.

Associations now under observations include algae-molluscs, algae-echinoderms, echinoderms-gorgonions, sponges-arthropods, omnivorous fishes, and mollusc-sipunculid-annelid-echinoderm-crustacean relationships to sediment compositions and sizes.

SCIENTIFIC BACKGROUND

Investigations of trace element distributions in the sea is of scientific interest in the field of oceanographic chemistry and in allied areas including those concerned with biological productivity, the influences of organic detritus upon the chemical and physical forms of elements in sea water, and the geochemical histories of elements introduced into the sea by natural processes.

In addition to the scientific value of the investigations, a knowledge of the biogeochemistry of trace elements is of critical importance to man insofar as radioactive isotopes of the same elements may become incorporated into food webs from which food for human consumption is derived. The distributions patterns of many of the trace elements in marine waters, organisms, and sediments have not been measured and even less is known of the relative influences of the physical, chemical and biological mechanisms which control the transport and distributions of these elements. Thus, little is known even of the relationships between rates of photosynthesis by marine phytoplankton and the rates of incorporation of trace elements into marine food webs.

Investigations designed to measure and define the relative and individual influences of the physical, chemical and biological mechanisms on the distribution of trace elements in a given marine environment may be better planned if they are based upon a prior knowledge of the natural distribution patterns, in the same environment, of selected trace elements which represent the different chemical groups. The analyses for the trace elements should be made on a limited number of minerals, rocks, soils, river waters and river sediments from the landmass which contributes trace elements to the neighboring marine waters and on a representative number of samples of estuarine and offshore deep-sea marine waters, pelagic and littoral organisms and sediments.

Several elements naturally present in trace amounts in the marine hydrosphere are concentrated by factors of at least 10^5 by some marine organisms. Radioisotopes of the same elements are present in radioactive wastes and contaminants produced in nuclear technology. An understanding of the geochemical routes of these stable elements may be utilized to predict geochemical routes of radioactive contaminants which may be introduced into the marine environment from a variety of sources.

The use of the oceans for disposal of low-activity radioactive contaminants is and will continue to be attractive for several reasons. Man resides primarily on land, which constitutes only 29.2% of the total surface of the earth. The remaining 70.8% is covered by the sea which is more or less remote from human habitation, contains a large volume of dilutant (approximately 1.4×10^9 Km^3), and has a mean depth of about 3800 $\pm$ 100 meters with deep trenches or depressions far removed from man or his food organisms. In addition, the division of the earth's crust between the deep sea and the continental blocks is abrupt, with the continental slopes accounting for not more than 6% of the total area of the earth. The oceans contain large amounts of salt (4.8×10^{16} tons) which may contribute to the process of isotope dilution (1). Because of the large quantity of contained salts, even those elements which occur in sea water only in trace amounts constitute a large reservoir of material for the dilution of radioelements introduced at a controlled rate.

The amount of a contaminant which may be introduced is dependent upon the degree of mixing or the distance in time and space from man or his marine food organisms. The degree of mixing is dependent upon dispersion, sedimentation and biological activity. Although some physical and chemical data are available which may be used to define the factors which govern the rates of dispersion and sedimentation of material introduced into given areas of the sea under specified conditions, other data are not available. The latter include (1) the distribution patterns of many trace elements in the marine environment both near and offshore,(2) the degrees to which specific marine organisms concentrate different elements and the individual variability which may exist within species from the same locality, and (3) the effects of biological activities and ecological relationships upon the distributions of the trace elements in a given geographical area.

The answers cannot be derived entirely from laboratory experiments but must be obtained from field observations, analyses, and experiments in a natural and functioning ecological and biogeochemical system. Certain laboratory experiments may be used to demonstrate and measure the underlying physical and biological mechanisms which control the patterns of distribution observed in the field work. Such laboratory investigations include: (1) the determination of the physical and chemical forms of trace elements in river water before and after mixing with sea water and the rates at which the changes in form occur, (2) the measurements of the rates at which precipitates, produced by the action of sea water on the major dissolved and colloidal elements in river water, settle as a result of gravity, (3) the measurement of the adsorptive capacities of known types of marine organic detritus, inorganic colloids and precipitates and specific marine sediments and (4) the determination of the rates of uptake and loss of radioisotopes of trace elements by dominant marine species of plants and animals.

SCIENTIFIC SCOPE OF THE RESEARCH

The research is designed to measure the distribution and, indirectly, the movements of selected trace elements from a land mass into the sea, the marine organisms and the marine sediments and to relate measurements of biological productivity and movements of organic components through food webs and chains with the incorporation and transfer of trace elements through the trophic levels.

The studies may be divided into two major divisions: (1) The measurement of the distribution patterns of trace elements in the watershed of the Añasco River, in the biosphere and hydrosphere of Añasco Bay and in the offshore areas in Mona Pass (fig. 1). This work includes studies on the interactions of the biosphere and hydrosphere upon the distribution patterns of the elements.

(2) The development of techniques with sufficient accuracy, reproducibility, sensitivity, and simplicity to achieve the measurements in a large number of samples. This includes not only the development of methods for trace element analysis in the microgram range, or less, but the adaption of ecological field procedures to quantitative measurements in which correlations of observations with large numbers of biological and environmental variables may be made by sorting the data with machine methods.

The initial plans for the geographical range of the marine biology program included the marine area west from La Parguera on the south coast of Puerto Rico, along the entire west coast, and east along the north coast to the town of Arecibo. However, the surveys which were needed to establish background conditions offshore from Punta Higuero, the site of the Bonus power reactor were given first priority in the program. This was done to establish the radioisotope levels in the offshore areas before start-up of the reactor so that subsequent alterations in the marine environment, produced by the operation of the reactor, might be utilized in the trace element studies. As a result of the observations in that work it became apparent that the geographical area of the investigations could be reduced without loss of scientific scope or coordination in program. Rather, a more closely integrated series of researches could be realized by studying a restricted but complete ecological and biogeochemical system-studies which included measurements of the movements of selected trace elements from the land mass, through the rivers, into the neighboring marine waters, through the marine biosphere and into the marine sediments.

The geographical area in which the marine phases of investigations have been concentrated for the last two years extends north from Mayaguez past Añasco Bay and Pta. Higuero to the mouth of the Culebrinas River and west into Mona Pass to Desecheo Island and Sponge Bank. The area includes the island shelf and waters to depths greater than 1000 meters (fig. 1).

A small sampling program was also initiated to provide samples from other marine environments for comparison with those collected in the experimental field area. Sampling, on a limited basis, has been completed in three areas: The open Atlantic Ocean to the north, the Caribbean Sea to the south. and an up-current area east of Puerto Rico. In addition, samples of sea water taken at depths to 4000 M in the open Atlantic Ocean have been provided by Dr. Vaughn T. Bowen of the Woods Hole Oceanographic Institute and dried samples of plankton and fish collected off Ilo, Callao, and

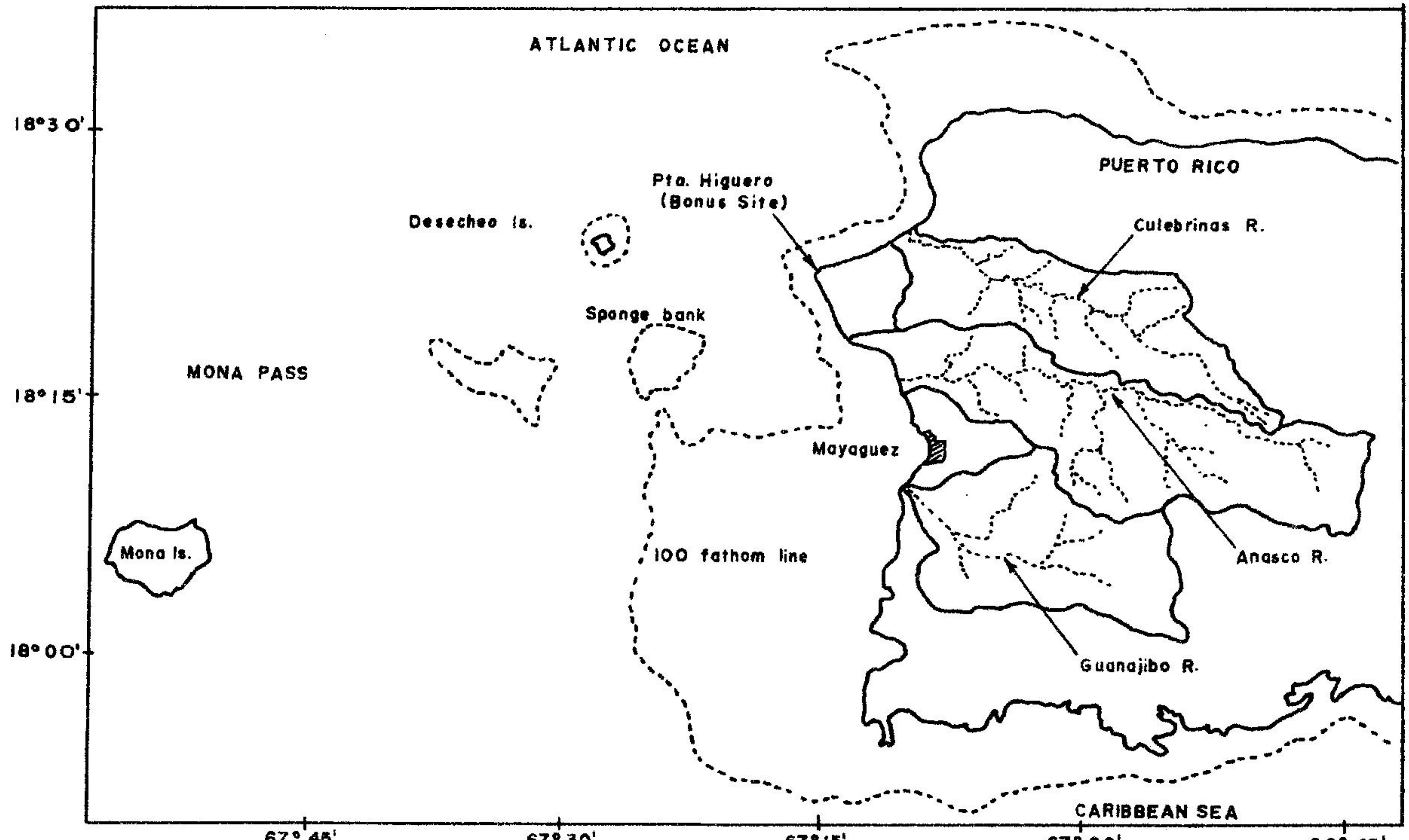

Fig. I. Chart of Western Puerto Rico and Mona Pass showing the Culebrinas, Anasco and Guanajibo watersheds.

Chimbote, Peru have been sent to the Marine Biology Program, PRNC, by Mrs. Blanco Rojas of the Peruvian Marine Research Institute.

The terrestrial studies have been restricted to the Añasco watershed which is located primarily in a mountainous area. Of the 129,000 acres comprising the watershed only 6400 acres are flat bottom land situated in the Añasco plain near the sea. All of the uplands of the watershed are rugged and most of the tributary streams have steep gradients and high rates of erosion.

The minerals and rocks exposed in the watershed are mainly extrusive (igneous, andesitic and basaltic rocks) or sedimentary rocks containing volcanic or igneous debris and limited amounts of limestones. The soils of the uplands are mainly of the sub-lateric, red acid type and contain silty clays. The soils of the flat land have high contents of silty clay, are neutral to slightly acid and are subject to frequent flooding.

Rainstorms in the watershed cause the introduction of varying but usually large amounts of silt-laden water into Añasco Bay. The introduction of the silt into the bay is the basis for locating the field studies of the marine biology program in the Añasco Area.

Upon entering Añasco Bay the river water, with its dissolved and suspended material, usually forms a surface layer of a few centimeters thickness over the heavier saline waters of the bay except during periods of high wave and breaker activity when rapid mixing occurs near the mouth of the river. During periods of relative calm, however, the lighter water of low salinity may maintain its identity as a district surface layer of high turbidity to as far as five miles out from the mouth of the river. Upon mixing of the river water with the ocean water, rapid precipitation occurs and sediments which are enriched with trace elements including manganese, iron and scandium are deposited in the bay.

The deeper and predominant current pattern in Añasco Bay results in transport of the river water to the north along the coast toward Pta. Higuero. Usually during the afternoon, however, wind driven surface currents displace the surface waters in a southerly direction although the deeper layers maintain their northerly movement. During the night the surface and deeper currents again move to the north. In the vicinity of Pta. Higuero, the western-most end of the island, the northerly current with the entrained Añasco River water is usually met by a southerly current containing added river water from the Culebrinas watershed. The currents merge at the point and move westward into Mona Pass. Occasionally a clockwise gyre forms immediately north of the point.

The Punta Higuero marine area is of interest biogeochemically because of the convergence of the north and south shore currents containing the entrained waters from the two rivers. The Añasco River drains a watershed primarily of volcanic origin. In contrast, the Culebrinas River drains a watershed predominantly comprised of limestone.

Because the marine waters containing the outflows of the Añasco and Culebrinas rivers converge at Pta. Higuero, individuals of the same species of organisms located to the north and to the south of the point live in waters containing different compositions of trace elements. The differences in environment are reflected in the trace element compositions of the organisms which have been analyzed thus far. Analyses for additional elements and species of organisms will be continued on samples from the two areas.

A limited number, of analyses are also being made for comparison of elemental content in marine organisms offshore from the outflow of the Guanajibo river which enters the sea seven miles to the south of the Añasco and drains a different type of watershed containing large areas of serpentine outcroppings.

In the proposed research, the trace element analyses are of limited value unless they are related to ecological investigations, especially to studies of food webs. The ecological studies are being conducted by direct observations using scuba gear, by analyses of calibrated plankton and dredge hauls, and by analysis of stomach contents. Quantitative estimates of infaunal abundance in sediments collected off the Añasco River have been started and will be continued. Species composition and feeding type have been related to distance offshore from the mouth of the river and analyses for trace elements in selected species of the benthic organisms have been started to determine if changes with distance offshore may be related to trace element content. The distribution of some of the elements in the sediments does change with distance from land. The amounts of scandium, manganese and iron decrease but the amounts of calcium and strontium increase with increased distance offshore from the mouth of the Añasco River.

In the open sea the Sr/Ca ratio has been reported to be independent of total salt concentration and to have a value of 8.9×10^{-3} (Schreiber, 1962)- about equal to that reported for the crustal average of the earth (9×10^{-3}) (Taylor 1964). These values differ from those found in the present work for Añasco River water (5.5×10^{-3}) and sediments of Añasco Bay (2.7×10^{-3} at 2 miles offshore and 5.5×10^{-3} at 5 miles offshore). Samples of benthic organisms have been collected from the sediment core stations and will be analyzed for Sr/Ca ratios to determine if the ratio of strontium to calcium in the sediment influences the ratios of the two elements in the organisms. A change in Sr/Ca ratio has been reported by Odum (1951) in studies in which the environmental Sr/Ca ratio was experimentally varied. However, the effect of the elemental composition of the sediments upon the elemental content of the contained benthic organisms is not dependent only upon the total amounts of a given element in the sediment but is also influenced by the chemical and physical forms of the elements in the sediments. The availability of the elements to the benthic organisms is being studied by leaching experiments and by the determination of crystalline components.X-ray diffraction and emission diagrams of sediments with X-ray diffraction measurements, from Añasco Bay and the offshore area have been made and more than 65 compounds have been identified. In addition, X-ray diffraction diagrams of the gut contents of deposit-feeders have been made and compared with those of the sediments. Differences were found in the diffraction diagrams of the gut content of the heart urchin Brissopsis sp., and the sediment in which it lives. These investigations are being continued in several species of benthic organisms, including deposit and suspension feeders.*

In addition to the use of X-ray diffraction analysis for the sediment studies, the technique is being used for the identification of precipitates which are formed when filtered Añasco River water is mixed with filtered sea water.

The interpretation of trace element analyses in marine organisms is complicated by the effects of individual variability. In the present studies, numbers of individuals of a given pelagic or littoral species collected at one place at the same time show greater individual variability than that found in benthic species. In addition, greater variability occurs with elements which are not biologically significant (ie. Sc) than with those which are thought to be biologically important (Mn, Zn), although at least one biologically important element, iron, exhibits a high degree of variability. Investigations on individual variability have been done with eight species of marine organisms including algae, echinoderms, coelenterates, molluscs and fishes. Further work is needed to determine the biological factors, including feeding habits and size of organisms, as well as the environmental factors which influence variability. In the case of littoral snails and chitons, uneven distribution of trace elements in and on the surface of the food substrate appears to be one contributing factor to non-uniformity in the elemental content of the organisms.

A useful "tag" for measuring incorporation of trace elements by marine organisms is provided by radioisotopes in world-wide fallout. Gamma spectrum analyses have been made on large samples of algae, plankton, sponges, gorgonians, corals, sea urchins, molluscs, and fishes. The analyses will be continued with samples of the same species collected in areas near the outflows of the three rivers in the field study area as well as in samples collected "up-current" from Puerto Rico. The data will be used for: (1) comparison with the amounts of radioisotopes measured in the marine organisms, sediments and waters near the outflow of the Bonus power reactor after the reactor is brought to power, (2) analysis of the effects of river effluents upon the radioisotope content of the marine organisms growing in the outflow patterns of the three water sheds, (3) specific activity analyses (d/m of radioisotope per gram of corresponding stable element) on a variety of marine organisms.

* The X-ray diffraction unit is located in the Solid State Physics Division of PRNC and the X-ray emission spectrograph is owned by the Dept. of Agriculture, College of Agriculture and Engineering, U.P.R. Through a cooperative agreement the use of the X-ray equipment is furnished without cost in exchange for the use of equipment in the Marine Biology Laboratories. The use of a computer at the College of Agriculture and Engineering for analyzing the diffraction and emission diagrams is also provided without cost.

Variations in specific activity between organisms collected at the same time and place provide indices of variations in rates equilibrium achieved by the organisms with the elements in the water. Variations in specific activity between organisms collected at the same time but in different localities or at different times in the same locality also provide methods for measuring variations in specific activities in the different environments. This would be true whether the variations in specific activities were due to variability in the rates of addition of the radioisotope or in the rates of addition of the stable element to the waters of a given area.

Among the marine organisms analyzed for world-wide fallout in the present work are phyto- and zooplankton. These two types of organisms exhibit markedly different patterns of radioisotopes content but both groups probably are at equilibrium with the radioisotopes and the corresponding stable element in the surrounding sea water. This assumption is based upon the concept that alterations in the specific activity of a given radioisotope in the water is of relatively long duration with respect to the average life of the plankton organisms and their turnover rates for the fallout elements, and that the organisms do not discriminate between the radioactive and stable forms of cobalt, manganese, zinc, ruthenium, and cerium.

The amounts of the radioelements present in the phytoplankton are probably related to the photosynthetic activity of the organisms. Bachman and Odum (1960) reported that the uptake of Zn^{65} by marine benthic algae was linearly related to oxygen production. They suggested that zinc was taken up in direct proportion to the rate of photosynthesis and was accumulated as a function of net biological production. In the present work the measurements of photosynthetic rates are being correlated with uptake of radioactive zinc, cobalt, manganese, ruthenium, cerium and iron.

Although methods are available for measuring the effects of photosynthesis by the primary producers upon the uptake of trace elements, the subsequent transfer of organic matter and the associated trace elements through ascending trophic levels cannot be easily measured. Hedgepeth (1957) stated that "the most difficult problem in modern ecology is that of defining and measuring efficiency" - in the transfer of energy and matter through food webs or chains. Although the measurements of such transfers through a given series of marine trophic levels will not necessarily provide applicable data for other marine food webs it will provide the basis for planning measurements and analyses of transfer in other ecological systems.

In measurements of organic and inorganic matter in food webs, one of the problems to be solved is that of determining which units of reference should be used for defining the amounts of trace elements in the samples.

In the present work the weights of trace elements have been reported on the bases of wet, dry and ash weights of organism - they are now also reported on the basis of organic nitrogen and carbon content. For correlations of movements of trace elements with transfer of potential energy (ie. organic matter) through the food webs the amounts of the elements should be related also to the calorific content of the organisms. Plans have been made to make calorimetric measurements on all biological samples during the next year. These analyses may also be made on samples which have already been analyzed for trace elements in the past since dried aliquots of the samples were retained.

The trace elements analyzed in the present work are related to wet, dry and ash weights as well as to contents of carbon and nitrogen so that the data may be used directly by other investigators for comparison with their measurements. In addition, the different bases of comparison are needed in the present work for the following applications.

(1) Wet weight - Comparison of trace element content per gram of living marine organism with the amount of the same element per gram of sea water.

(2) Dry weight - comparison of "trace element to food value" ratios between trophic levels: comparison of food values and ecological significance of the dominant species.

(3) Ash weight - comparison of trace element content of infaunal deposit feeders with the amounts of the corresponding elements in the sediments.

(4) Carbon and nitrogen content - comparison of protein content and food (energy) values of the species involved: comparison of "trace element to protein" ratios between trophic levels.

(5) Caloric content - comparison of trace element contents with amounts of potential energy in successive trophic levels.

The correlation of trace elements with wet, dry and ash weights and with the carbon, nitrogen and caloric contents of the successive trophic levels, must also be related to other characteristics of the species and populations involved. These measurements have been started and will be continued.

REFERENCES

1. Defant, A. 1961. Physical Oceanography, Vol. I, Pergamon Press, New York, 729 pp.

2. Bachman, R. W. and E. P. Odum. 1960. Uptake of Zn^{65} and primary productivity in marine benthic algae. Limn. and Oceanogr. V: 349-355.

3. Hedgpeth, J. W. 1957. Concepts of marine ecology in Treatise on Marine Ecology and Paleoecology, Vol. I (J. W. Hedgpeth ed.) Memoir 67, Geol. Amer. Wash. D. C. 1296 pp.

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Senior Investigator:	
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Research Associate: Raúl McClin, M.S.	100
Laboratory Technician: Edgar Ramos Seda	100
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" " Lydia Quiñones Rivera	100
" " Sara Lugo Ufret	100
" " Rafael J. Garcia	100
" " Russell W. Davis	100
" " Donald S. Erdman	25
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Boat Engineer: Edwin Zapata Silvestry	100

	% of time devoted to project
Crewman: Edwin Jusino Laboy	100
Secretary: Noemi Del Toro	100
Watchman: José Almenia	100

Marine Biology Program
Puerto Rico Nuclear Center
College Station, Mayaguez, Puerto Rico

PROGRAM ACCOMPLISHMENTS AND WORK IN PROGRESS DURING FY-1965

Introduction:

The research program in marine biology was started at the Puerto Rico Nuclear Center in January, 1962. It was, and is, sponsored by the Environmental Sciences Branch, Division of Biology and Medicine, U. S. Atomic Energy Commission.

The work in progress in the Marine Biology Program is being done with a staff of 14 scientific workers including four senior investigators. The boat crew and secretarial staff include a total of six people.

Although the program is comprised of five major projects and supporting areas of research, it functions as an integrated research program with no well-defined divisions of staff, equipment or operations budget. Research in all of the projects is being carried out although greater emphasis has been placed upon some phases than on others.

During the early part of the program, trace element analyses were done on a variety of samples collected in selected geographical areas in order to arrive at a general determination of the distribution patterns of the elements in the organisms and in the environment. The survey-type analyses are being continued but the emphasis on trace element determinations is now directed toward investigations of specific groups of benthic and epibenthic organisms in restricted areas offshore from rivers as well as the sediments in which they live. Other studies on the accumulation of specific trace elements by closely related species are in progress as well as studies on the influences of geographical location on the uptake and retention of selected stable elements by given species.

Until recently the amounts of trace elements in the organisms have been related to ash, dry and wet weights. In the ecological studies, and especially in the food web investigations, the elements should also be related to carbon and nitrogen content for comparison of "trace element to protein ratios" in trophic levels and to caloric content for comparison of "trace element content to potential energy" between trophic levels. Carbon, hydrogen and nitrogen analyses have been in progress during the past year and the trace element contents are being related to the levels of these primary elements.

Investigations on the accumulation of radioisotopes of world-wide fallout by marine organisms are being related to the observations on stable trace elements. The same species collected in different areas exhibit geographical effects in contained radioisotopes while species differences are found in samples taken in a given geographical area. The fallout contents of local marine organisms have been compared with those of samples from Peru and the open Atlantic Ocean.

Investigations on marine sediments collected off the Añasco River have been continued. A preliminary report was presented last year concerning the trace element analyses of the first series of sediment cores. This phase of the work has been completed and a summary of the distribution of the elements in the cores is given in the present report. In addition to the elemental analyses, the sediment samples are being subjected to analysis of grain size by the dry sieving technique and the pipette method. Investigations on the biogenous and terrigenous components of the sediments are in progress and the physical studies on the sediments have been expanded to include x-ray diffraction analyses. The diffraction diagrams are analyzed by a machine-sorting program. A limited program of x-ray fluorescence analysis on sediment samples has been initiated. The fluorescence peaks are analyzed by a computer technique.

A method for the determination of stable scandium in rocks, minerals, soils, clays, sands, sediments, plankton, algae, invertebrates, vertebrates, and river and sea water was reported last year. The method has been in use for more than a year and a total of 260 samples have been analyzed. The method is reliable and reproducible and the analyses are being continued.

Due to lack of adequate control over air contamination in the present laboratories, analyses for elements in sea water, other than scandium, cannot be done. The problem will be alleviated this summer with the completion of the new laboratory for sea water analysis. Rapid methods have been developed during the past year, however, by the use of radioactive spikes, for the determination of lithium, zinc and bismuth in sea water. In addition, a method, utilizing neutron activation has been developed for biological samples in which sodium, phosphorus, calcium, rubidium, antimony, cadmium, cesium, iron, manganese, copper, zinc, strontium and gold may be determined in two aliquots of an ashed sample. A total of 0.4 g of ash is required and dried material may be used if desired.

The elements which are now being determined by the atomic absorption and flame spectrophotometric method include calcium, strontium, magnesium, thallium, cesium, potassium, rubidium, lithium, manganese, iron, cobalt, zinc, nickel, chromium, antimony, vanadium, cadmium, lead, bismuth, rhodium, molybdenum, tungsten, platinum and gold. The results from the atomic absorption method are being checked against those from neutron activation analysis.

The productivity measurements have been continued and will be reported at a later time when sufficient analyses have been completed to demonstrate geographical and seasonal patterns of production.

Uptake experiments with radioactive tracers were continued during the past year. Measurements of the accumulation and loss of zinc (labeled with Zn^{65}) were made with young and old specimens of the algae *Penicillus capitatus* and *Udotea flabellum*. In addition, experiments were done to determine the turnover rates of several species of algae for Ta^{182}. Because of the lack of adequate laboratory space the uptake experiments were done in the laboratory used for processing samples for stable element analysis. The sea water reservoirs containing the radioisotopes, were aerated with compressed air. The air stream carried trace amounts of the radioisotopes into the room. The experiments were stopped when the contamination problem was discovered. This summer (1965) the marine laboratory of PRNC will be completed at the Bonus site. The laboratory is equipped with a salt water system and the uptake experiments will be started anew this year.

The amounts of data which may be collected by using the several methods of instrumental analysis have increased to a degree that manual methods of tabulation and analysis are no longer feasible. During the past year an IBM method of data storage and retrieval has been adapted to the marine biology program. This method, as well as the individual research projects are described in the following sections of this report.

BENTHIC STUDIES - AÑASCO BAY

Benthic Infauna

Initial results from a survey of benthic infauna, being carried out in Añasco Bay, indicate that numbers of organisms decrease with distance from the river's mouth and with increasing depth (Fig. 2). This decrease in numbers of organisms appears to follow sediment gradients, since sediments become increasingly more coarse with distance from the river's mouth and with increasing depth. Relationships between sediment and faunal distributions have been well substantiated (Petersen 1913, Davis 1925, Thorsen 1957, Sanders 1956, 58, 60, 62).

Numerical abundance of benthic fauna/m^2, as a measure of standing crop, places Añasco Bay ($\bar{X}$ = 2,346), on a par with the English Channel ($\bar{X}$ = 2,365), a little under Buzzard's Bay, Massachusetts ($\bar{X}$ = 4,430), but well under Loch Craigland, Scotland ($\bar{X}$ = 14,275) (Mare 1942, Sanders 1958, Raymont, 1949).

Forty six species of polychaetes, 42 species of pelecypods, 27 species of amphipoda, isopoda, decapoda combined, five different echinoderms, 3 holothuria, 2 nemerta and 2 ostracoda have been collected to date. Special taxonomic interest is being paid to the polychaetes, since they represent the major group, and since most of them have not been described previously from Puerto Rico.

The qualitative distribution of organisms follows relationships between feeding requirements of fauna and the nature of sediment composition as initially described by Davis (1925). Deposit feeders dominate populations in fine sediments located close to the rivers mouth. Filter feeders become more important in population structure as the finer portions of the sediment decrease with depth and distance from river inflow. Polychaetes dominate fine sediments while mollusks and crustacea become increasingly more significant as the coarse sedimentary fraction increases. (Fig. 3).

An intensive sampling program was initiated during October and November 1964. Samples collected during this period are still being processed. From these data, more precise information regarding qualitative and quantitative distributions with depth and distance from the rivers mouth will be forthcoming. Another sampling of these stations is currently being conducted to monitor effects of seasonal changes. Future sampling is planned to follow stability of population structure over time.

Stable Elements

As samples are processed, fauna having comparatively large biomass are analyzed for trace element content immediately. Fauna having

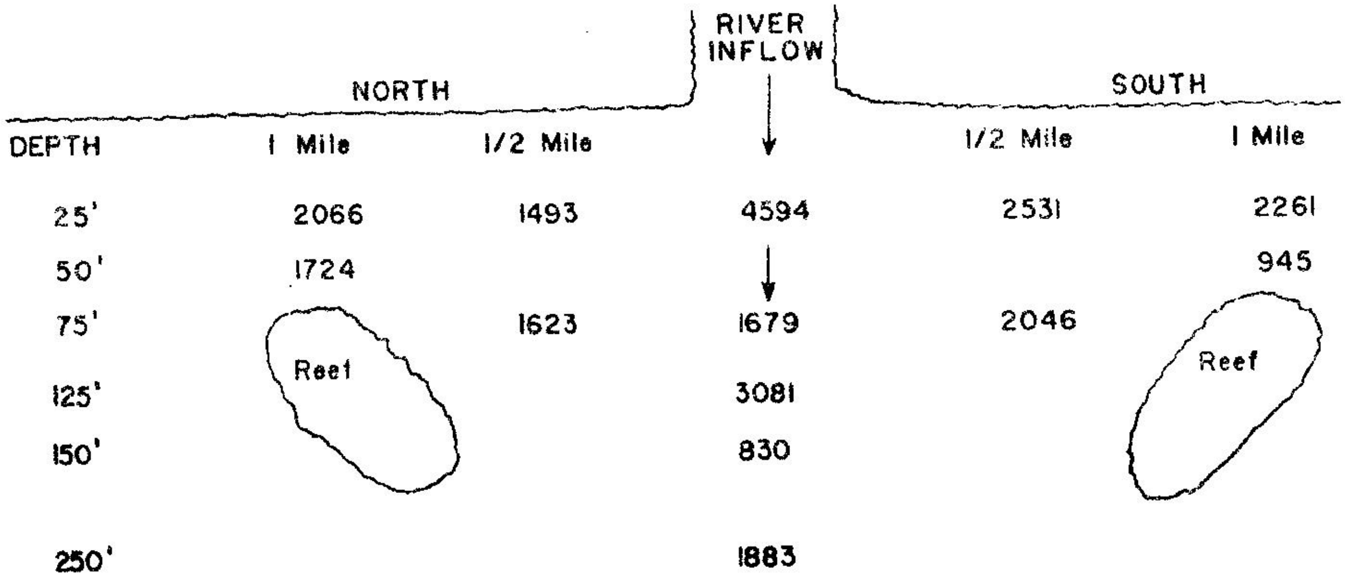


FIG. 2 Illustration of the influence of Anasco River on abundance of total organisms/m2

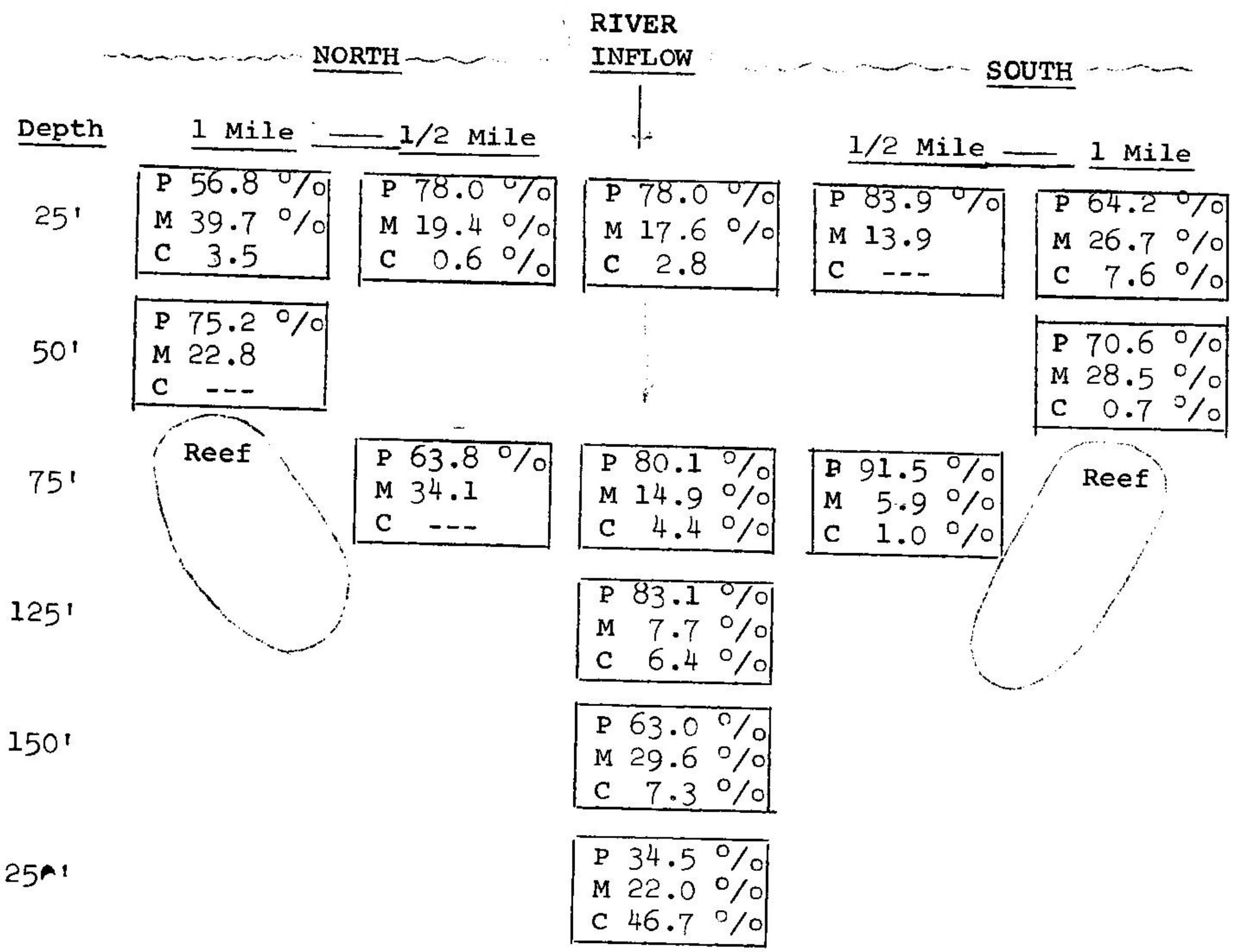


FIG.3. Illustration of the effect of the Añasco River on the composition of populations. P = polychaetes, composed mostly of deposit feeders. M = molluscs, composed mostly of suspension feeders (some deposit feeding molluscs are found in the fine shallow water sediments). C = crustacea, composed primarily of suspension feeders.

a lesser biomass are saved until enough material has been accumulated for the various analyses. Certain echinoderms, polychaetes, mollusks and crustacea have been analyzed for K, Fe, Co, Zn, Mn, and Ni by atomic absorption analysis, and for Sc by activation methods. (Figs. 4 through 7).

Sediments are now being prepared for analyses. The nature of clastic physical properties is being determined by standard sieving and pipetting analyses. Trace element content is being determined by atomic absorption as well as activation analysis and elemental composition is being studied with X-ray diffraction methods. To date, the stable element composition of the detrital fraction of some sediments has been accomplished for K, Fe, Co, Zn, Mn, Ni by atomic absorption and Sc by activation analysis (Figs. 4 through 7).

A qualitative sample of benthic feeding fish was made in December, 1964. Qualitative analysis of stomach contents demonstrated that *Symphurus plaguisa* and *Larimus breviceps*, dominant forms, concentrated detritus and shrimp in their respective gastrointestinal tracts. As with the invertebrates, abundance of fish decreased markedly with depth. Similar hauls will be made in the future, to monitor and attempt to quantify this next higher trophic level.

The fish are being analyzed for K, Fe, Co, Zn, Mn and Ni by atomic absorption methods. Results obtained to date are listed in Table 1, and presented graphically in Figures 4 through 7.

Symphurus plaguisa, was analyzed with and without its gastrointestinal tract. The stomach contents of this fish consisted primarily of detritus. While the content of Fe was much higher in fish with their gastrointestinal tracts intact, the level of the other trace elements were not apparently affected. The level of Fe in detritus is very high (Fig. 4) and in this instance presence of detritus in the stomach apparently influences the elemental analyses directly (Table 1).

Levels of K and Zn are generally higher in *Symphurus plaguisa* which feeds directly in the bottom sediments as compared to *Larimus breviceps* which feeds primarily on shrimp. Nickel seems to be more evenly distributed between species in general (Fig. 6). Differences in levels of K and Zn may reflect differences in feeding habits between these two species of fish.

Discussion

Data listed in Fig. 6 suggests that while levels of Ni and Co remain comparatively constant from the detritus on through the various animal groups, there are distinctly different levels of K, Fe,

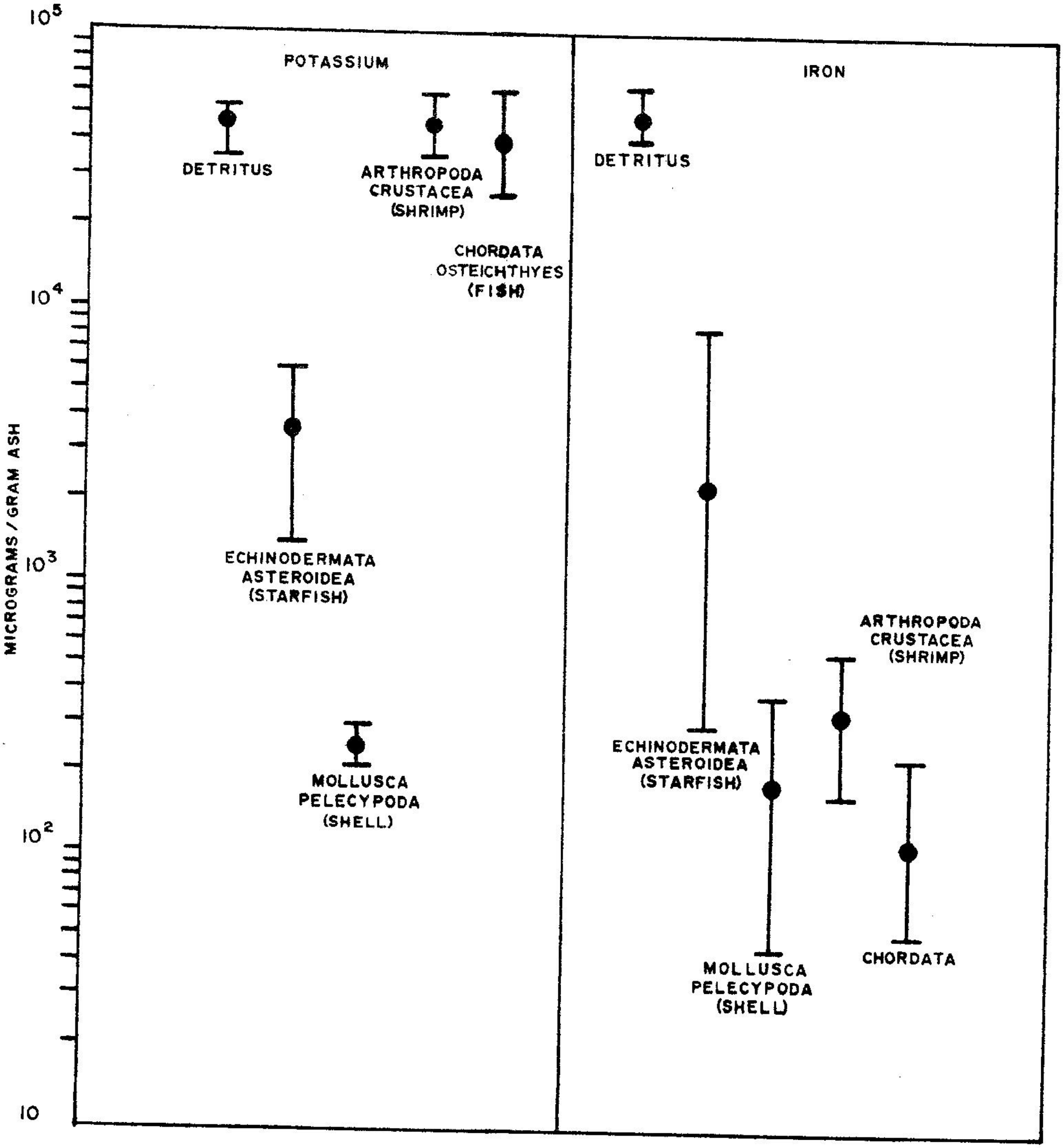


Figure 4 Mean levels (●) and total range (I) of stable elements from representative benthic groups (ashed) collected in Añasco Bay, Puerto Rico.

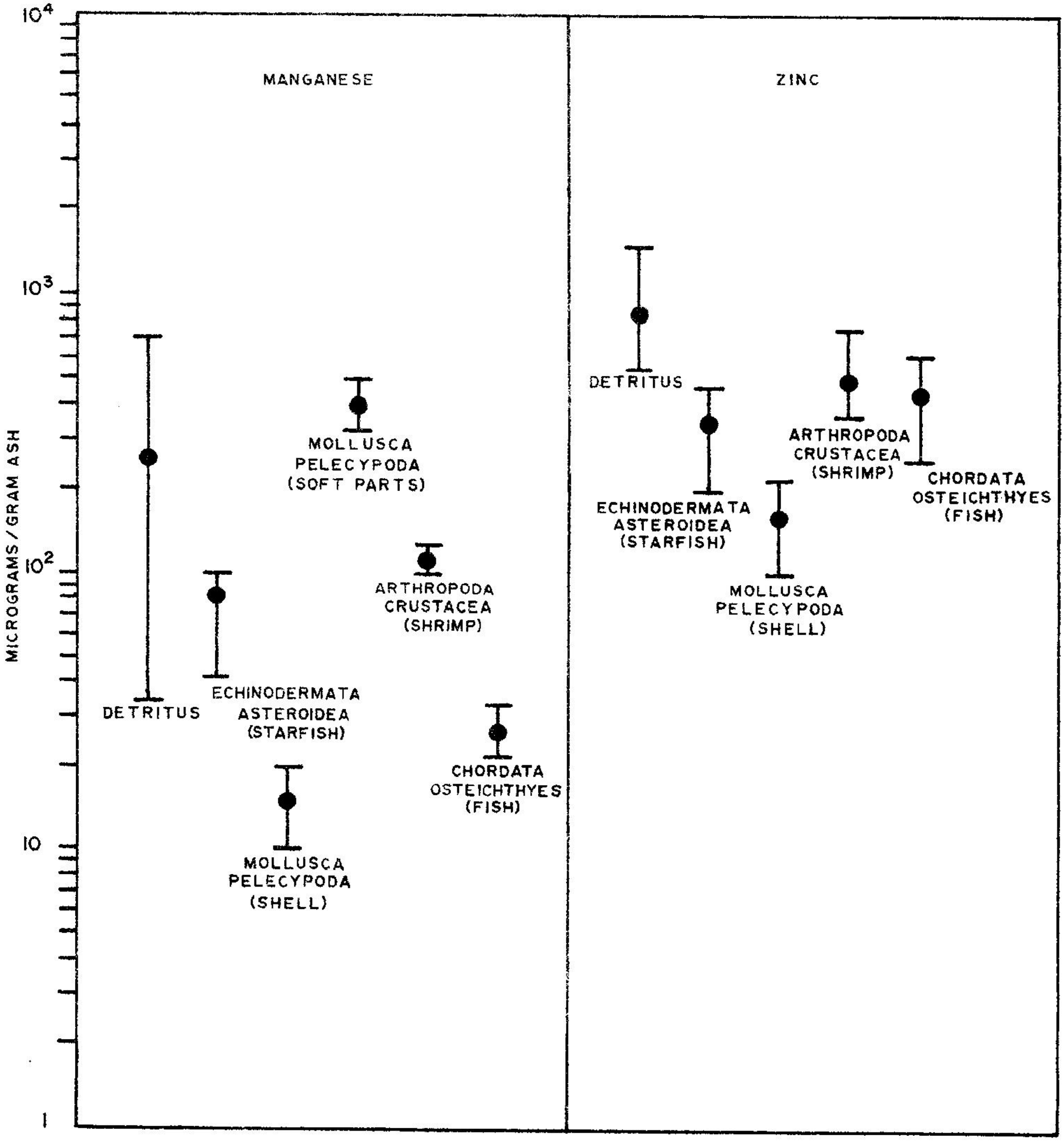


Figure 5. Mean levels (•) and total range (I) of stable elements from representative benthic groups (ashed) collected in Añasco Bay, Puerto Rico.

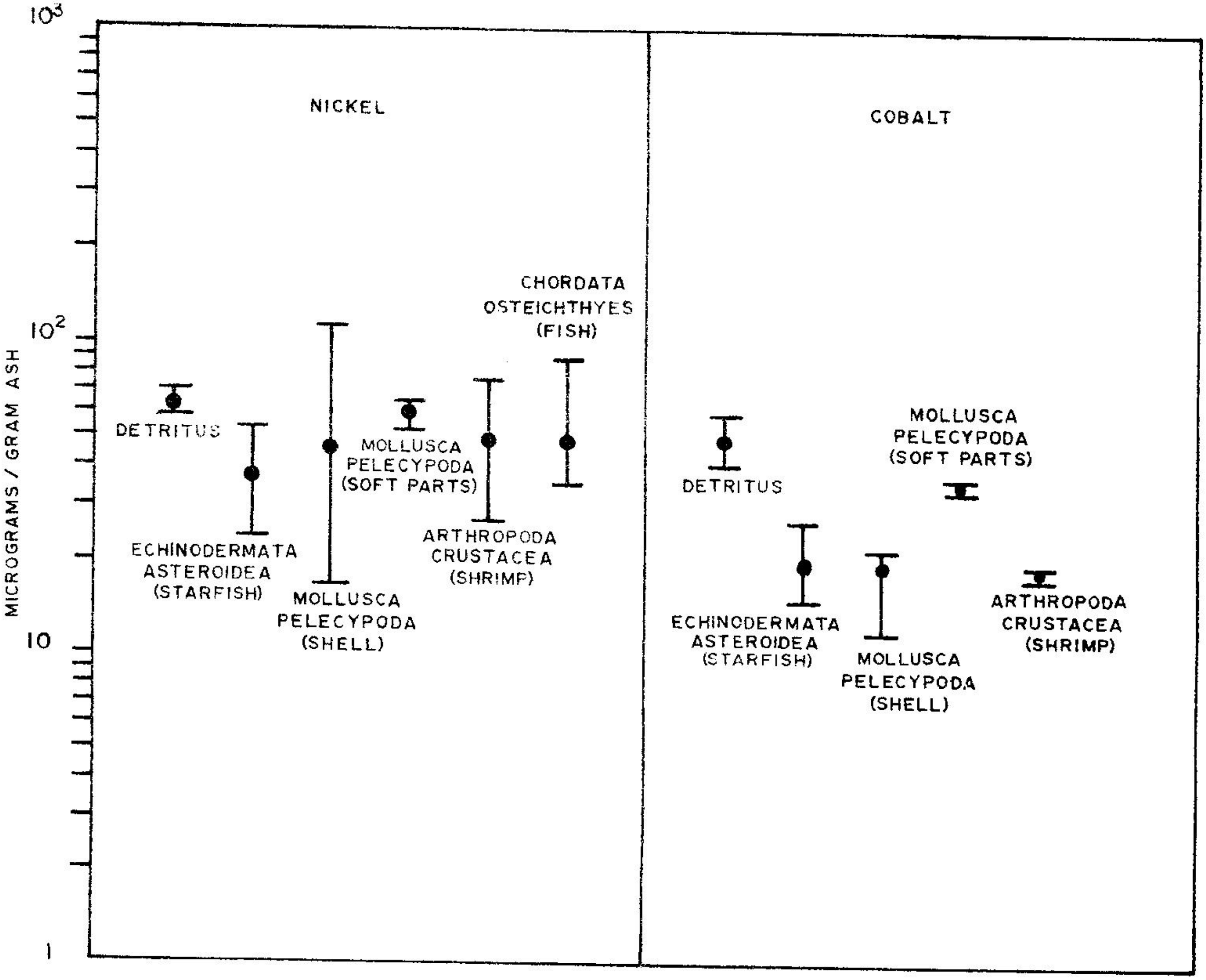


Figure 6. Mean levels (•) and total range (I) of stable elements from representative benthic groups (ashed) collected in Añasco Bay, Puerto Rico.

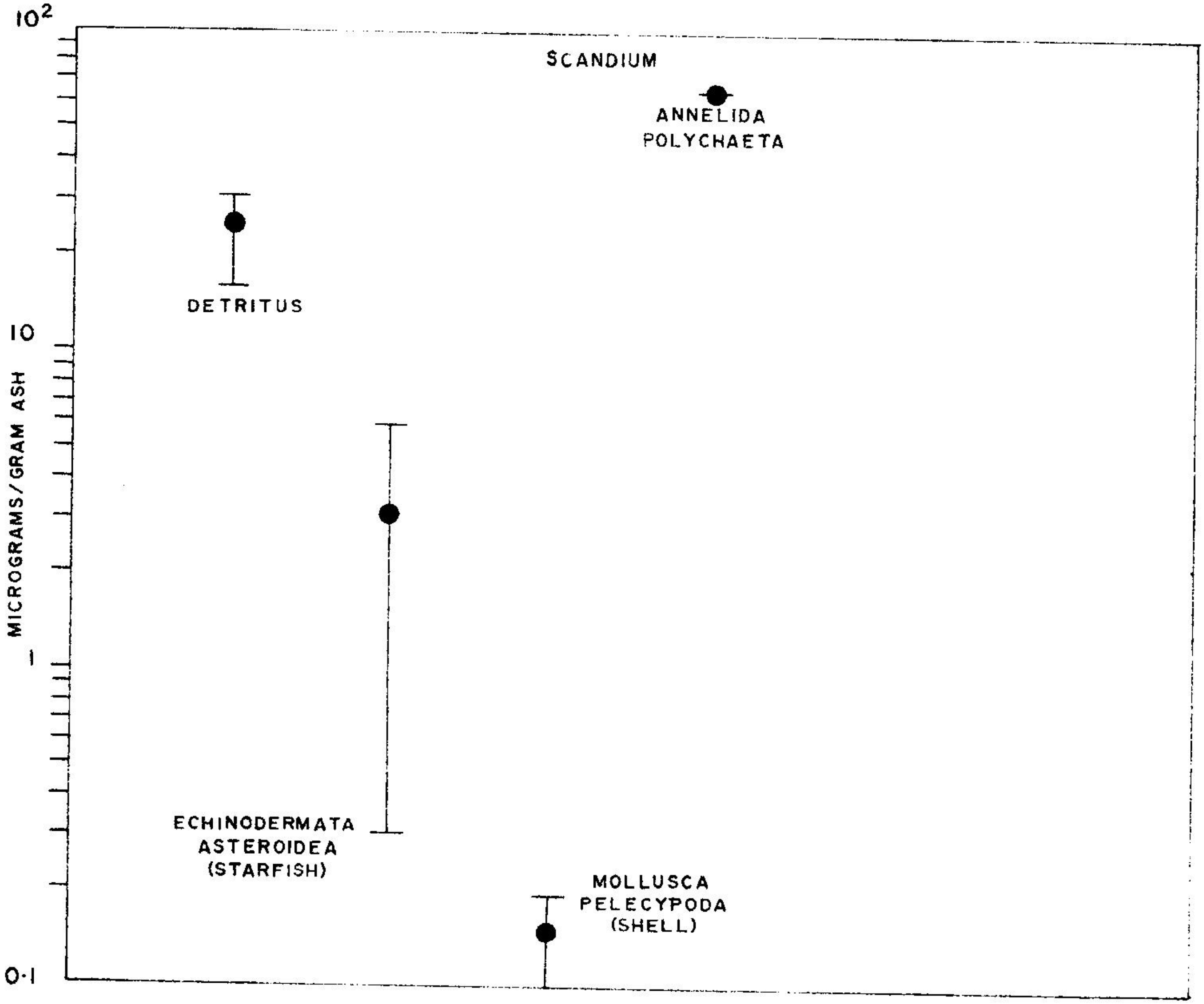


Figure 7. Mean levels (•) and total range (I) of stable elements from representative benthic groups (ashed) collected in Añasco Bay, Puerto Rico.

TABLE I

µg/gm. Ash

	K	Fe		Ni	Zn
Symphurus plaguisa	53,000	395	G. I. tract removed	40	570
"	52,000	122	"	41	625
"	43,000	340	"	59	535
"	43,500	160	"	41	330
"	43,000	210	"	35	475
"	54,000	2,200	Intact	50	580
"	55,000	518	"	28	475
"	40,000	985	"	58	460
"	62,000	720	"	51	560
Larimus breviceps	40,000	200	"	90	570
"	39,000	210	"	39	585
"	38,000	160	"	53	350
"	31,000	470			310
"	27,000	650			380
"	31,000	680			320
"	27,000	570			320
"	26,000	720			260
"	33,000	1,100			380

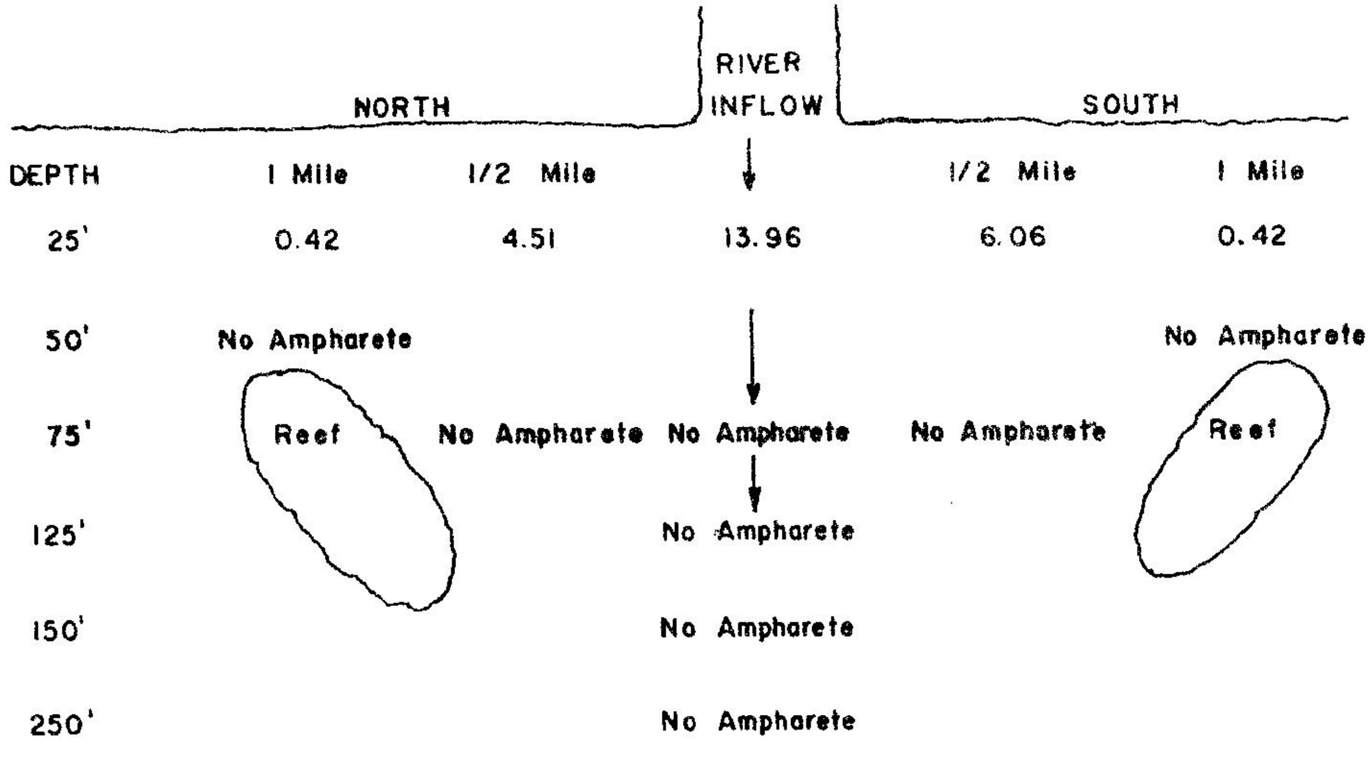


FIG. 8 Micrograms of Scandium contained in biomass of a polychaete (Ampharete sp.) collected in Anasco Bay. Indicates influence of a single species on distribution of certain trace elements in an ecological system.

Zn, Mn and Sc maintained within each group. While the distribution of the former group of elements throughout an ecological system would be a function of total biomass, the latter elements would be obviously affected by variations in faunal abundance and composition (Fig. 8). The reservoir of certain stable elements at any one point in time would then be a function of the benthic communities existing in a given area as they interact with the next lower and higher trophic levels (Figs. 4 through 8). It is within the scope of this study to establish representative amounts of stable elements as they exist throughout the ecological system under consideration at several points in time. Future studies will be developed to relate passage of trace elements to energy flow through this system.

Of taxonomic interest is the discovery of a single living brachiopod. This organism apparently of the genus Lingula, was collected at a depth of 125' from a muddy-sand substrate. Definitive identification is being carried out.

REFERENCES

Davis, F. M. 1925. Quantitative studies on the fauna of the sea bottom. No.2. Results of the investigations in the southern North Sea, 1921-24. Gt. Brit. M. A. F. Fishery Investigations. Series II, 8(4): 1-50.

Mare, M. F. 1942. A study of a marine benthic community with special reference to the microorganisms. J. Mar. Biol. Ass. U. K., 25: 517-554.

Petersen, C. G. J. 1913. Valuation of the sea. II. The animal communities of the sea bottom and their importance for marine zoogeography. Rep. Dan. Biol. Sta. 21: 110pp.

Raymont, J. E. G. 1949. Further observations on changes in bottom fauna of a fertilized sea lock. J. Mar. Biol. Ass. U. K. 28(1): 9-19.

Sanders, H. L. 1956. Biology of marine bottom communities. Bull. Bingham Oceanogr. Coll., 15: 345-414.

_______. 1958. Benthic Studies in Buzzard's Bay. I. Animal-sediment relationships. Limnol. oceanogr. 3(3): 245-258.

_______. 1960. Benthic Studies in Buzzard's Bay. III. The structure of the soft-bottom community. Limnol. oceanogr. 5(2): 138-153.

_______, E. M. Goudsmit, E. L. Mills, and G. E. Hampson. 1962. A study of the intertidal fauna of Barnstable Harbor, Massachusetts. Limnol. oceanogr. 7(1): 63-79.

Thorsen, G. 1957. Bottom communities. Geol. Soc. America, Memoir 67, 1: 461-534.

FALLOUT RADIOISOTOPE INVESTIGATIONS

The studies on the amounts and distribution of radioisotopes from world-wide fallout were continued during the past year. The measurements have been hindered by difficulties in obtaining large samples of organisms free of detritus and other organisms and by the relatively high radiation backgrounds which occur in the shield of the gamma spectrometer detector as a result of the presence of the research reactor and a gamma irradiation pool in the vicinity of the counting facility. The latter problem will be solved by mid-1965 when the counting facility is moved to the new building which is shielded from the two radiation sources.

In comparison with the amounts of plankton normally found in more temperate marine areas, the tropical seas are usually relatively sterile. Repeated tows of 10 or more plankton nets over a period of 10 to 20 hours are often required to collect a settled-volume of one liter of plankton. Some types of zooplankton may be easily collected however, by the use of lights. In the present work, it has been observed that separations of species of plankton may be made by attracting the plankton at night with lights of different intensity. In an area populated with some species of isopods and euphausid shrimps the former organisms were attracted to a 1000 watt water-cooled lamp placed three to six feet below the surface of the water on one side of the boat while the shrimps were, at the same time, attracted to a 300 watt lamp placed immediately above the surface of the water on the other side of the boat. One liter settled-volumes of these organisms were collected within a one-hour period with cross-contamination of species in the two collections amounting to less than 1% (based on counts).

Algae, gorgonians, corals and large fishes are easily collected in volumes sufficient for fallout analyses. Sponges are abundant but must be carefully dissected to remove the symbiotic organisms from the pores and canals. Small fishes are collected in kilogram lots by means of monofilament nylon gill nets and total body contents of fallout radioisotopes may be determined. However, attempts to dissect organs from individuals in numbers sufficient for gamma spectrum analyses have been only partially successful.

The wet-weight of material required for gamma spectrum analysis depends upon the type of organism and varies from one-half to ten kilograms. The samples were carefully cleaned (dissected if necessary) and were weighed in the wet condition. They were dried for 24 hours at 95°C, weighed, and ashed at 450°C. The ash was placed into beakers which had been calibrated for volume, tamped to a minimum volume and counted with a 3" x 3" NaI(Tl) detector for periods of 200 to 400 minutes. Background counts were made daily and the background spectra were subtracted from the sample spectra by a data reduction system. Corrections were made for geometry, detector efficiency, decay schemes of the isotopes, and physical radioactive decay after collection.

After the gamma spectra were made, aliquots of the samples were taken for stable element analyses. The analyses for gamma emitters are being related to stable element content in the same samples and observed amounts of radioelements are being related to food webs, geographical effects (influences of river outflows) and to species differences.

The gamma spectra of two plankton samples of one liter settled volume each are shown in Figure 9. Both samples were collected in Mona Pass within a one week period in June, 1964. Marked differences in radioisotope content between the phytoplankton and zooplankton are shown. The phytoplankton contained relatively large amounts of Ce^{144} Pr^{144} (62% of the total fallout activity) but the isotope was not detected in the zooplankton. The amounts of Mn^{54}, Co^{57}, Co^{60} and Zn^{65}, on a wet-weight basis, were three to four times higher in the zooplankton than in the phytoplankton but the Ru^{106} Rh^{106} contents were about the same in both trophic levels. Thus, on a wet-weight basis the zooplankton, which represent the second trophic level in the food web, concentrated the transition elements manganese, cobalt and zinc in relation to their food source but strongly discriminated against the uptake of cerium.

At the time the zooplankton were taken separate collections were made of isopods and euphausid shrimps by use of the lighting method previously described. Because these isopods are selective feeders and the shrimps, filter feeders, it was thought that the feeding habits would be reflected in different patterns of accumulation of fallout radioisotopes. The gamma spectra of the two organisms are shown in Figure 10. No difference in radioisotope content exists between these two types of organisms of the same trophic level. Additional work is in progress with other plankton organisms which occupy the same trophic level and which are collected at the same time in a given locality.

Another group of organisms which are being studied for fallout content are the algae. These plants are capable of concentrating a large number of trace elements and were found at the Pacific Proving Ground to actively concentrate fallout radioisotopes. In Figure 11(A) the gamma spectra of the same species of alga collected at two sites are shown. One sample was collected at Punta Higuero on the west coast of Puerto Rico and the other at Guanica on the south coast. The land area of Puerto Rico which is drained to the west coast received approximately 100 inches of rainfall per year in comparison to an average rainfall of 30 inches per year for those areas which drain to the south coast. The gamma spectra of the same species collected at the two sites reflect the differences in environmental conditions. Corresponding differences in stable element contents of marine organisms from the same areas have been reported in another section of this report. In addition to the environmental differences imposed by the amounts of runoff from the land, the organisms in the two areas are subjected to markedly different current patterns.

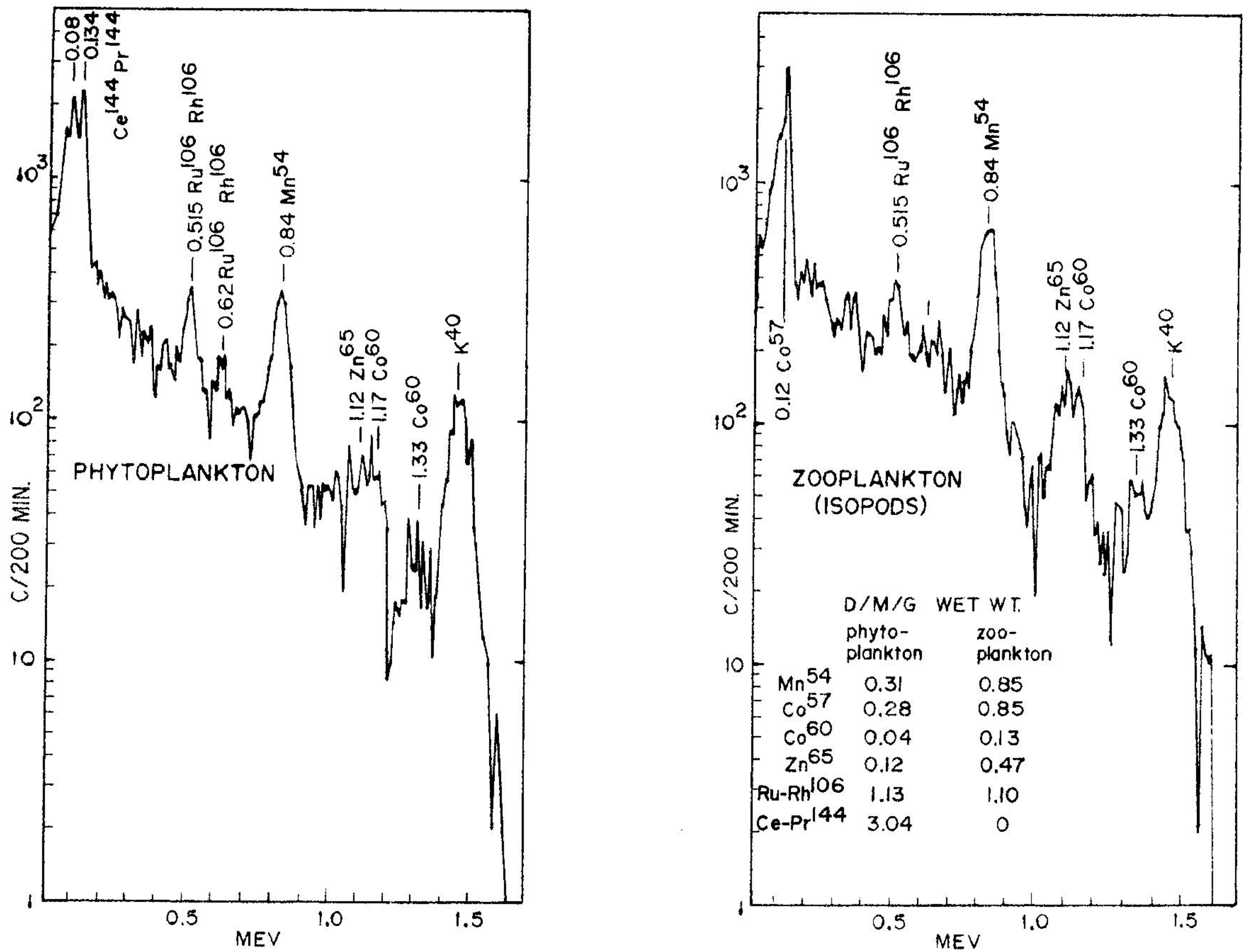


FIG. 9 Gamma spectra of two plankton samples of one liter each collected in Mona Pass. The phytoplankton contained a few zooplankters. The zooplankton sample was composed almost entirely of isopods.

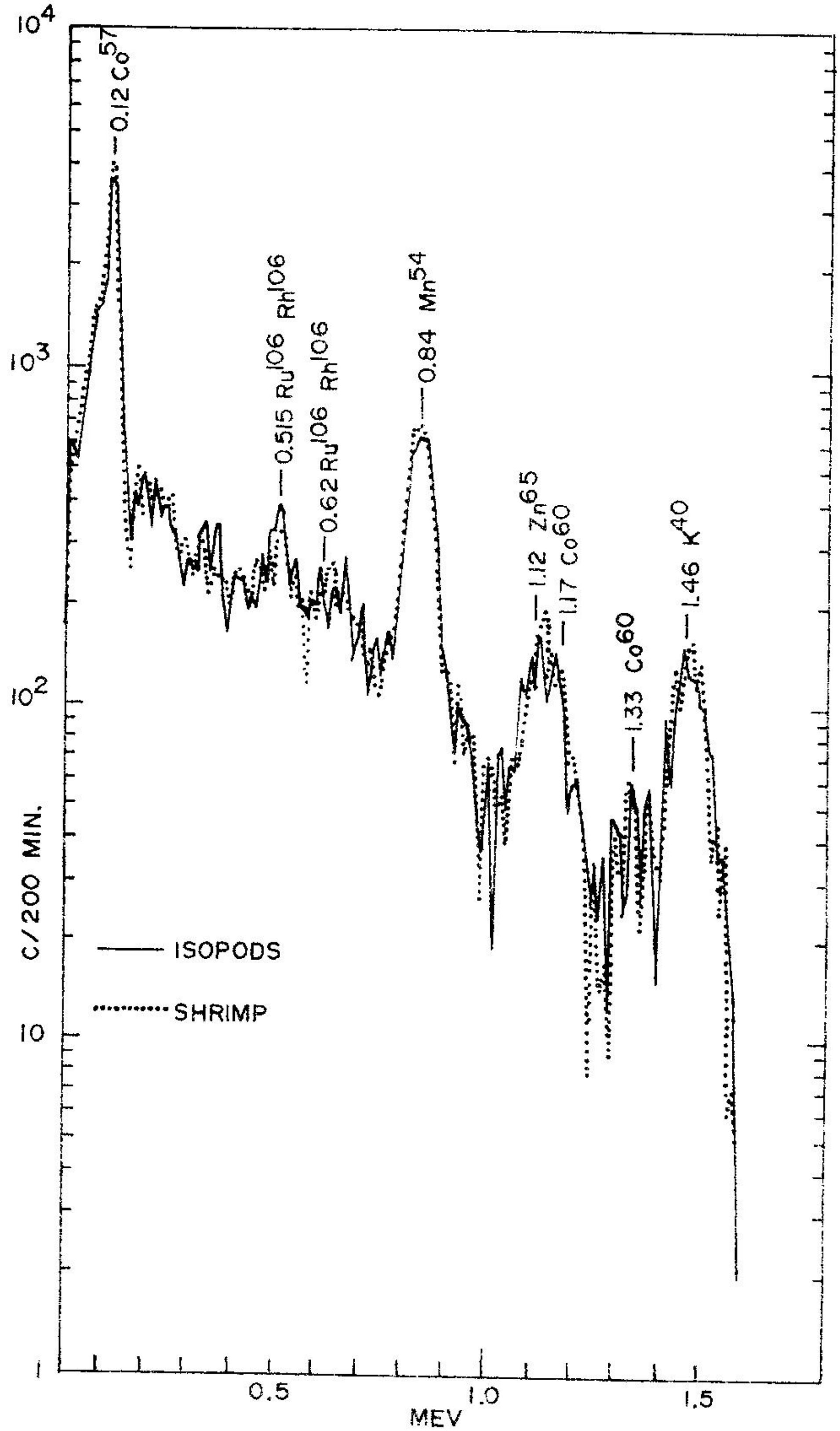


FIG. 10 Gamma spectra of two samples of plankton, each of one liter settled volume, collected at Mona Island on June 18, 1964.

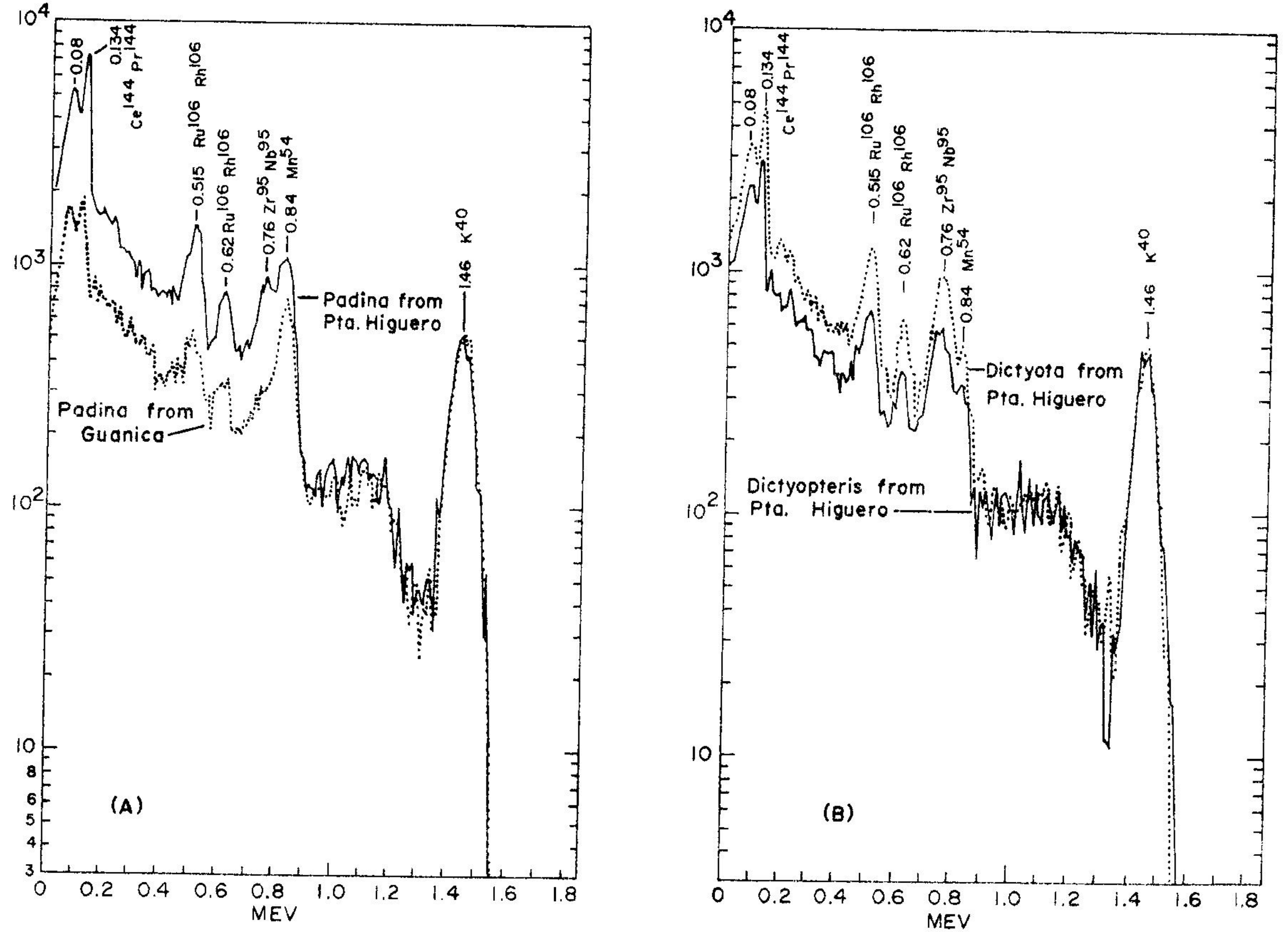


FIG.11 (A) Gamma spectra of one species of alga collected at Pta. Higuero (west coast) and at Guanica (south coast). (B) Gamma spectra of two related species of algae collected at Pta. Higuero.

Those off the south coast are exposed to single-pass currents whereas those from the areas of study off the west coast exist in areas containing numerous current gyres and oscillating currents.

The amounts of K^{40} in the algae collected at the two sites were approximately the same. However, the amount of Mn^{54} in Padina collected off the south coast was about two thirds of that collected off the west coast. The decrease in amounts of Zr^{95} Nb^{95}, Ru^{106} Rh^{106}, and Ce^{144} Pr^{144} from Guanica was even greater.

In another investigation two similar species of algae collected at Punta Higuero were compared and the gamma spectra are shown in Figure 11(B). The differences between the gamma spectra of the two related species, (Dictyota and Dictyopteris) collected at Punta Higuero (11 B) are less than those of the same species, (Padina) collected at the two different sites (11 A).

In Figure 12 A are shown the spectra of two species of algae collected at Punta Higuero. The species are not closely related although both are brown algae. Differences in accumulation patterns of the two species are shown. Padina accumulated approximately twice as much Mn^{54} and two thirds as much Ce^{144} Pr^{144} as did Dictyota. The two species contained approximately equal amounts of Ru^{106} Rh^{106}, and Zr^{95} Nb^{95}.

Of all of the organisms collected, only the algae accumulated radiozirconium in amounts that could be measured by gamma spectrometry.

The gamma spectra of samples of Sargassum collected at Punta Higuero (west coast) and at Guanica (south coast) are shown in Figure 12 B. As was shown for another species (Figure 11 A), the algae collected from the west coast contained larger amounts of radioisotopes than did those from the south coast. Only trace amounts of Mn^{54}, Ru^{106}, Ce^{144} Pr^{144}, and Zr^{95} Nb^{95} were found in the Sargassum from Guanica but relatively large amounts were present in the same species collected at Punta Higuero.

Another group of organisms under investigation are the sponges. Figure 13(A) shows the gamma spectra of two samples of the same species _Spheciospongia vesparia_ collected at Punta Higuero. Except for a small difference in the amounts of Mn^{54} the two specimens do not show differences in radioisotope content. Figure 13(B) demonstrates significant differences in the gamma spectra of two specimens of the same species collected at Punta Higuero and Negro Reef (13 miles to the south). Thus, a change in collection site of 13 miles on the west coast of Puerto Rico resulted in significant differences in the amounts of Mn^{54} and Co^{60}. The same effect may be seen in gamma spectra of another species of sponge, _Ircinia strobilina_, (Fig.14(A), (B)).

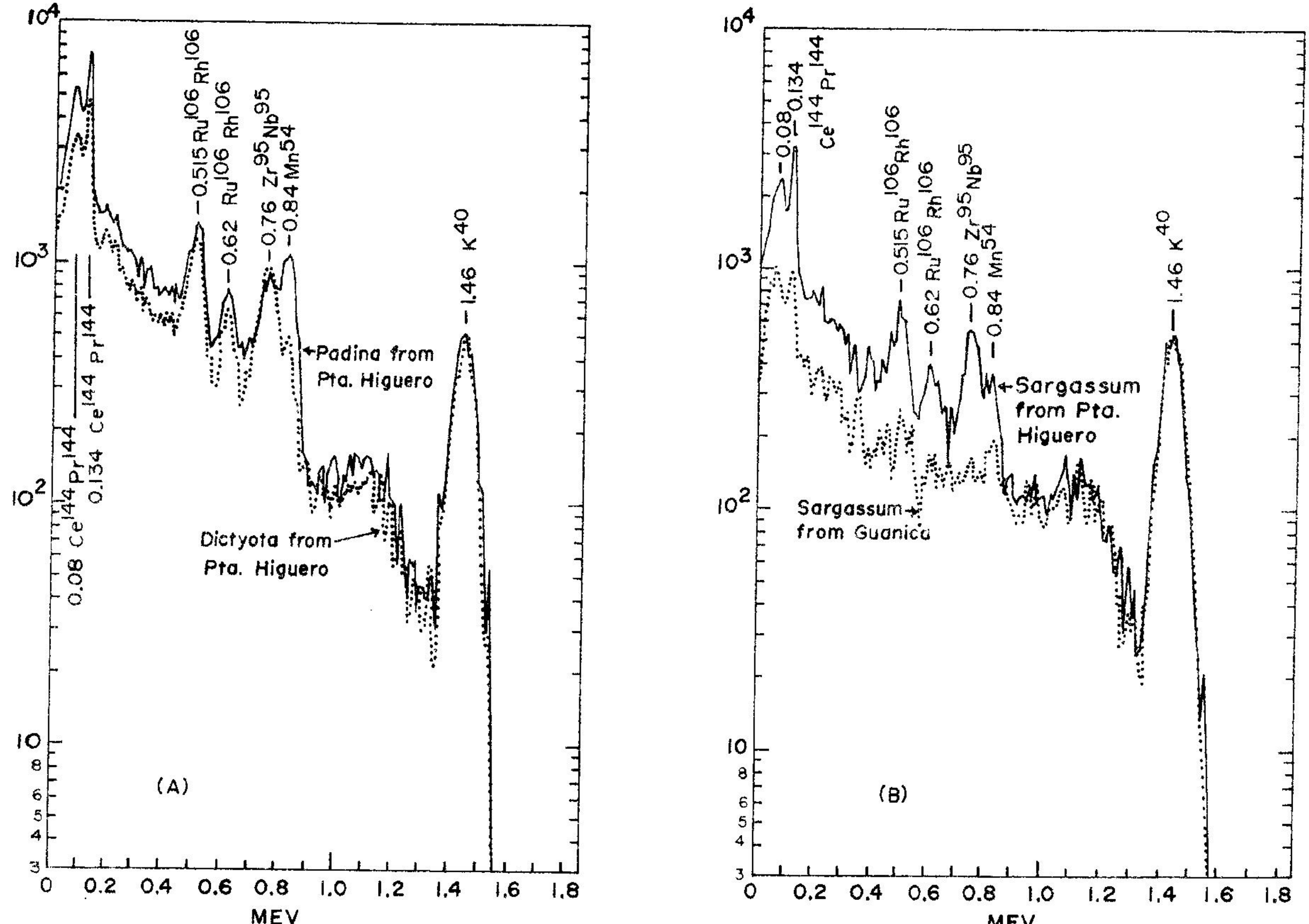


FIG.12 (A) Gamma spectra of two species of algae collected at Pta. Higuero (west coast of Puerto Rico). (B) Gamma spectra of one species of alga collected at Pta. Higuero (west coast) and at Guanica (south coast).

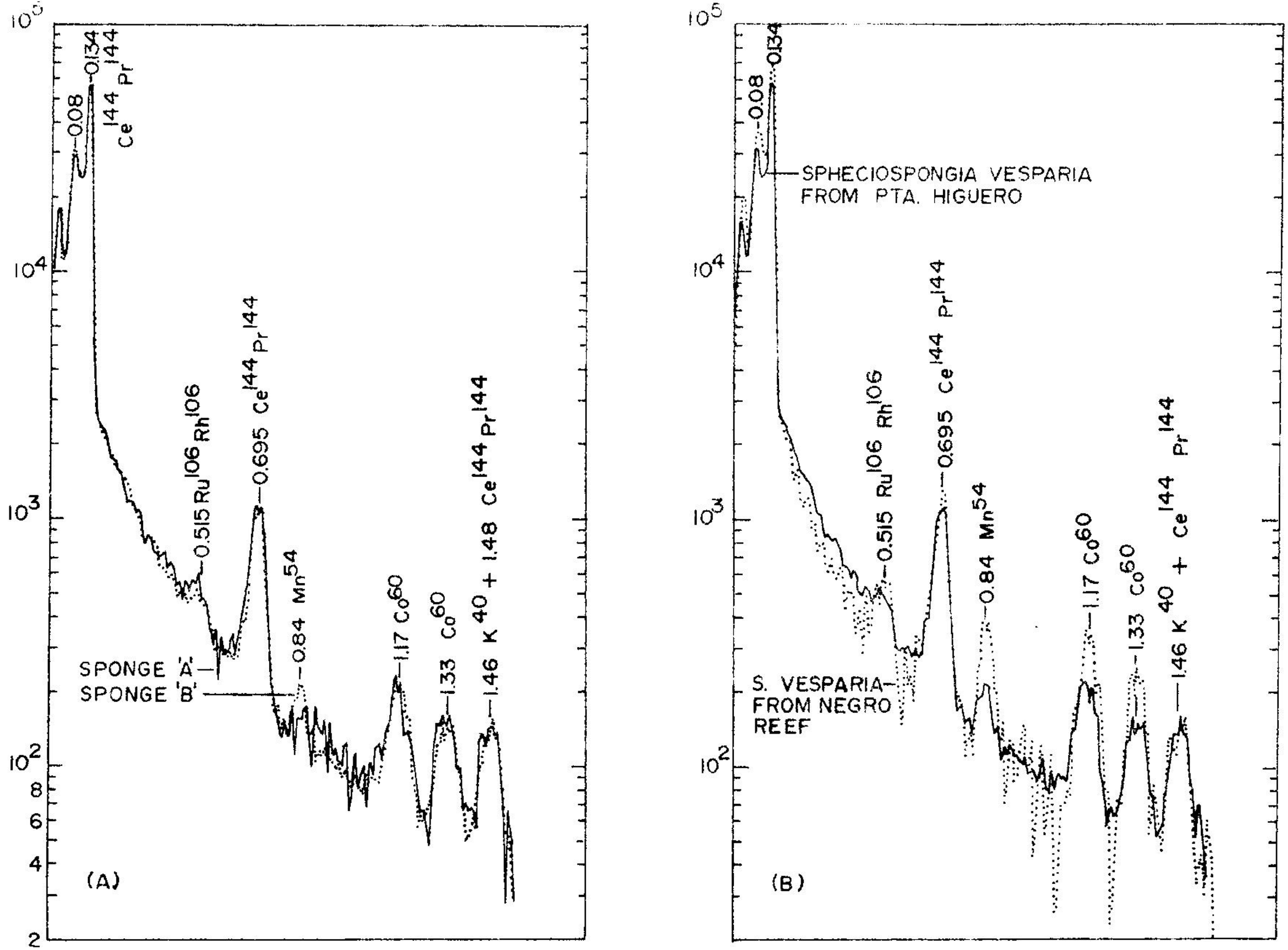


FIG. 13 (A) Gamma spectra of two specimens of Spheciospongia vesparia collected at Pta. Higuero on July 9, 1964. The spectra do not differ except for minor differences in the amounts of Ru^{106} Rh^{106} and Mn^{54}. (B) Gamma spectra of two specimens of one species of sponge collected at sites 13 nautical miles apart off the west coast of Puerto Rico. The sample from Negro Reef contains significantly greater amounts of Mn^{54} and Co^{60}.

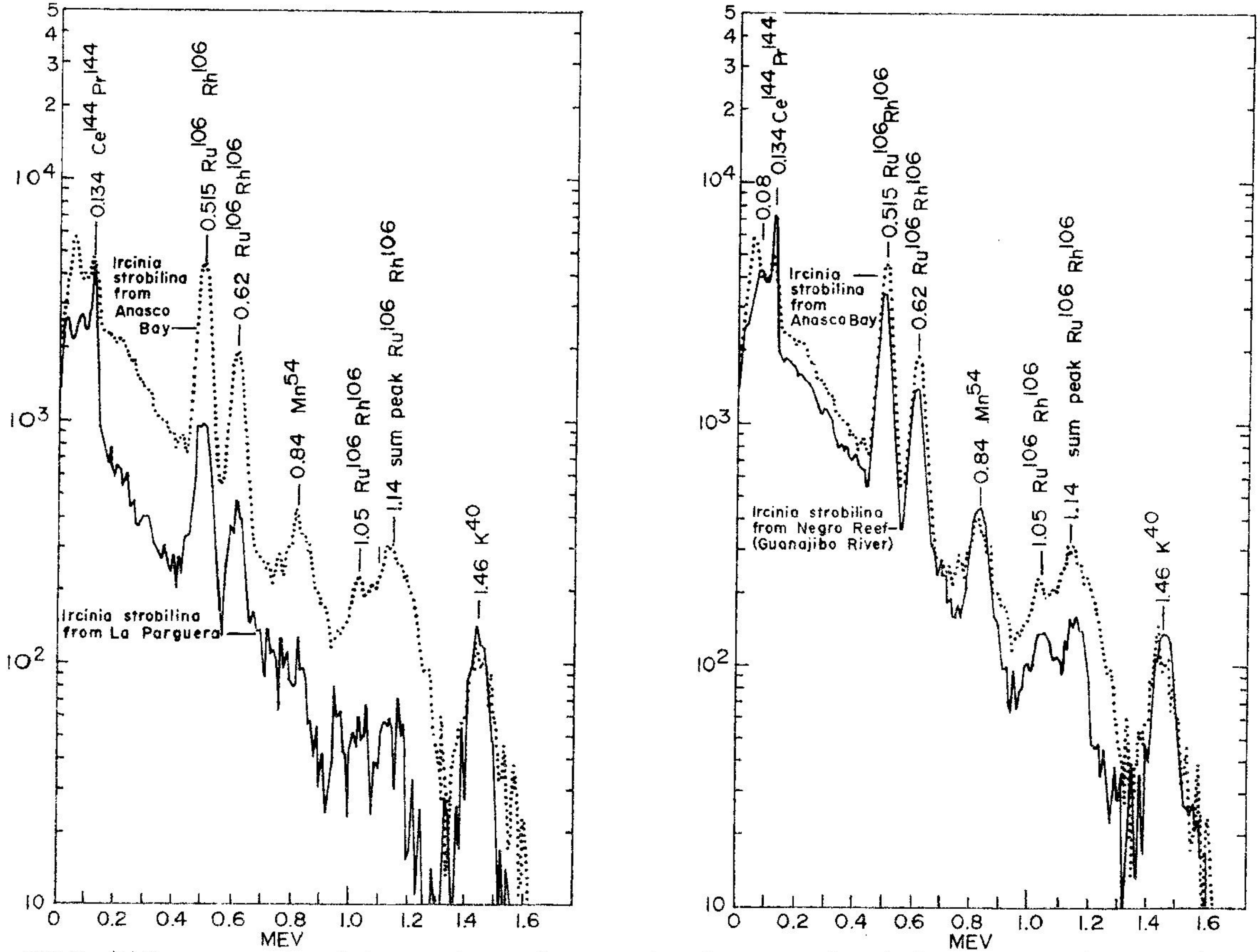


FIG. 14 (A) Gamma spectra of two specimens of one species of sponge collected in Anasco Bay (west coast) and at La Parguera which is 3! miles from Anasco Bay and on the south coast. Smaller amounts of $Ru^{106}Rh^{106}$ and Mn^{54} were present in the sample from La Parguera. (B) Gamma spectra of two specimens of I. strobilina collected at sites 13 miles apart off the west coast of Puerto Rico. The radioisotopes Ce^{144} Pr^{144} are present in higher and $Ru^{106}Rh^{106}$ in lower amounts in the specimen from Negro Reef.

The gamma spectra shown in Figure 14 A indicate much lower amounts of Ru^{106} Rh^{106} and Mn^{54} in samples collected on the south coast of Puerto Rico in comparison with those from the west coast. Smaller differences for specimens of the same species are shown in samples collected 13 miles apart on the west coast (Fig.14 B). Thus, the degree of change in uptake pattern for fallout radioisotopes appears to be related to the degree of environmental change and is here related to distance.

Marine fishes exhibit remarkably different patterns of fallout content than do the other organisms under investigation. The species of fish reported here (Makaira nigricans are of especial interest in their radioisotope content since they form a third trophic level of the series: primary producers (phytoplankton), grazers (zooplankton) and carnivores (fish).

Figure 15(A) shows the gamma spectra of the gastro-intestinal tract and spleen of a large female blue marlin collected at Virgin Gorda Island east of Puerto Rico. Almost 100% of the fallout radioactivity in the spleen was contributed by Zn^{65}. In contrast to the gamma spectrum from the spleen, the GI tract shows, in addition to Zn^{65}, a large photopeak of Mn^{54} and a detectable amount of Cs^{137} Ba^{137m}. The presence of significant amounts of cesium in the organs and tissues of this species is different from the pattern of distribution found in most other marine organisms. During a sampling period of 13 years at the Pacific Proving Ground Cs^{137} Ba^{137m} was not observed in any marine organism in amounts that could be detected in a total gamma spectrum although several thousands of samples were taken, in the lagoons and the surrounding seas.

Figure 15(B) shows the gamma spectra of gonads and liver from the fish described above. In the gonad the main radioisotope is Zn^{65} although small amounts of Mn^{54} are evident. In distinction to the other three organs, the liver contains Co^{57} and Co^{60} in addition to the larger amounts of Zn^{65} and Mn^{54}. The pattern shown in the four gamma spectra is similar to those taken from tissues and organs of most of the pelagic fishes collected in the offshore areas of Puerto Rico.

The ratio, Co^{57}/Co^{60} in the marine samples collected near Puerto Rico in the summer of 1964 had a value of approximately five. The same ratio in samples collected at the same time at the Pacific Proving Ground were: Eniwetok, 0.059; Bikini, 0.060. Thus the ratio Co^{57}/Co^{60} in the Caribbean area is approximately 100 times that in the Pacific. Co^{57} has a physical half-life of 267 days and Co^{60}, 5.27 years. The radiocobalt in the Pacific area is primarily derived from older weapons' debris from the U.S. tests at Bikini and Eniwetok. On the basis of measurements of fallout in rainfall made by the Marine Biology Program and the observed Co^{57}/Co^{60} ratio reported above, the principal source of radiocobalt in the Caribbean was supplied by the last Russian test series.

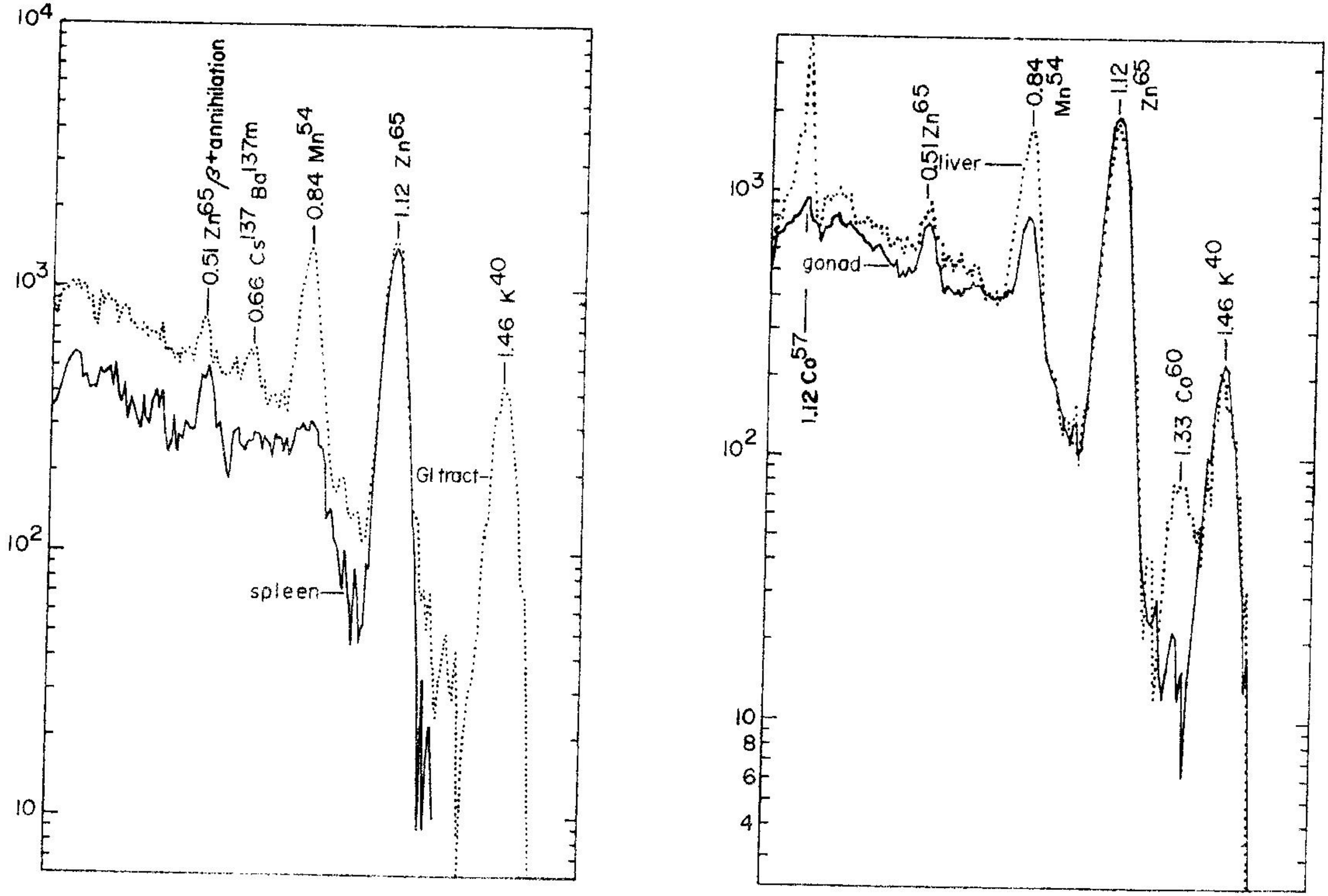


FIG. 15 Gamma spectra of four organs of a **female** blue marlin (Makaira nigricans) collected at Virgin Gorda Island east of Puerto Rico. The fish weighed 498 pounds.

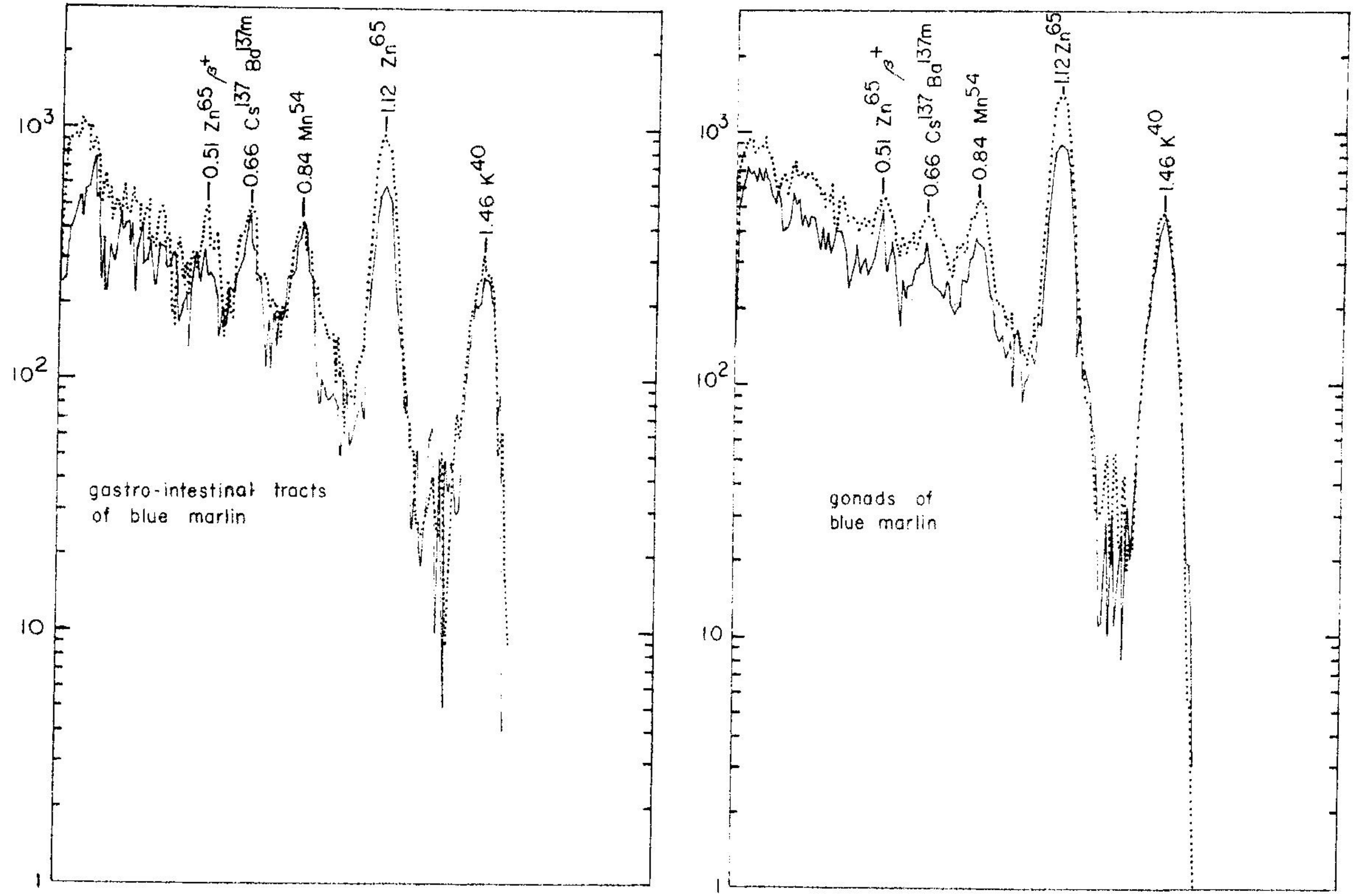


FIG. 16 Gamma spectra of the gastro-intestinal tracts and gonads of two blue marlin (*Makaira nigricans*) taken near Arecibo on the north coast of Puerto Rico July 17, 1964.

The gamma spectra of gastro-intestinal tracts and gonads of two blue marlin taken near Arecibo on the north coast of Puerto Rico in July, 1964 are shown in Figure 16. The gamma spectra of the GI tracts (Fig.16A) are similar to those in Figure 15 A except that the latter two fish have relatively higher amounts of Cs^{137} Ba^{137} and lower amounts of Mn^{54}. In the gamma spectra of the gonads of the blue marlin samples (Fig.16B) the amounts of Zn^{65}, Mn^{54} and Cs^{137} Ba^{137m} are similar but the amounts of K^{40} are different.

The following is a tabulation of the fallout contents in the three trophic levels described above:

Isotope	Phytoplankton	Zooplankton	Marlin		
			G.I. Tract	Liver	Gonad
Mn^{54} d/m/g	0.31	0.85	0.08	0.9	0.16
Co^{57} d/m/g	0.28	0.85	---	0.5	---
Co^{60} d/m/g	0.04	0.13	---	0.1	---
Zn^{65} d/m/g	0.12	0.47	0.8	4.3	3.4
Cs^{137} d/m/g	---	---	0.15	---	0.22

Of the five radioisotopes, only Zn^{65} exhibited marked increases in concentration with increase in trophic level. Radiozinc content per gram of wet material increased from a value of 0.12 d/m/g in the phytoplankton to 0.47 d/m/g in the zooplankton. In the G.I. tract of the marlin the amount of Zn^{65} was approximately double that of the zooplankton (0.8 d/m/g). The values in the liver and gonad were higher, 4.3 d/m/g and 3.4 d/m/g respectively. Thus, from the first trophic level to the third an increase of 7 - 30 for Zn^{65} content was shown. A similar pattern was noted between trophic levels investigated at the Pacific Proving Ground (Lowman, 1963). In that study only Zn^{65} and radioiron were concentrated with increased trophic levels.

REFERENCE

Lowman, F. G., 1963 in Radioecology (eds. V. Schultz and A. W. Klement, Jr.)

Reinhold Publ. Corp and Am. Inst. Biol. Sci. Chapman Hall, Ltd. London pp. 145-149.

Radioisotopes and Stable Elements in Plankton, Fish Meal and Guano from Perú

The Peruvian coastal waters constitute one of the most productive areas of the entire world ocean. Three lines of evidence support this statement: Plankton is abundant in the said area throughout the whole year, fish meal is being manufactured at the annual rate of over 1.5×10^6 metric tons and about 1.8×10^5 metric tons of guano are produced by large colonies of marine fish-eating birds whose numbers average approximately 12×10^6 actively fishing individuals.

These facts form the basis for undertaking the determination of the level of radioactivity and the concentration of some stable elements in the plankton, fish meal and guano from Perú*. Of particular interest to the Marine Biology Program of the PRNC is the comparison of the conditions obtained in the marine waters of Puerto Rico, whose fertilization mechanism is primarily dependent on land run-off, with those of the Perú Current, whose fertilization depends mainly on upwelling.

Fallout was investigated by means of a 512 channel gamma spectrometer, and the stable elements were determined either by the atomic absorption method or by a gas chromatographic method for carbon, hydrogen and nitrogen analysis.

Results are summarized in Tables II, III, IV and V and Fig. 17.

Table II presents the results of atomic absorption and gas chromatographic analyses run on anchoveta fish meal samples from three different localities of the Peruvian coast, namely Chimbote, Callao and Ilo. The elements analyzed were Fe, Co, Ni, Cr, Pb, Mn, Zn, C, H and N.

Table III summarizes the results of similar analyses carried out on two assorted Peruvian plankton samples, one from Chimbote and the other from Callao.

Table IV is again a tabular presentation of the analyses conducted on a guano sample collected in Chincha Norte Island, Perú from the nesting ground of a large colony of Peruvian cormorants (*Phalacrocorax bougainvillii* L.), by far the most abundant species of the guano ornithofauna, (Avila, 1955).

* The plankton samples were supplied by Dr. B. R. de Mendiola, IREMAR, La Punta, Perú.
The fish meal samples were provided by Dr. T. Sparre, Inst. Invest. Recursos Marinos, La Punta, Perú.
The guano sample was sent by Mr. J. M. Cabrera, Corp. Nl. Fertilizantes, Lima, Perú.

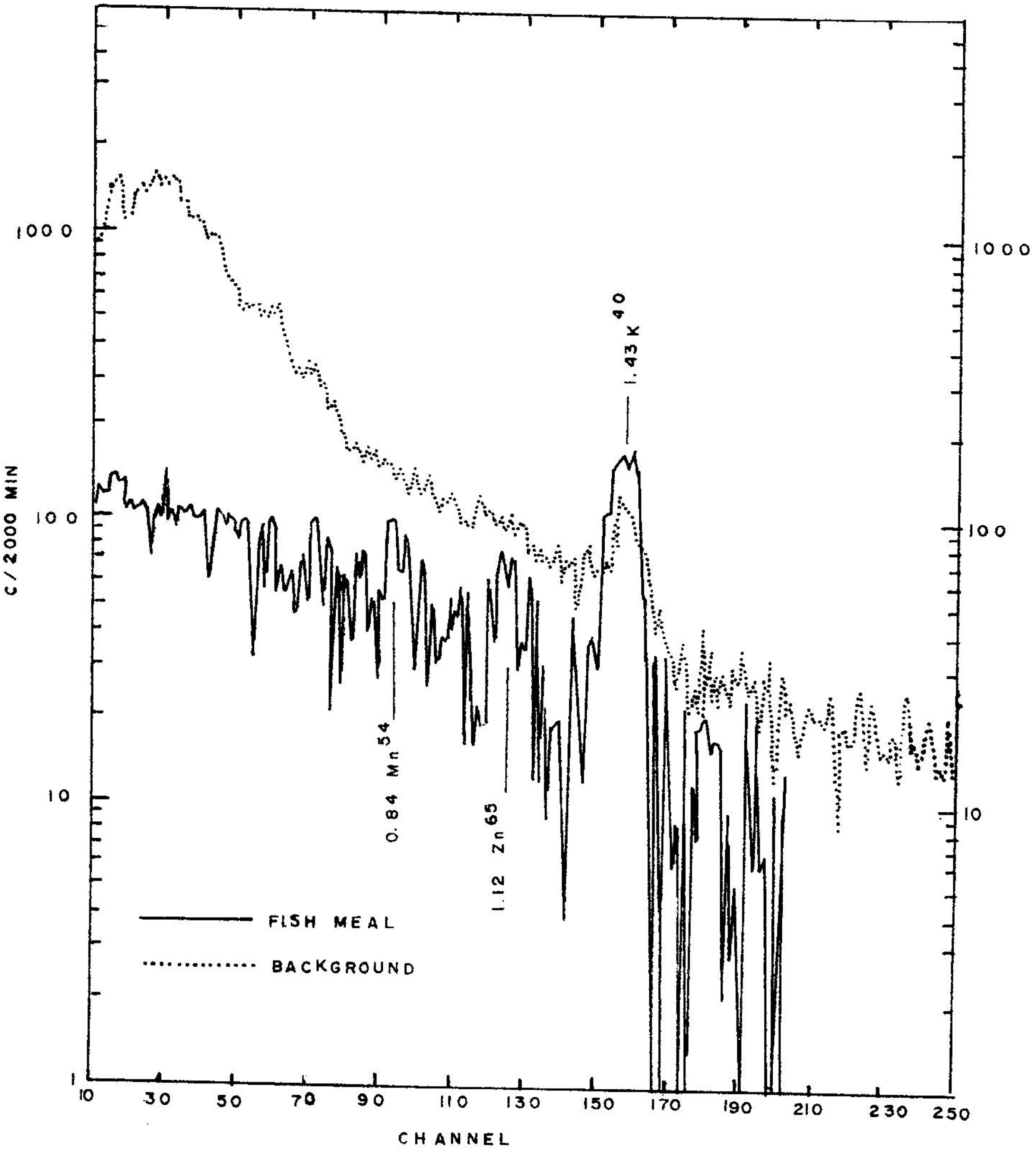


FIG. 17 GAMMA SPECTRA FOR PERUVIAN ANCHOVY (*Engraulis ringens* J.) FISH MEAL FROM CHIMBOTE, PERU

TABLE II

Material	Chimbote Wet	Chimbote Dry	Chimbote Ash	Callao Wet	Callao Dry	Callao Ash	Ilo Wet	Ilo Dry	Ilo Ash
Peruvian anchovy (*Engraulis ringens* J.)									
Amount of sample, grams	4320	800	115	4800	800	124	4480	800	132
μg Fe/g	16.7±.4	90.2±2.3	627±16	26.9±2	162±11	1040±70	27.7±.6	155±3.4	941±20
μg Co/g	0.4±.05	2.2±.3	15.0±2.	0.4±.05	2.3±.3	15.0±2	0.5±.01	2.5±.03	15.3±.6
μg Ni/g	0.6±.2	3.4±.9	23.0±6.3	0.5±.1	3.0±.7	19.0±4.2	0.5±.1	2.9±.6	17.5±3.5
μg Cr/g	0.8±.1	4.1±.7	28.0±4.9	.7±.2	4.1±1.4	26.±8.8	0.8±.1	4.7±.5	28.4±2
μg Pb/g	1.4±.1	7.6±.7	52.6±4.5	1.5±.01	8.8±.02	56±.1	1.5±.1	8.4±1.3	51.2±8.
μg Mn/g	1.0±.02	5.5±.1	38.5±.9	1.0±.1	6.0±.4	38.0±2.6	0.8±.07	4.7±.4	28.3±2.3
μg Zn/g	12.6±.6	68.0±3.5	472.5±23	11.8±2.	73.0±11	472.1±70.5	15.9±.6	88.7±3.3	538.6±20.
% H	--	6.3	--	--	6.7	--	--	6.8	--
% N	--	8.4	--	--	8.5	--	--	9.1	--
% C	--	44.8	--	--	43.4	--	--	44.7	--

TABLE III

Material	Chimbote			Callao		
	Wet	Dry	Ash	Wet	Dry	Ash
Assorted mixture of Peruvian plankton						
Amount of sample, grams	247.4	22.1	13.4	1064.7	65.2	45.0
μg Fe/g	383.±85	4288±957	7033±1568	196±21	3196±352	4633±513
μg Co/g	2.1±0.21	23.9±2.3	39.3±4	1.8±0.16	30.3±3.5	43.7±5
μg Ni/g	3.1±0.6	35.2±6.7	57.7±11	1.9±.1	30.8±.1	44.7±0.6
μg Cr/g	3.4±0.6	38.6±6	63.3±10	2.4±0.8	39.8±14	57.7±20
μg Pb/g	13.1±1.3	147.4±19	242±31.7	7.1±0.6	116.1±7.2	168±10
μg Mn/g	1.8±0.5	20.7±2.8	34.4±4.6	1.2±.1	19.1±1.5	27.7±2.1
μg Zn/g	24.8±10.8	278.8±121	457±198	6.4±0.9	104±14.7	150.7±21.4
% H	--	3.12	--	--	2.22	--
% N	--	2.5	--	--	2.22	--
% C	--	13.1	--	--	8.1	--

TABLE IV

Material	Chincha Norte Island		
	Wet	Dry	Ash
Guano of Peruvian Cormorant (*Phallacrocorax bougainvillii* L.), grams	3200	400	126.8
μg Fe/g	286±47	2291±382	7217±1199
μg Co/g	0.6±0.0	4.9±0.0	15.5±0.0
μg Ni/g	0.7±0.1	5.4±0.84	17±2.6
μg Cr/g	0.7± ?	5.5± ?	17.3± ?
μg Pb/g	1.8±0.1	14.7±1.8	46.3±8.3
μg Mn/g	2.5±0.2	20.3±1.8	64.±5.6
μg Zn/g	14.9±0.84	119.6±6.6	376.7±20.8
% H	--	4.1	--
% N	--	17.6	--
% C	--	20.5	--

Table V is a summary of the radioactivity found in the fish meal samples. Part A gives the radioactivity of K^{40}, Zn^{65} and Mn^{54} as disintegrations per minute per gram of sample. Part B presents the specific activities* of Zn^{65} and Mn^{54} compared to the corresponding maximum permissible specific activities, as given in Table I-B of Disposal of Low-Level Radioactive Waste into the Pacific Coastal Waters (ISAACS et al., Nl. Acad. Sc., Nl. Res. Counc., Pub. 985, Washington, D.C., 1962).

Table III indicates that both Fe and Zn are the most abundant trace elements among those analyzed. This result is in keeping with the knowledge on the metabolic characteristics of diatoms (the most important aliquot in the plankton sample which was analyzed), since these organisms actively take up these elements from the environment. Marine plant organisms are capable of utilizing ferric hydroxide as colloidal micelles or even larger aggregates which are first adsorbed onto the surface of the organisms and later incorporated, to varying degrees, in the protoplasm of the unicellular algae (GOLDBERG, 1963; HARVEY, 1955). Zinc is a well known constituent of several enzymatic systems and has been shown to catalyze the utilization of some sugars intracellularly (SEYMOUR, 1963; RICE, 1963; DAY, 1963; CALDECOTT, 1960).

Cobalt was present in low amounts in the plankton although its biological significance may be out of proportion to the minute amounts in which it is present in the organisms. It is known, for instance, that glycyglycinase is activated by cobalt, and it is contained in the vitamin B_{12} (DAY, 1963).

It was surprising to find a relatively high concentration of Ni, about 50 µg per gram of wet plankton, since this element is not known to be of any biological importance.

The amounts of lead were unexpectedly high. It is not known to have any biological role and its relationship to the plankton organisms should be investigated.

Tables II and IV may be generally interpreted in terms of what has been said for Table III. Both fish meal and guano are one or two rungs higher, respectively, in the same trophodynamic ladder of the Peruvian waters. In effect, fish meal is manufactured from an engraulid locally known as "anchoveta" (*Engraulis ringens* J.), whose diet is made up, to a great extent, of members of the *Bacillariophiceae* and Dinophiceae. Guano is the waste product of three marine bird species that feed almost exclusively on the anchoveta.

Table V demonstrates that the Peruvian fish meal is essentially free of radioactive nuclides, except for the very low concentration

* Specific activity defined as disintegrations per minute per gram of the element concerned.

TABLE V

Radioactivity in the Peruvian anchovy (Engraulis ringens J.)

A. Disintegrations/minute/gram

Sample from	d/m/g, K^{40}			d/m/g, Zn^{65}			d/m/g, Mn^{54}		
	Ash	Dry	Wet	Ash	Dry	Wet	Ash	Dry	Wet
Chimbote	51.6	7.44	1.38	0.52	0.07	0.01	0.69	0.10	0.02
Callao	62.8	9.8	1.63	0.86	0.13	0.02	0.52	0.08	0.01
Ilo	63.7	10.5	1.87	0.84	0.14	0.02	0.15	0.03	0.005

B. Specific radioactivity in fresh Peruvian anchovy

Sample from	Radio-nuclide	Specific Activity of radionuclide (μc/g of stable element)	Maximum permissible activity (μc/g of stable element)	Safety factor for fresh Peruvian anchovy
Chimbote	Zn^{65}	5×10^{-4}	26*	52000
Callao	Zn^{65}	8.5×10^{-4}	26	31000
Ilo	Zn^{65}	6.8×10^{-4}	26	39000
Chimbote	Mn^{54}	8.3×10^{-3}	10*	1200
Callao	Mn^{54}	6.09×10^{-3}	10	1600
Ilo	Mn^{54}	2.03×10^{-3}	10	4900

* According to Table I-B of Disposal of Low-Level Radioactive Waste into Pacific Coastal Waters, National Academy of Sciences, National Research Council Publication 985, Washington, D.C., 1962.

of K^{40}, Zn^{65} and Mn^{54}. This result was to be expected for two main reasons: a) It is well established that present world-wide fallout is principally restricted to the northern hemisphere and, therefore, considering the circulation pattern of the Pacific Ocean, it is natural that the contamination of the Peruvian waters is only of a minor character, and b) The upwelling, so prevalent a phenomenon along the Peruvian coast, brings to the surface waters from deeper levels that are essentially uncontaminated by world-wide fallout.

The results of this investigation were compared briefly, in the preceding section, with the findings for fallout radioactivity in the organisms from Puerto Rico.

REFERENCES

AVILA, E. Second Report to the Marine Biology Program of the PRNC entitled On the Biological Aspects of the Peru Current, MS, Lima, Perú, 1963.

CALDECOTT, R.S. and L.A. Snyder, Editors, A Sympossium on Radioisotopes in the Biosphere. Univ. of Minnesota, Minn., 1960.

DAY, F.H. The Chemical Elements in Nature. Reinhold Publishing Corporation, New York, 1963.

EISENBUD, M. Environmental Radioactivity, McGraw Hill Book Company, Inc., New York, 1963.

GOLDBERG, E. Mineralogy and Chemistry of Marine Sedimentation, in Submarine Geology, 2nd. Edit. by F.P. Shepard. Harper and Row, New York, 1963.

HARVEY, H.W. The Chemistry and Fertility of Sea Waters, Cambridge at the University Press, London, 1955.

RICE, T.R. Review of Zinc in Ecology. In Radioecology, Edit. V. Schultz and A.W. Klement, Jr., Reinhold Publishing Corp. and The American Institute of Biological Sciences, 1963.

SEYMOUR, A.H. Radioactivity of Marine Organisms from Guam, Palau and the Gulf of Siam, 1958-1959. In Radioecology, Edit. V. Schultz and A.W. Klement, Jr., Reinhold Publishing Corp. and The American Institute of Biological Sciences, 1963.

ANALYSES OF RIVER WATER

Analyses of river waters were begun in 1964 in an effort to determine the contribution of elements by rivers in western Puerto Rico to the surrounding sea water. Three main rivers in western Puerto Rico drain watersheds that have a somewhat different mineral composition. The Añasco River drains a watershed that is predominately igneous in origin, whereas the Culebrinas River drains a watershed that contains a large amount of limestone as well as igneous materials. In addition to areas that contain igneous materials, the Guanajibo River drains deposits that are rich in serpentine. All of these rivers enter the sea alongan 18 mile length of coastline. Consequently there exists an opportunity to compare the distribution, abundance, elemental make-up, and amounts of fallout materials in marine organisms that live close to these river outflows as well as those that might be affected by materials from more than one river.

Since the major part of the program is concerned with the influence of the Añasco River, investigations began with an analysis of water from that river. In August, 1963 one litre of surface water was collected approximately 300 feet inland from the mouth of the river. The sample was filtered through a 0.5μ Millipore filter and the filtrate was evaporated to a few ml and then diluted to 10 ml with 0.2N HCl. A white precipitate was filtered out and was washed with 15 ml of 0.2N HCl. This filtrate was added to the original filtrate to give a final volume of 25 ml.

The filtrate was analyzed by atomic absorption spectrophotometry for content of Ni, Cr, Mn, and Fe. An aliquot of the filtrate was mixed with an equal amount of 0.2N HCl which contained 4000 ppm of lanthanum as the chloride and was analyzed as above for Mg, Sr and Ca.

The results of stable element analyses on the soluble fraction of the water were as follows:

Element	μg/liter
Mg	9,500
Sr	130
Ca	25,000
Ni	18
Cr	4.3
Mn	3.5
Fe	20.
Sc	0.63

Total dissolved solids/liter 0.32 gms.

Of the elements analyzed, Ca and Mg were present in the highest amounts. Iron, Cr, Ni, Mn and Sc were present in amounts of 20 μg/liter or less.

A comparison of the amounts of the elements in the Añasco River water with those found in some major U. S. rivers (Clarke, 1924) showed that the amounts of most elements were approximately the same. However, there was about one order of magnitude less Fe and Mn in the Añasco River than in other U. S. rivers.

In February, 1965, samples of water were collected from the Añasco, Culebrinas and Guanajibo Rivers. Collections were made by lowering a Van Dorne bottle into the rivers and taking the water immediately beneath the surface. The two aliquots from each river were analyzed as above except that 6N acid was used in the washing process.

The water was not processed until the day after collection and it was noted that floccular material, probably of bacterial origin, had formed in the samples from the Añasco and Guanajibo Rivers. Water from the 2 rivers was collected a short distance downstream from sugar mills which dump waste products into them. Water from these 2 rivers had a strong odor of bagasse which probably provided a substrate for a high rate of bacterial activity. Although is not known to what extent such activity may have altered the amounts of dissolved elements studies have been started to evaluate the effects of organic material on the physical states of the trace elements in the river waters.

The following table shows the analyses that have been performed to date:

Element	Añasco	Culebrinas	Guanajibo
Ni	0.009	0.017	0.016
Mn	0.018	0.007	0.109
Co	0.002	0.003	0.004

The quantities observed here are much smaller than those previously observed for the Añasco River. The recent samples were collected during the dry period of low river flow and the near drought conditions that prevailed during the winter may have resulted in the greatly reduced amount of dissolved elements. Another factor that would help to account for the low values is the fact that the samples were taken several miles upstream from the previous Añasco samples where the amount of dissolved material is greatly reduced (Lowman, in press).

Additional samples are being taken to determine seasonal fluctuation in the amounts of elements in the three rivers.

The data to date suggest qualitative differences in the trace element composition of the three rivers. An expanded and intensified sampling program will be carried out over time to define seasonal variations within and between these rivers. Automatic stations to monitor height, flow rate, oxygen content and pH levels of the three rivers should be installed in order to provide a quantitative basis for interpreting the observed trace element contents in relation to total contribution into the marine environment.

TEMPERATURE AND CURRENT STUDIES AT PUNTA HIGUERO

Studies of marine organisms and their environment at the Bonus site were begun in 1963 and are continuing. These studies are being made to provide background information for the evaluation of possible changes induced by the future operation of the Bonus nuclear power plant. Because of the release of large amounts of thermally hot water from the plant, the environmental parameters temperature and currents are considered to be of primary importance and consequently are receiving particular attention. Abundance and distribution of the more common flora and fauna are being made to determine temporal and spatial fluctuations. Levels of stable elements in organisms are being determined in order to provide the basis for determining specific activities in the event that radioactive materials enter the environment.

Temperature

Temperatures were measured by holding the thermometer about one foot beneath the surface of the water and by observing it through a face mask. Observations were made at a distance of about 3 meters from shore. With two exceptions, readings were made at least once each month. When more than one reading was taken within any month, each value is reported separately.

Figure 18 shows the fluctuations in temperature observed during 1963-1965. During this period of time the average temperature was 28.3°C and the range extended from 26.5 to 29.6. Total seasonal fluctuations are similar and are of the slight magnitude characteristic of tropical areas.

The dominant feature shown in the figure is the relatively wide variation within periods of one month. These variations are most likely due to a combination of diurnal changes in air temperature, wave action, and geographic and hydrographic features. During daylight hours, intense solar radiation results in an accumulation of heat in water adjacent to shore where waves pick up heat from the warmer sand and where flushing is relatively poor. During the night when the sand cools, the waters become correspondingly cooler. During periods of slight wave activity, warm water extends farther offshore in the "pocket" formed by the curve of the beach, but stronger waves tend to flush the area and to bring sea water temperatures closer to shore.

Currents

The path of coolant water which leaves the plant has been traced in a dye experiment reported last year. At that time, water was observed to flow southward along the beach and to turn westward at Punta Higuero and then to form a gyre which rotated in a clockwise direction

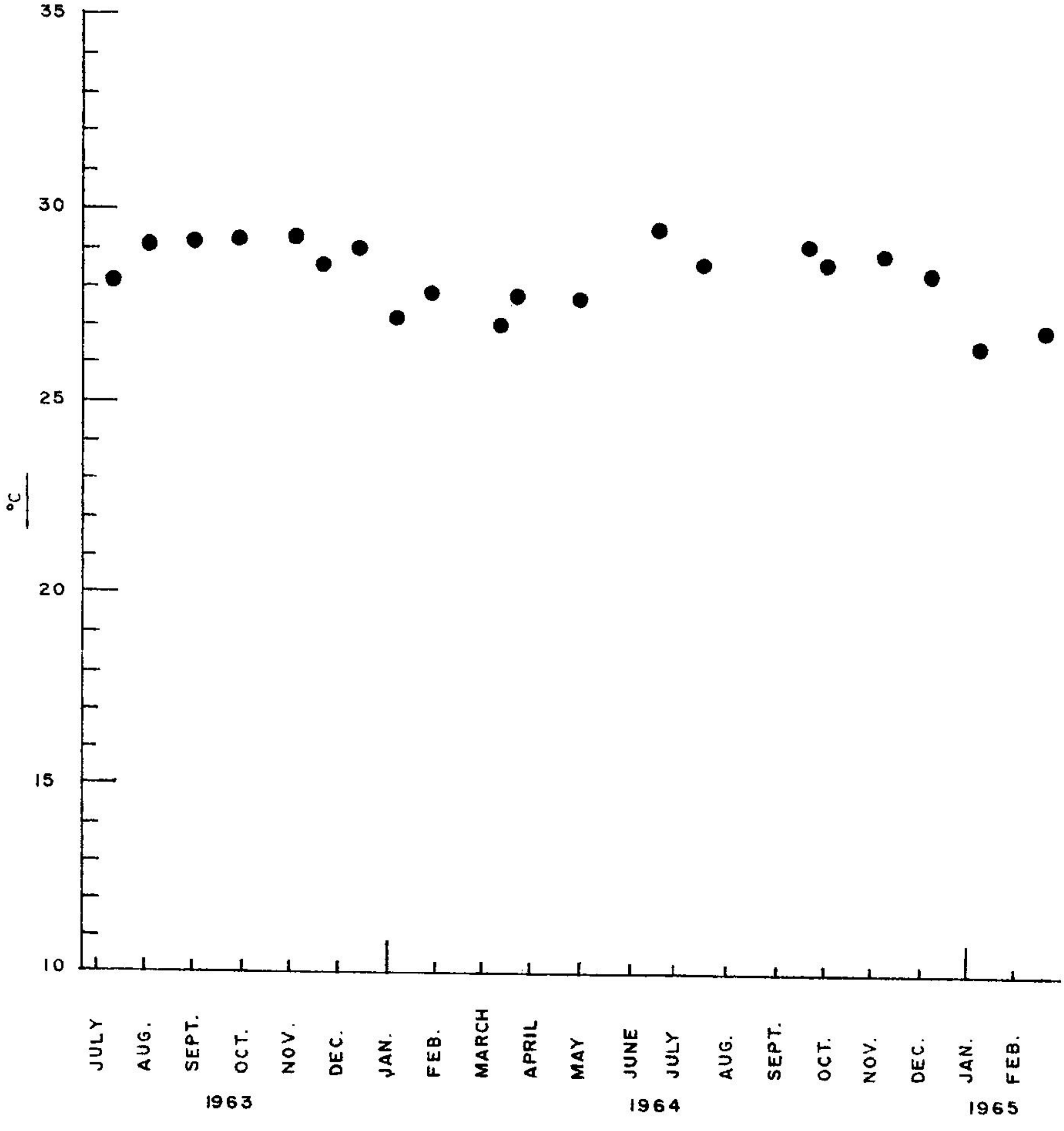


Figure 18. Seasonal variation in temperature (°C) of sea water adjacent to the beach at the Bonus site.

back toward the beach. Since then, another dye experiment and studies of temperature structure have further clarified the path of water after it leaves the outlet from the plant.

On November 19, 1963, 3/4 pound of rhodamine-B dye dissolved in acetone was poured into the outlet while the water was being expelled at the normal capacity of 30,000 gallons/minute. The path of the dye was observed and notes were later integrated with photographs taken throughout the 48 minute period during which the dye was visible.

As in the previous experiment, the dye flowed south along the beach and then turned westward where it eventually began to form a gyre as it turned to the north. A small amount of dye flowed halfway around Punta Higuero, but then turned northward again to join the seaward sweep of the remaining dye. One small body of dye flowed a short distance northward soon after passing the point. This patch of water remained above a sandbar discovered in aerial photographs and probably explains the origin of the sandbar.

When the dye was first introduced into the water the currents spread it into the shape of a fan. After about two minutes, the body of dyed water diverged into two separate streams (Fig.19). One stream of dye followed the beach southward toward Punta Higuero. The other flowed southward about 80 meters from shore and traced the main course of water flow from the outlet. The two streams of water remained distinct, but followed the same course after they left the point. The forward edge of the dye moved southward along the beach at a measured speed of one knot.

On October 13, 1964 a series of temperature measurements were made while the plant was operating at a total power output of 20 megawatts (Fig.19). Four temperature readings were taken at distances of approximately 3, 8, 20, and 40 meters from the beach at four locations of 25 meter intervals southward along the beach. Two additional temperatures were taken farther south along the beach and one was taken in the coolant water and another farther off the beach in the unheated sea water.

Dilution effects can be seen when the observed temperatures are compared with the temperature of the coolant water (33.8°C) and with the unheated sea water (29.3°C) (Fig.19). The temperature of the water dropped rather uniformly as seen in the 1st 3 transects southward along the beach, although it dropped more slowly farther offshore in the second transect (33.1°C). In the fourth transect the temperature declined until it approached that of sea water (29.5°C). Although strong wave action prevented further observations offshore, the strength and direction of the current at the most seaward stations indicate that a warm current containing the flow from the outlet, passed offshore to the south. The reading of 29.5°C cited above

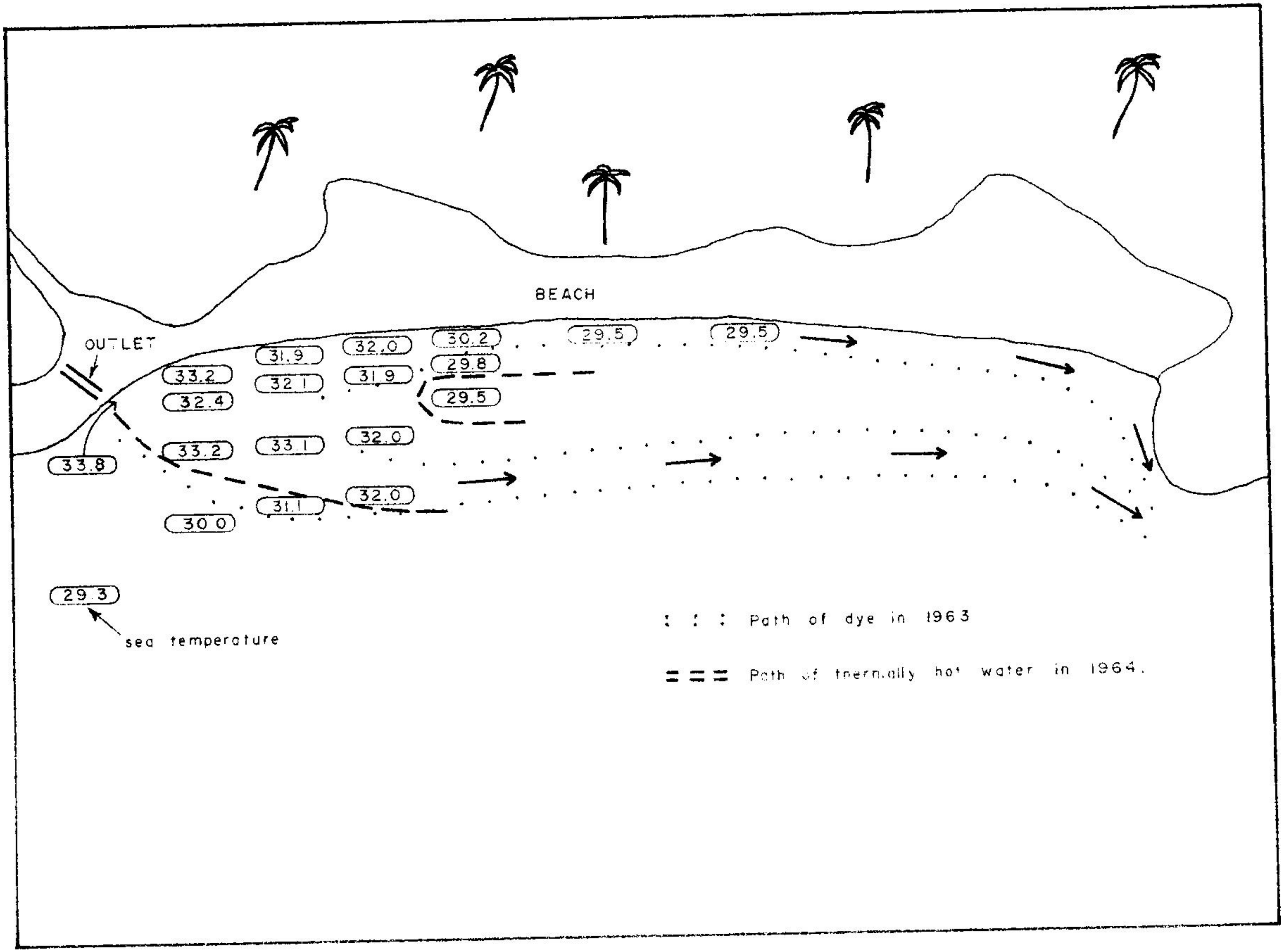


Figure 19. Path of dye and coolant water after entering the sea from Bonus nuclear plant.

represents the area between the two streams of warm water. Therefore, the situation was much the same as seen in the dye experiment one year earlier and suggests that this type of current pattern may frequently prevail. Observations are being made to determine whether zonation of marine organisms is occurring that conform to the current patterns.

ABUNDANCE AND DISTRIBUTION OF MARINE ORGANISMS AT PUNTA HIGUERO

Because of the difficulties encountered in working in an area of rapid currents and strong wave action only a few of the more abundant species were selected for study. Their abundance and distribution are determined periodically insofar as is possible, in five different locations. One location is upcurrent from the outlet and was intended to be a control area. The other four locations extend downcurrent to Punta Higuero. Collections were made at distances 5 to 15 meters from shore. During a survey of the locations, a grid of 1/16 square meter area was randomly thrown on the bottom and all of the algae in the quadrate were collected and placed in a plastic bag. This procedure was followed eight times at each location. In the laboratory, the species, Dictyota dentata, D. cervicornis, Cladophora sp., Padina sp., and Sargassum sp. were separated for each quadrate (grid) and an average wet weight/square meter was calculated. A similar procedure was followed with the sea urchin Echinometra lucunter which was the most abundant of the large invertebrate animals in the area. The urchins were counted on the bottom and were not removed.

Figures 20, 21, 22, show the distribution and abundance of the algal species over a one year period. The two species of Dictyota were small and less abundant than the other species and therefore were grouped together. They were most abundant in areas close to the outlet, but a limited number were present throughout the area (Fig.20). Species of Padina were the most abundant and widespread of the alga studied (Fig.21). They were the most abundant species upcurrent from the outlet and large numbers extended about half-way to Punta Higuero. Cladophora sp. had the narrowest range of any alga. It was abundant only at the location indicated in Figure 21. Species of Sargassum tended to be less abundant in the area closer to the outlet, and were most abundant at Punta Higuero where they covered rocks in a dense mat (Fig.22).

During the winter of 1964-65 sand completely covered the bottom, as well as the algae, in the survey area above the outlet. Much of the algae within about 30 meters of the outlet was also covered but less complete inundation was observed with increasing distance southward along the beach. The sand was so deep that water leaving the

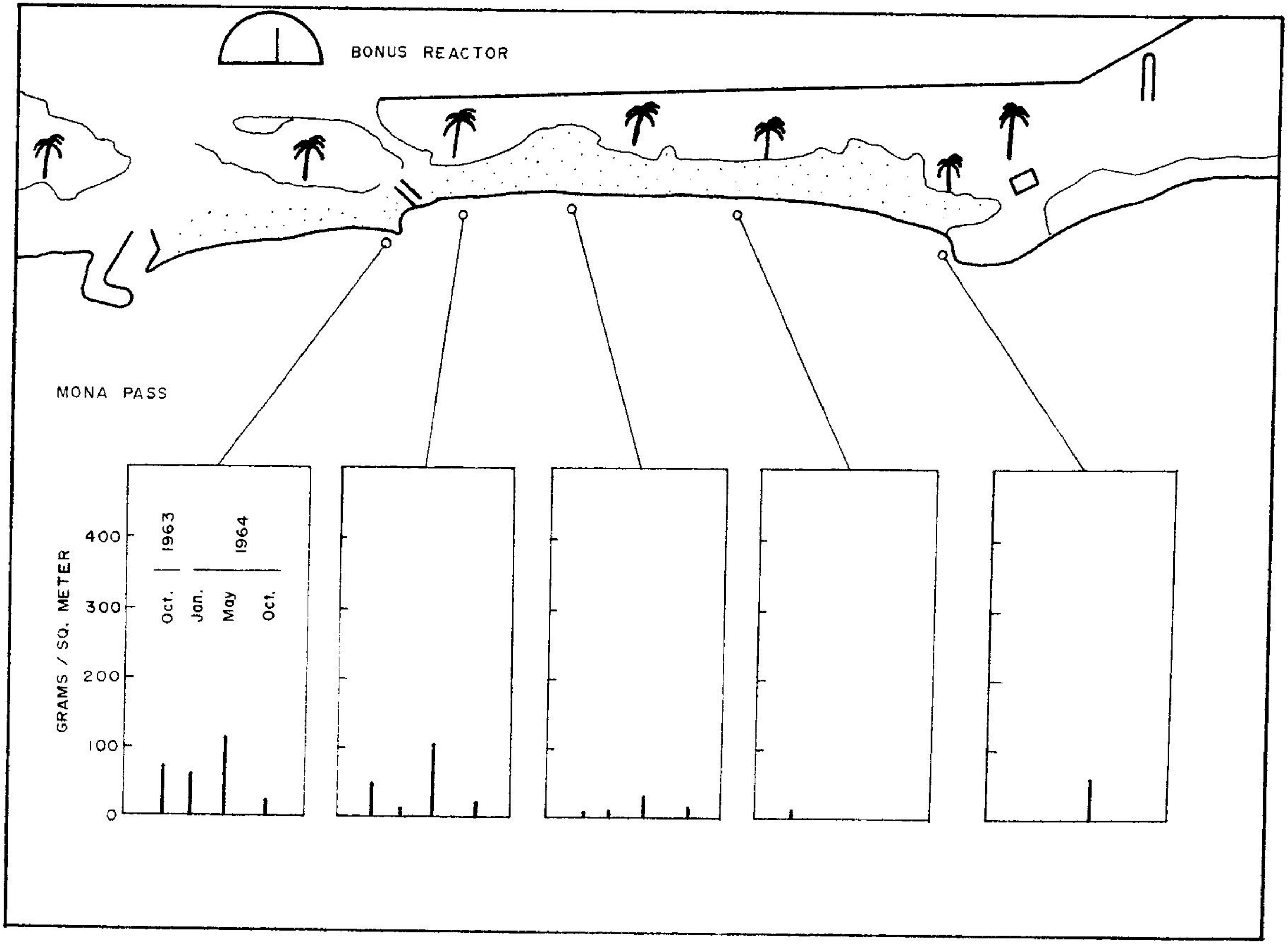


Figure 20. Abundance and distribution of Dictyota cervicornis and D. dentata (combined) at Bonus site during 1963, 1964.

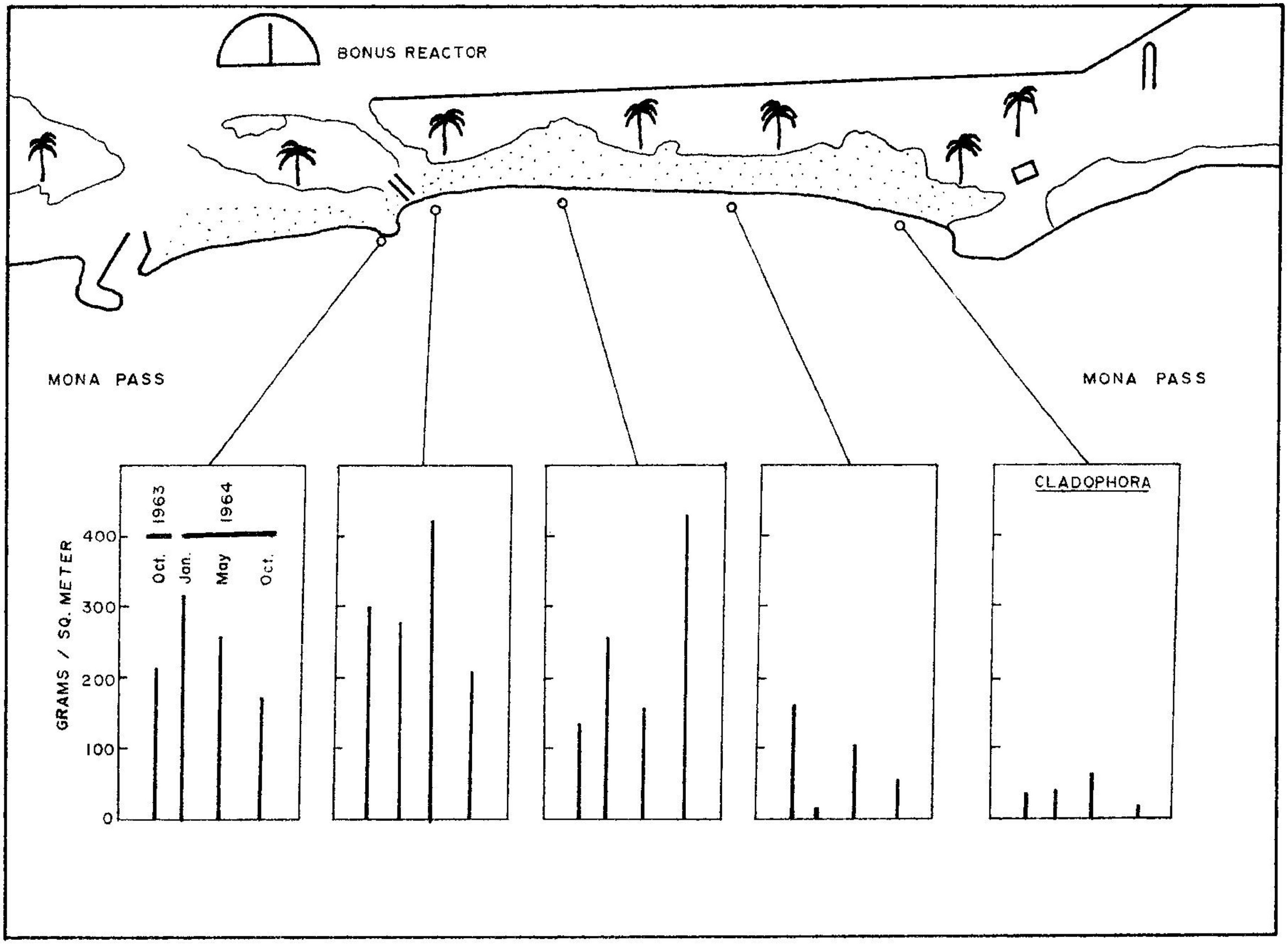


Figure 21. Abundance and distribution of species of Padina and of Cladophora sp. at Bonus site during 1963, 1964.

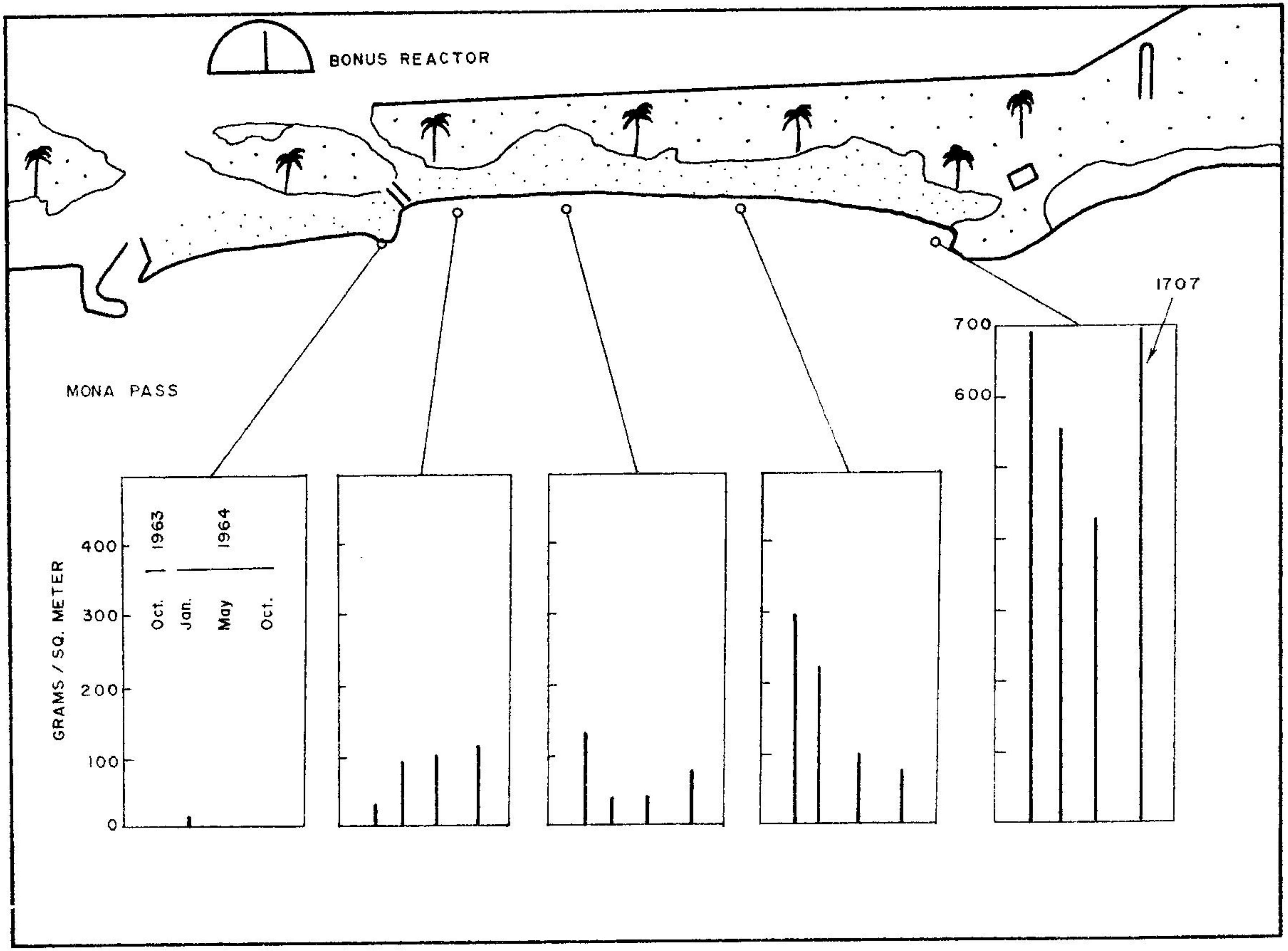


Figure 22. Abundance and distribution of species of Sargassum at Bonus site during 1963, 1964.

outlet at low tide was contained in a channel that had been cut in the sand. The data do not show cyclic fluctuations in abundance of algae over the one year period reported. This may be due to sampling problems or it may reflect the changes that have occurred in the environment due to the construction of a jetty.

Another inundation by sand that occurred early in 1964 influenced the numbers of sea urchins in the vicinity. At that time the study area upstream from the outlet received most of the sand. A decrease in numbers of Echinometra lucunter at that location in April is probably due to the effects of the sand (Fig.23).

Because urchins move around when the holes and crevices in which they live become filled with sand, large numbers were swept onto the beach by waves. Advantage was taken of the situation to gain some information as to the size distribution of the population. The lengths of 189 urchin tests were measured and Figure 24 shows their size frequency distribution when the measurements were grouped into 2 mm. intervals. A large, distinct mode appeared between 20 and 30 mm, and two smaller modes at 34 and 38 mm. The modes represent the bulk of the population and when correlated with weights of urchins, they afford a basis for the calculation of biomass and hence the amounts of stable elements/square meter.

Levels of Stable Elements in Epibenthic Organisms

Analyses of the stable element content of epibenthic marine organisms are continuing in accordance with procedures outlined in the section on Stable Element Analyses. One of the considerations that determine the number of analyses performed on a particular species is the variability of levels of elements within that species. Figure 25 shows the slight amount of variability of Fe, Ni and Mn in four intact individuals of the gorgonian Eunicea mammosa collected at Punta Higuero, Puerto Rico. Iron varied the most, but in comparison with other species reported here, all three elements showed little variability. Greater variability was encountered in the tissues of six individuals of the sponge, Ircinia strobilina, collected at Negro Reef in western Puerto Rico (Fig.26). Except for one value, the level of Ni was only slightly more variable than that in Eunicea. However, there was more than a 3-fold difference between the lowest and highest values for Mn. Data are not yet available for Fe.

As more organisms were analyzed, it became apparent that levels of elements within a particular species might vary with location. The mean values and standard deviations in Figure 27 show that levels of Fe in the skeletons of 15 Tripneustes esculentus collected at Punta Higuero, Puerto Rico (west coast), were significantly higher than amount of Fe in as many individuals of the same species collected at La Parguera, Puerto Rico (south coast). Differences of the same magnitude were noted when the work was repeated one year later. In general, the levels varied within an order of magnitude from data presented by Vinogradov 1953 for other echinoderm skeletons.

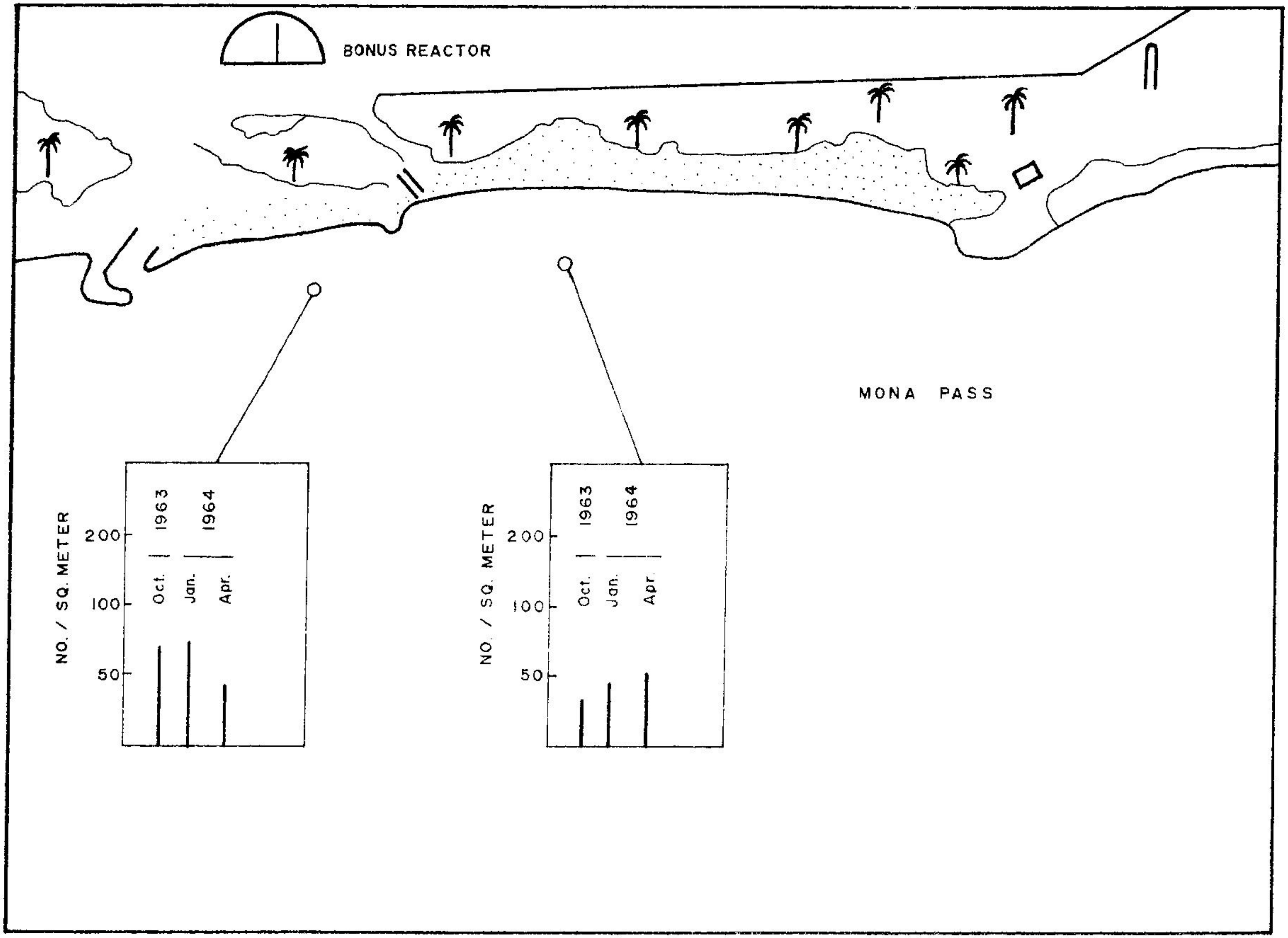


Figure 23. Abundance of <u>Echinometra</u> <u>lucunter</u> in two locations at the Bonus site during 1963, 1964.

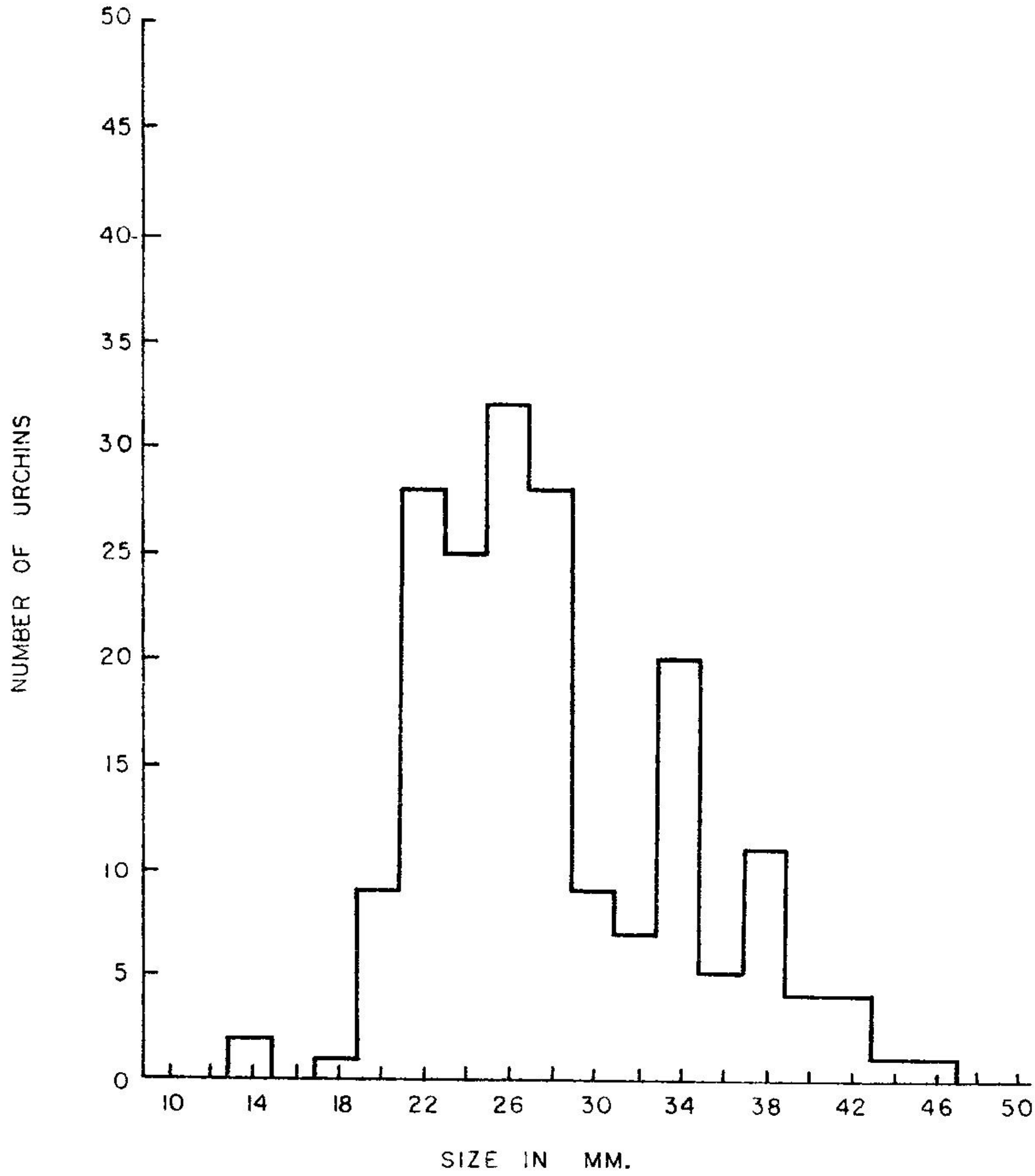


Fig. 24 Size-frequency distribution of *Echinometra lucunter* at Bonus Site in April, 1964.

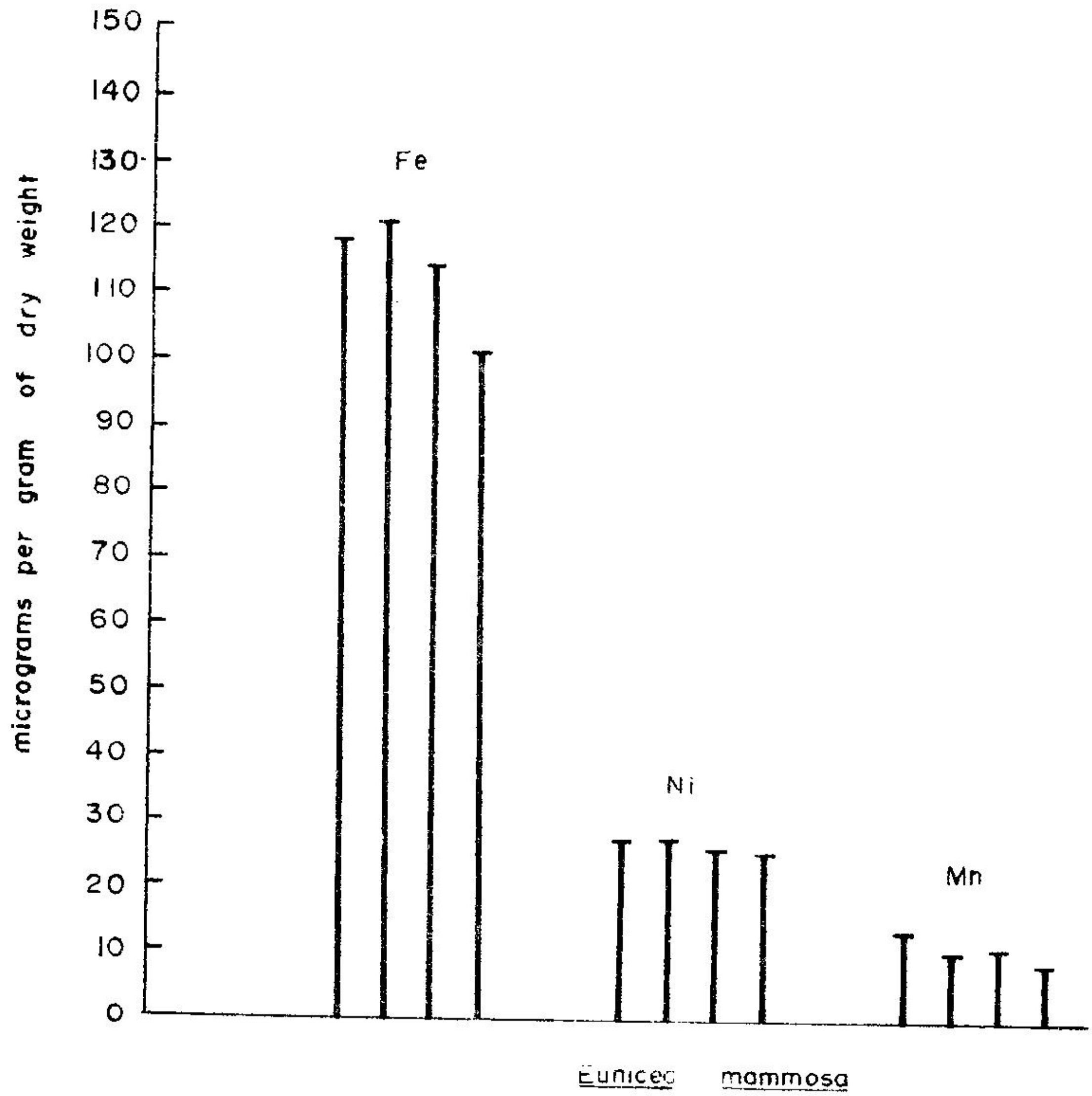


Fig. 25. Variability of Fe, Ni and Mn in four individual *Eunicea mammosa* from Punta Higuero, Puerto Rico.

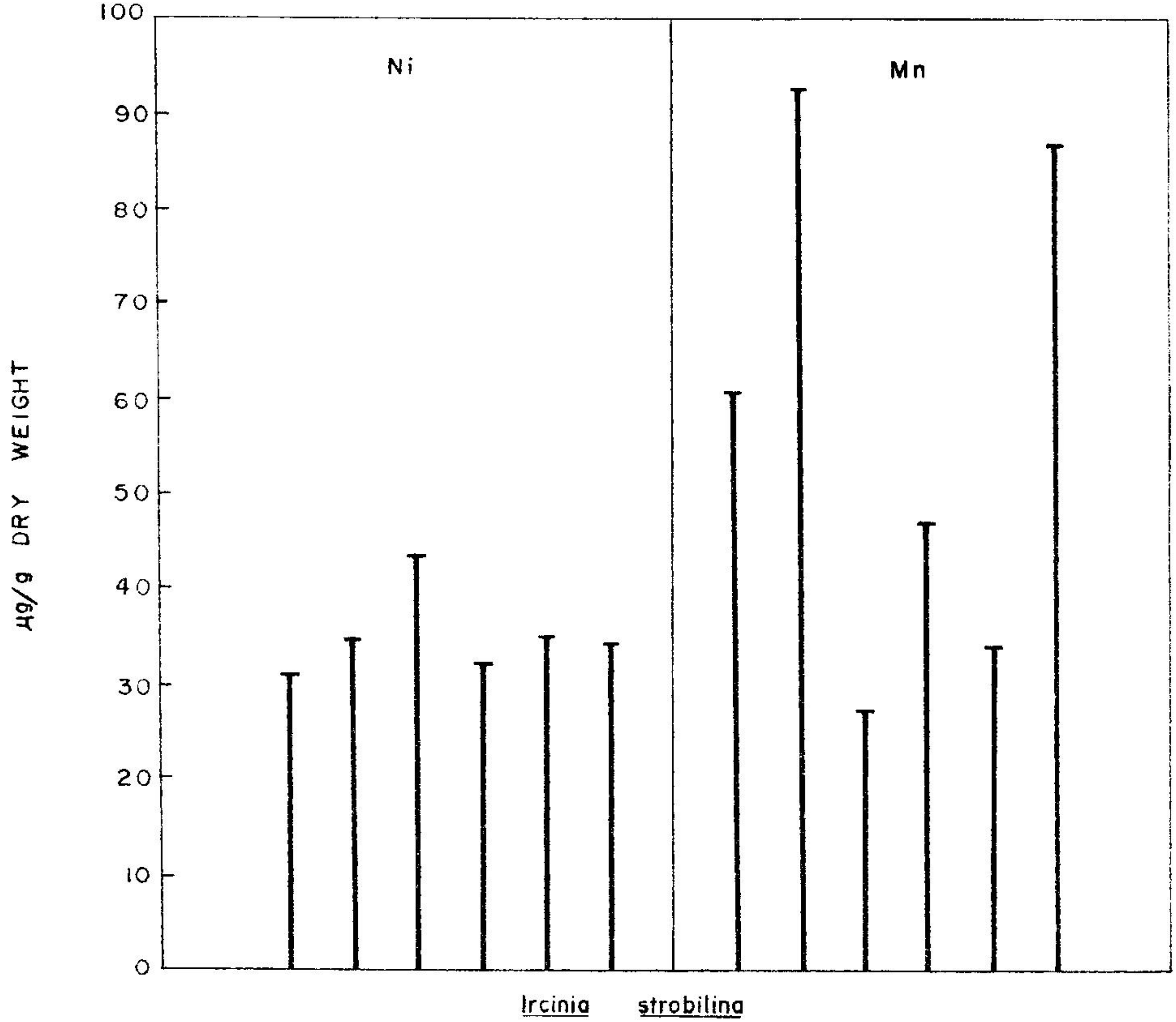


Fig. 26. Variability of Ni and Mn in 6 individual *Ircinia strobilina* from La Parguera, Puerto Rico.

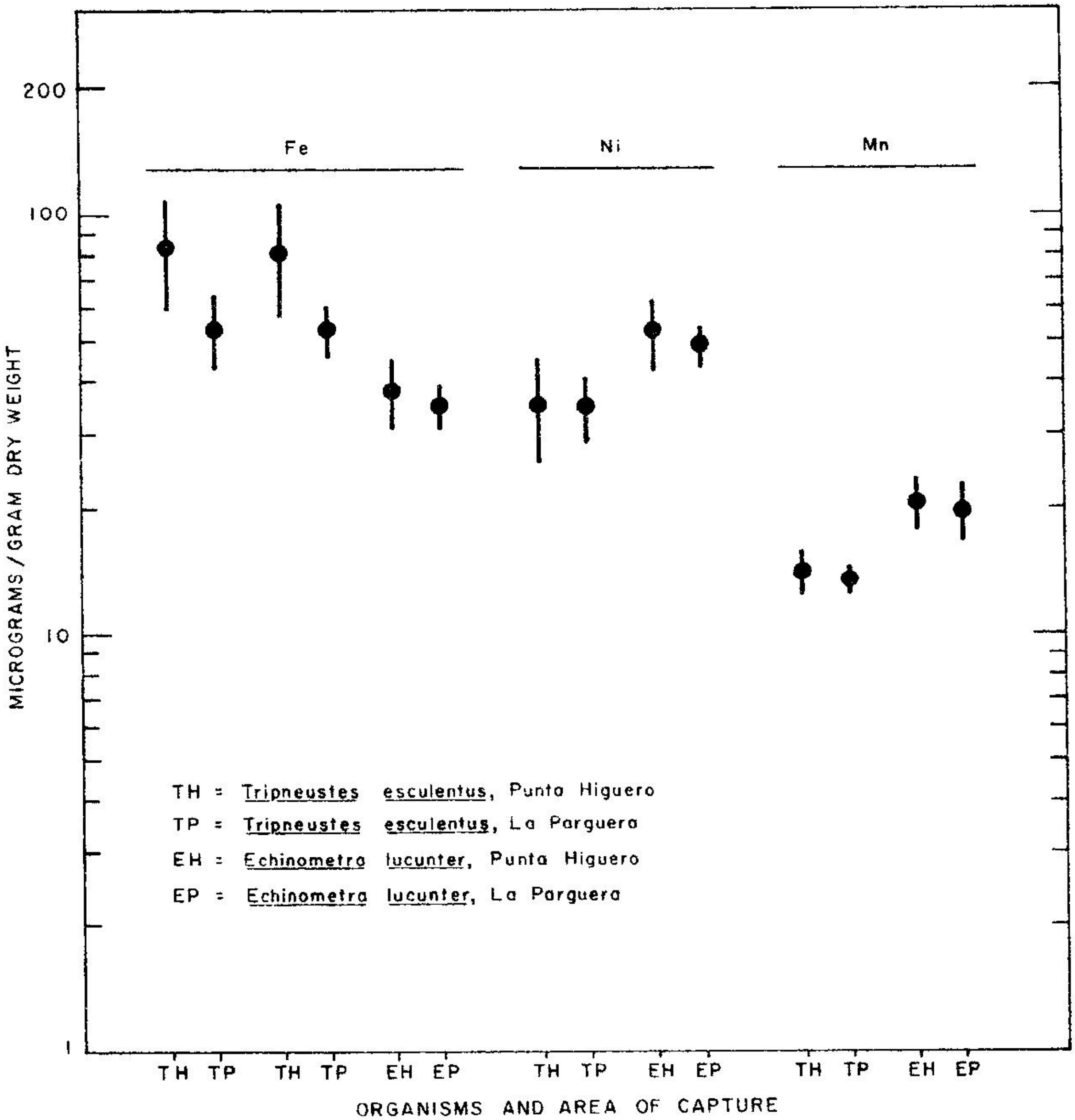


Figure 27. Mean values and standard deviation of Fe, Ni and Mn in the same species of sea urchins from different localities. First two Fe values are for urchins collected in 1965 and all others are for urchins collected in 1964.

A comparison was made between the food of Tripneustes Punta Higuero (Padina gymnospora) and the food of the same species at La Parguera (Thalassia testudinum). Figure 28 shows that there were much higher levels of Fe in the urchin's food at Punta Higuero than there were at La Parguera. A relationship, therefore existed between the higher levels of Fe in the urchin's skeletons and in their food. Significantly higher levels of Ni and Mn in the urchins food at Punta Higuero were not reflected in their skeletons. A comparison between the stable element content of species of Fucus from Scotland (Black and Mitchell 1952) and Padina showed that the latter contained one order of magnitude less Fe and Ni, but one order of magnitude more Mn than did Fucus.

Figure 29 shows a comparison between elements in a single batch of the same species of plants collected at La Parguera, Punta Higuero, and Negro Reef (west coast). Iron was high in Thalassia from Negro Reef, but was low in the same species from the other two locations. There was little difference in levels of Ni between the locations, but Mn was slightly higher on the south coast. The figure also shows a comparison between single batches of Padina gymnospora collected on the south and west coasts. In this case, a greater amount of each element was found in the plants from the south coast. The batch from the south coast was growing on an iron bridge piling and further work is underway to clarify the possibility that the proximity to the iron resulted in the higher levels observed in the plants.

The level of Sr, the only element analyzed to date (data not reported) in the starfish Oreaster reticulatus, was almost twice as high in a specimen from the west coast that was compared in a specimen from the south coast. In the organisms reported, it is evident that at least some trace elements can be expected to be found in higher levels in individuals of the same species from different locations.

Differences within the same species of organism have also been found in two locations along the west coast. Figure 30 shows similarities and differences between the same species of organisms that occur in two locations, each of which is influenced by a river draining a different watershed. The figure shows a comparison between average values in the tissues of four individuals of an unidentified keratosoid sponge, the skeletons of three gastropods (Strombus pugilis) and the skeletons of two individuals in each of two species of coral (Meandrina meandrites). Levels of Sr were almost identical in Meandrina and Eusmilia at the two different locations. Although levels of Sr were lower in Strombus, individuals from both locations contained similar amounts. No Sr was detected in the sponge at either site. The Mg content of Strombus was noticeably higher in the locality influenced by the Culebrinas River, whereas some tendency toward a higher Mg content occurred in both Meandrina and Eusmilia in the locality influenced by the Añasco River. Levels of Sr and Mg in the gastropod Strombus were of the same order of magnitude as the amount in three different species of gastropods from the west coast of the U. S. A. (Krinsley 1960).

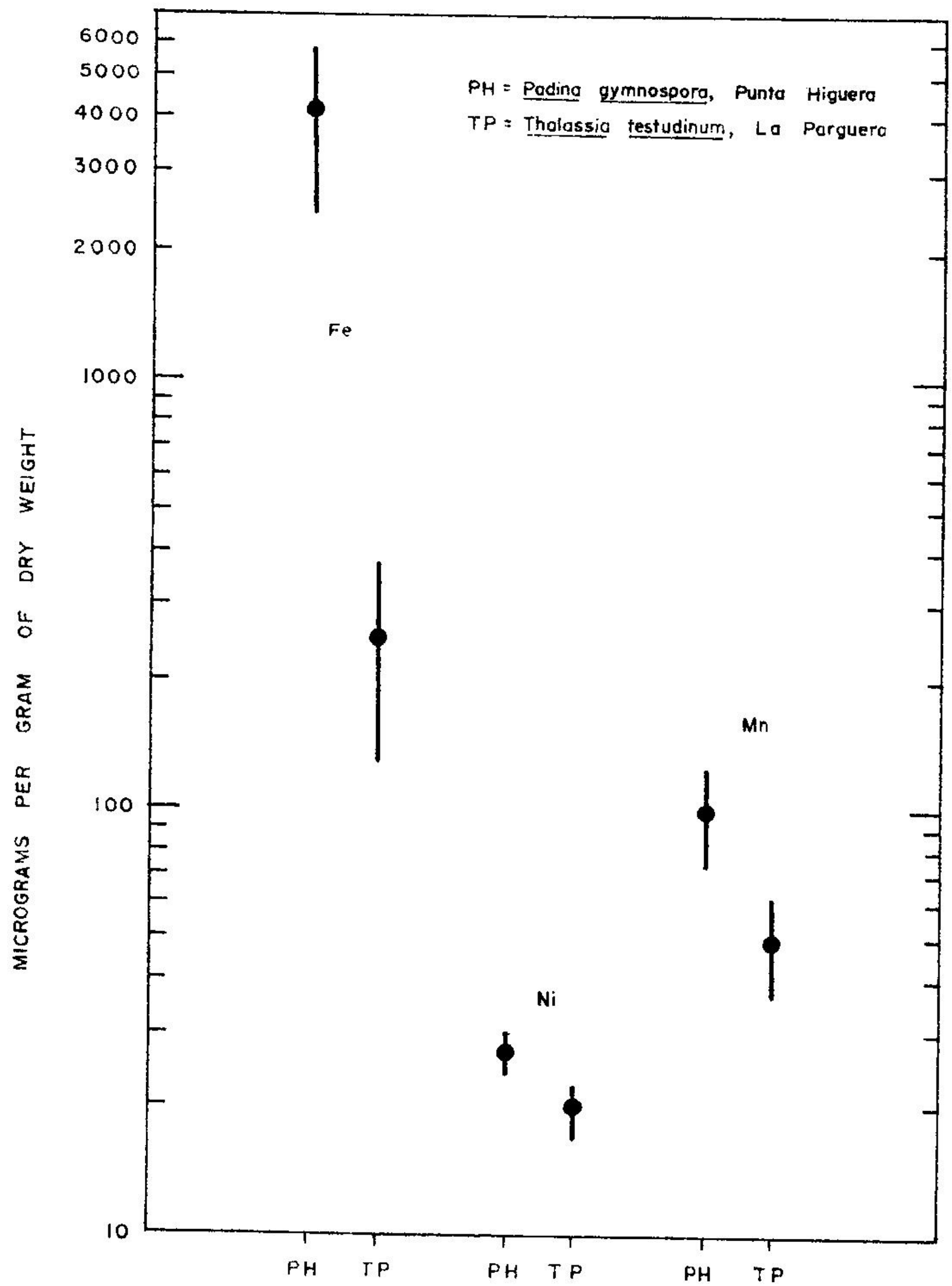


Fig. 28 Mean values and standard deviation of Fe, Ni, and Mn in two species of marine plants

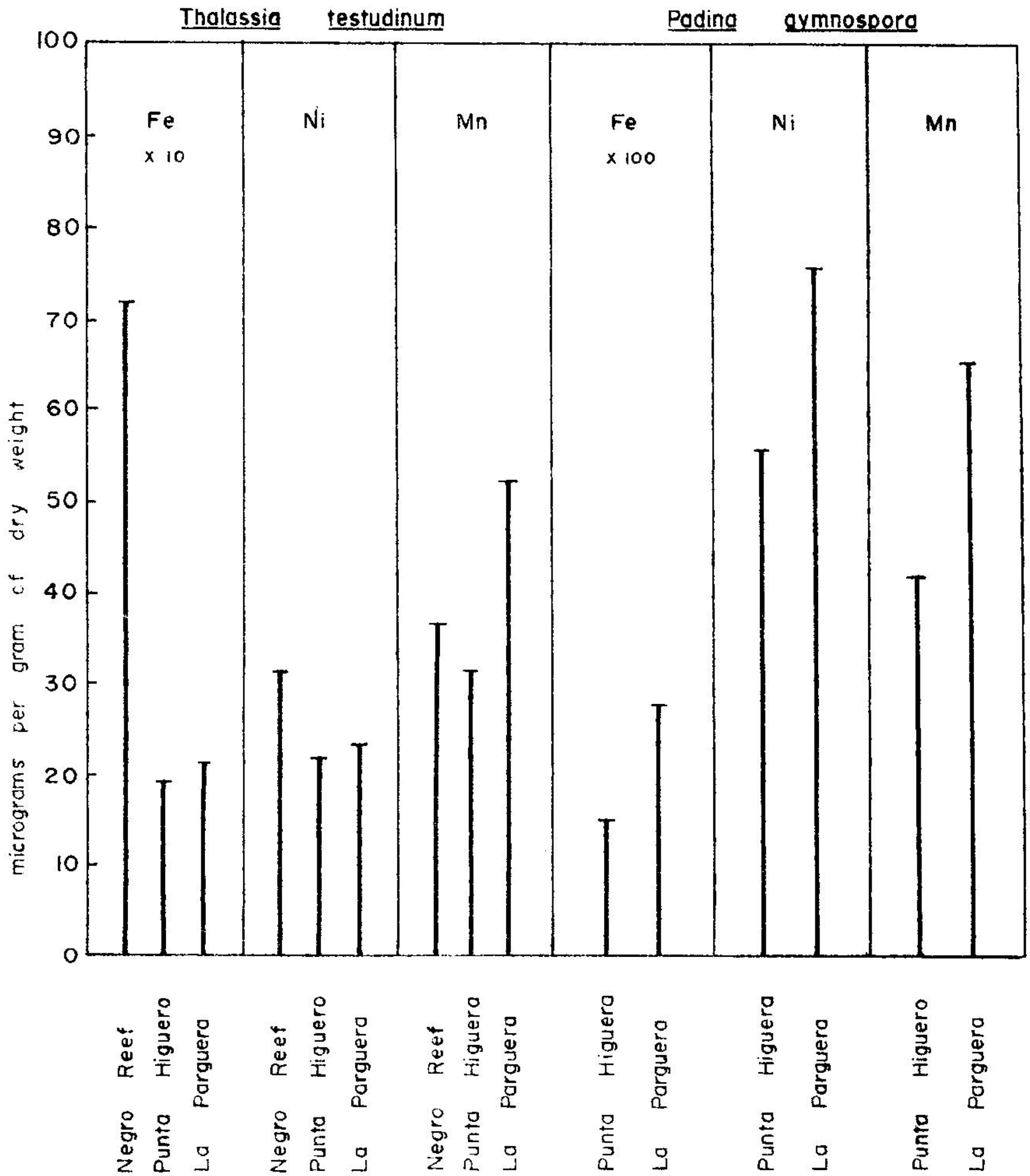


Figure 29 Varibility of Fe, Ni, and Mn in the same species of marine plants from different localities.

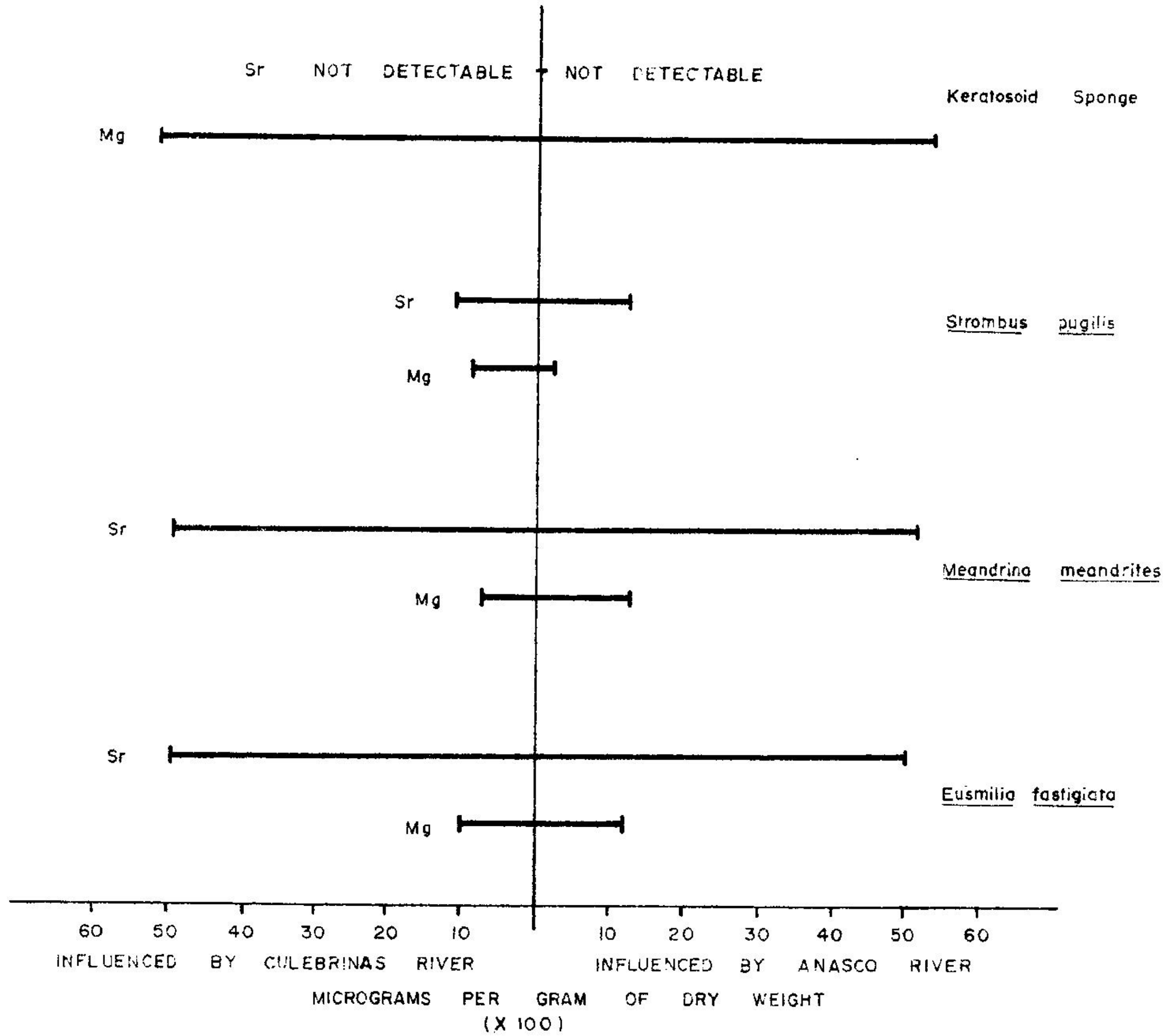


Fig. 30 Levels of Mg and Sr in marine organisms influenced by river outflow. The vertical line separates levels in organisms influenced by the Anasco and Culebrinas River.

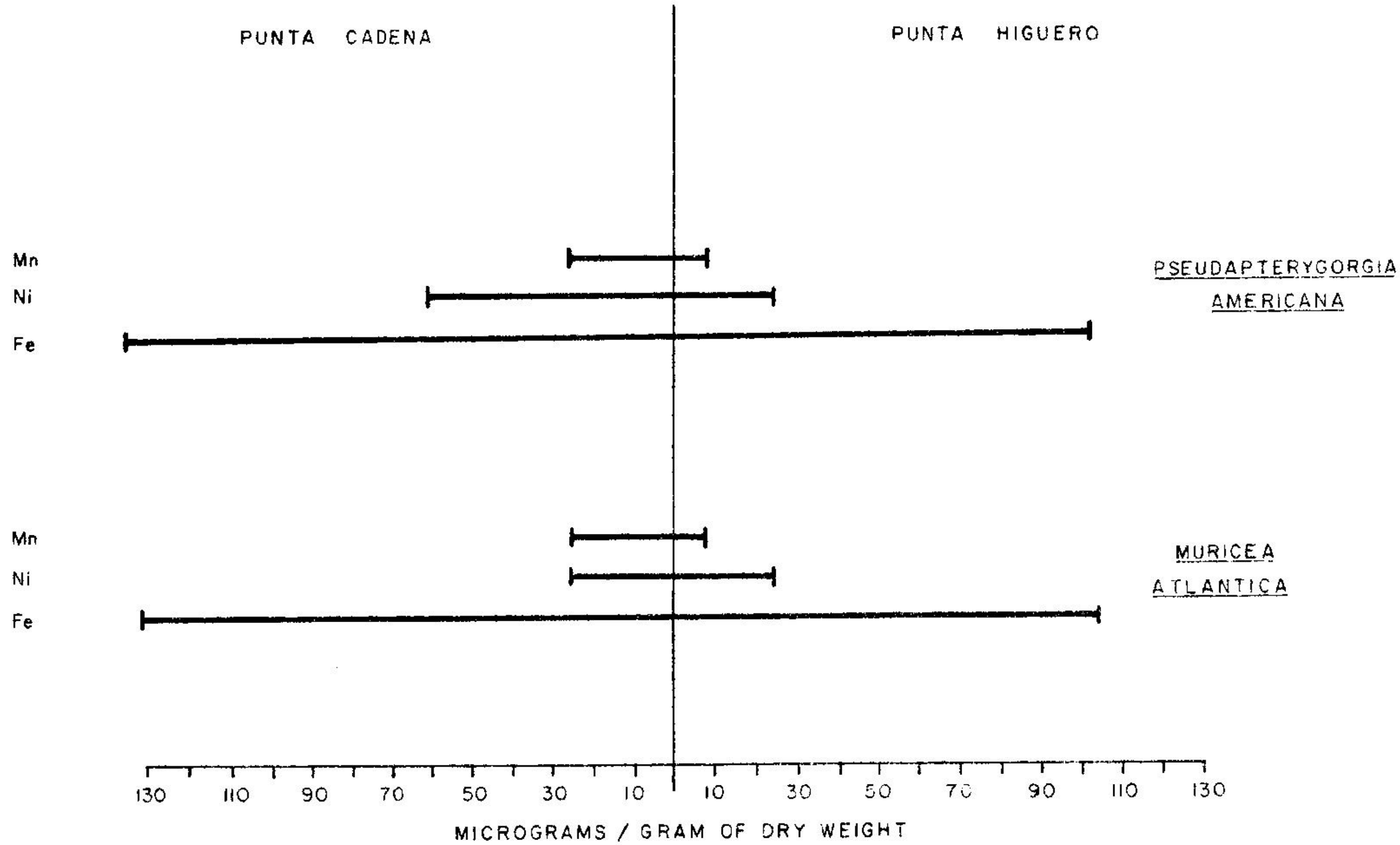


Figure 31. Levels of Fe, Ni and Mn in gorgonians influenced by the Anasco River. The vertical line separates levels in organisms from Punta Cadena (about seven miles from the river) and Punta Higuero (about sixteen miles from the river).

The levels of Fe, Ni, and Mn in two species of gorgonians varied with distance from the mouth of the Añasco River. Results of analyses of intact single individuals of both species appear in Figure 31. The individuals of both species from Punta Cadena, approximately three and one-half miles from the river mouth, had higher levels of all three elements than corresponding individuals from Punta Higuero, eight miles from the river mouth.

The foregoing observations point out the variability that may occur within individuals of a single species that are separated by short distances. Observations of local variability will aid efforts to determine paleoecological conditions (Pilkey and Goodell, 1963), studies in biogeochemistry (Chave 1962, Lowenstam 1954, Odum 1957), and studies involving indicator organisms (Osterberg et al, 1964).

The stable element content of organisms from five locations along the west coast and one location on the south coast are now being studied. Work is continuing to more adequately quantify the differences that have begun to appear and new species that are found in different locations are being analyzed. The food items of selected organisms are also being analyzed to determine whether relationships exist between levels of stable elements in an organism and in its food, and to determine the positions the organisms occupy in trophic levels. An increasing number of both micro and macro elements are also being analyzed.

Bibliography

Black, W. A. P., and R. L. Mitchell, 1952. Trace elements in the common brown algae and in sea water. Jour. Mar. Biol. Assoc. U. K., 30(3):575-584.

Chave, K. E., 1962. Factors influencing the mineralogy of carbonate sediments. Limnol. Oceanogr., 7(2):218-223.

Clarke, F. W., 1924. The Data of Geochemistry. Fifth Edition. U.S. Geol. Surv., Wash. D. C.:841 pp.

Krinsley, D., 1960. Magnesium, strontium and oragonite in the shells of certain littoral gastropods. Jour. Paleontol. 34(4):744-755.

Lowenstam, H. A., 1954. Factors affecting the aragonite: calcite ratios in carbonate-secreting marine organisms. Jour. Geol., 62:284-322.

Lowman, F. G., L. Quiñones, M. Miro, I. O. de Padovani, E. Ramos, V. R. de Vega, and H. J. Bielen (in press).

Odum, H. T., 1957. Biogeochemical deposition of strontium. Inst. Mar. Sci., U. Texas, 4(2):38-114.

Osterberg, C., J. Pattullo, and W. Pearcy, 1964. Zinc 65 in euphausiids as related to Columbia River water off the Oregon coast. Limnol. Oceanogr. 9(2):249-257.

Pilkey, O. H., and H. G. Goodell, 1963. Limnol. Oceanogr., 8(2): 137-148.

Vinogradov, A. P., 1953. The elementary composition of marine animals. Sears Foundation for Marine Research, Memoir 2. Yale Univ. : 647 pp.

CARBON, HYDROGEN, NITROGEN ANALYSES

Introduction:

In order to relate energy flow through an ecological system to the distribution of trace elements through that system, it is necessary to know the stable element content, the "food value" and the caloric content of the individuals and groups of organisms that compose the system. A survey of the stable element content of various marine organisms is well underway. The study of "food value" has recently been initiated in the Marine Biology Program.

"Food values" are being determined on the basis of the carbon, hydrogen, nitrogen content of representative forms from various trophic levels. The per cent composition of C, H, and N are analyzed directly from a single sample using the F. & M. Scientific Corporation's Carbon Hydrogen Nitrogen Analyzer Model 180. A small dried sample (from 0.2 to .3 mg) is introduced into a combustion chamber. Combustion products are cooled and collected in an expansion chamber. When combustion is complete, the products are introduced into a gas chromatograph. Levels of C(as CO_2), H(as H_2O), and N as N_2 are sensed by appropriate detectors and permanently recorded on a strip chart recorder. The height of the peak for each element is directly proportional to its occurrence in the sample. The entire analysis takes less than ten minutes.

Using Acetanilide as a standard, ten replicates were run to determine the reproducibility of the method. The results are contained in **Table 8.** The values for the 95% confidence level varied by 0.6%, 0.1% and 0.09% for H, C, and N respectively. Conventional (Pregl or Dumas) methods showed 0.34%, 0.6, 0.4% variation in H, C, and N respectively. The least favorable comparison between the two methods is between H values. There is 0.26% greater variation using the Model 180. However, the greater precision with C and N values and the ease of operation and time saving aspects of the Model 180 make it the more desirable of the two choices.

In order to relate stable element content and relative quantities of C, H, and N directly to the energy contained in animals comprising different levels in the food chain, calorimetry of representative forms will be carried out. These direct energy measurements by calorimetry will be started after July 1.

Results:

Results of CHN analyses are listed in Tables 6 and 7. In general it will be noted that aside from mollusk shells, the detrital fraction of the sediments has the lowest values of N. This most likely results from di-nitrification through bacterial activity. Echinoderms have the lowest values of C, H and N. The soft parts of

Type of sample	Collection site	% H_2	% N_2	% C
Detritus	Añasco Bay	2.89	1.30	24.3
"	"	2.87	1.00	24.4
Sipunculid	"	6.52	12.7	42.3
"	"	6.52	12.3	42.9
"	"	6.79	11.8	42.7
Sipunculid	"	5.81	10.5	36.3
Polychaete (<u>Nepthys</u>)	"	4.72	11.5	44.7
"	"	6.27	9.42	46.9
"	"	5.92	9.27	45.8
"	"	6.70	10.8	45.2
"	"	5.80	8.60	42.8
" (<u>Spionidae</u>)	"	5.56	9.72	44.17
"	"	5.25	9.24	41.66
"	"	6.30	10.56	46.23
Mollusk (<u>Codalia</u>) Soft parts	"	6.56	8.12	41.3
Mollusk " "	"	5.18	6.40	43.3
" " "	"	4.69	5.40	39.3
" (<u>Codalia</u>) Shell	"	0.00	0.00	11.3
" (<u>Shell</u>)	"	0.00	0.00	9.60
"	"	0.00	0.00	10.3
Shrimp	"	5.28	11.0	40.0
"	"	5.67	11.0	42.8
"	"	5.79	11.3	44.7
"	"	5.57	11.2	42.7
Copepod	"	4.57	9.22	37.6
"	"	3.52	8.27	35.6
"	"	5.04	12.00	39.5
"	"	--	3.53	42.9
"	"	6.43	--	38.0
"	"	5.82	3.97	34.24
"	"	5.88	9.00	36.9
"	"	5.52	10.1	35.2
Fish	"	4.92	11.7	35.2
"	"	4.92	10.4	34.8
"	"	4.95	11.0	34.0
"	"	7.00	12.3	51.3
"	"	5.15	13.0	37.5
Echinoderm (Arm only)	"	0.76	0.00	10.6
"	"	1.10	0.00	10.0
"	"	0.70	0.00	9.40
Echinoderm (Body legs arms)	"	2.30	2.30	20.7
"	"	1.70	1.80	16.4
"	"	2.70	1.80	18.7

Table 6. Percent of dry weight of organisms and tissues contributed by hydrogen, nitrogen and carbon.

Type of Sample	Collection site	% H_2	% N_2	% C
Phytoplankton	Peru	1.4	0.3	3.5
"	"	2.23	1.8	7.7
"	"	--	3.0	8.5
"	"	2.21	1.8	8.2
"	"	2.95	2.3	1.21
"	"	2.85	2.3	12.2
"	"	3.41	2.6	15.5
"	"	3.27	2.7	12.5
Fish Meal (Chimbote)	"	6.27	8.6	44.3
"	"	6.37	8.1	45.3
" (Callao)	"	6.34	8.5	43.3
"	"	6.92	8.4	43.4
"	"	6.97	8.6	43.2
" (Ilo)	"	6.83	9.5	46.4
"	"	6.75	8.7	43.0
Guano	"	4.12	17.8	20.2
"	"	4.31	16.7	20.3
"	"	3.82	18.3	21.1
"	"	3.77	18.9	24.3
"	"	3.88	18.2	23.4
"	"	3.99	17.3	28.3
"	"	3.56	14.3	24.6
"	"	3.51	17.4	23.7
"	"	3.33	16.3	22.5
Giant Clam Kidney (Heavy Fraction)	Marshall Islands	4.26	3.70	39.6
"	" "	4.56	3.50	40.3
Giant Clam Kidney (Light Fraction)	" "	4.55	4.30	37.3
"	" "	5.72	4.40	38.9
Giant Clam Visceral Mass	" "	6.29	5.40	42.3
"	" "	5.13	4.70	41.8
"	" "	5.85	4.30	45.5
Giant Clam Kidney (Heavy Fraction)	" "	6.20	4.60	41.8
Giant Clam Kidney (Light Fraction)	" "	5.31	4.70	37.3
Giant Clam Visceral Mass	" "	6.90	5.60	43.1
Tewa Crater - 2	" "	0.68	0.70	10.7
"	" "	1.12	0.80	10.7
"	" "	0.82	1.20	10.2

Table 7. Percent of dry weight contributed by hydrogen, nitrogen and carbon in samples from Peru and the Marshall Islands.

Standard: Acetanilide

HYDROGEN ANALYSES:

Sample #	Weight of sample in mgs.	% Hydrogen in sample
1	0.8212	6.79
2	0.7098	6.77
3	0.6104	6.78
4	0.5082	6.78
5	0.4348	6.78
6	0.3984	6.80
7	0.3432	6.78
8	0.2718	6.80
9	0.1952	6.81
10	0.1010	6.73
	Average - % Hydrogen =	6.872
	(95 % confidence level) ±	0.0440

CARBON ANALYSES:

Sample #	Weight of sample in mgs.	% Carbon in sample
1	0.8212	70.99
2	0.7098	70.91
3	0.6104	71.00
4	0.5082	70.99
5	0.4348	70.99
6	0.3984	71.00
7	0.3432	71.00
8	0.2718	70.93
9	0.1952	71.00
10	0.1010	70.99
	Average - % Carbon =	70.980
	(95% Confidence level) ±	.0644

NITROGEN ANALYSES:

Sample #	Weight of sample in mgs.	% Nitrogen in sample
1	0.8212	10.36
2	0.7098	10.34
3	0.6104	10.35
4	0.5082	10.35
5	0.4348	10.34
6	0.3984	10.36
7	0.3432	10.37
8	0.2718	10.37
9	0.1952	10.34
10	0.1010	10.39
	Average - % Nitrogen =	10.357
	(95% confidence level) ±	.09818

Table 8: Test for accuracy of the gas chromatographic method for determining carbon, hydrogen, and nitrogen on samples of biological origin.

mollusks from Añasco Bay, Puerto Rico, as well as from the Marshall Islands, while having levels of C that compare favorably with other organisms, have relatively low levels of N (3.7% to 8.1%). Polychaetes, Sipunculids, Crustacea, and fish have slightly larger amounts of N, in that order of occurrence, generally ranging from 8.3% to 14.4%. The highest levels of N (14.3% to 18.9%) were found in Peruvian guano. Low levels of H, N and C were found in phytoplankton samples from Peru. The greatest bulk of these samples appeared to be diatom frustules. This could account for the low per centages which were determined on the basis of total weight.

Discussion:

A point of interest becomes apparent in Fig. 32. While there is little correlation between weight, H and C content of organisms, there is a direct relationship between increase in weight, and the N content.

The comparative ease with which the H, N and C analyses may be carried out allows an intensive study of variation within individuals of the same species, and between individuals of different taxa. The importance of such information is emphasized by the relationship between size (weight) of individual animals and their N content demonstrated in these preliminary results. Through such intensive studies of groups composed of many individuals, will come representative "food value" estimates upon which sound evaluations of the role that energy flow through an ecological system plays in the distribution of stable elements throughout that system.

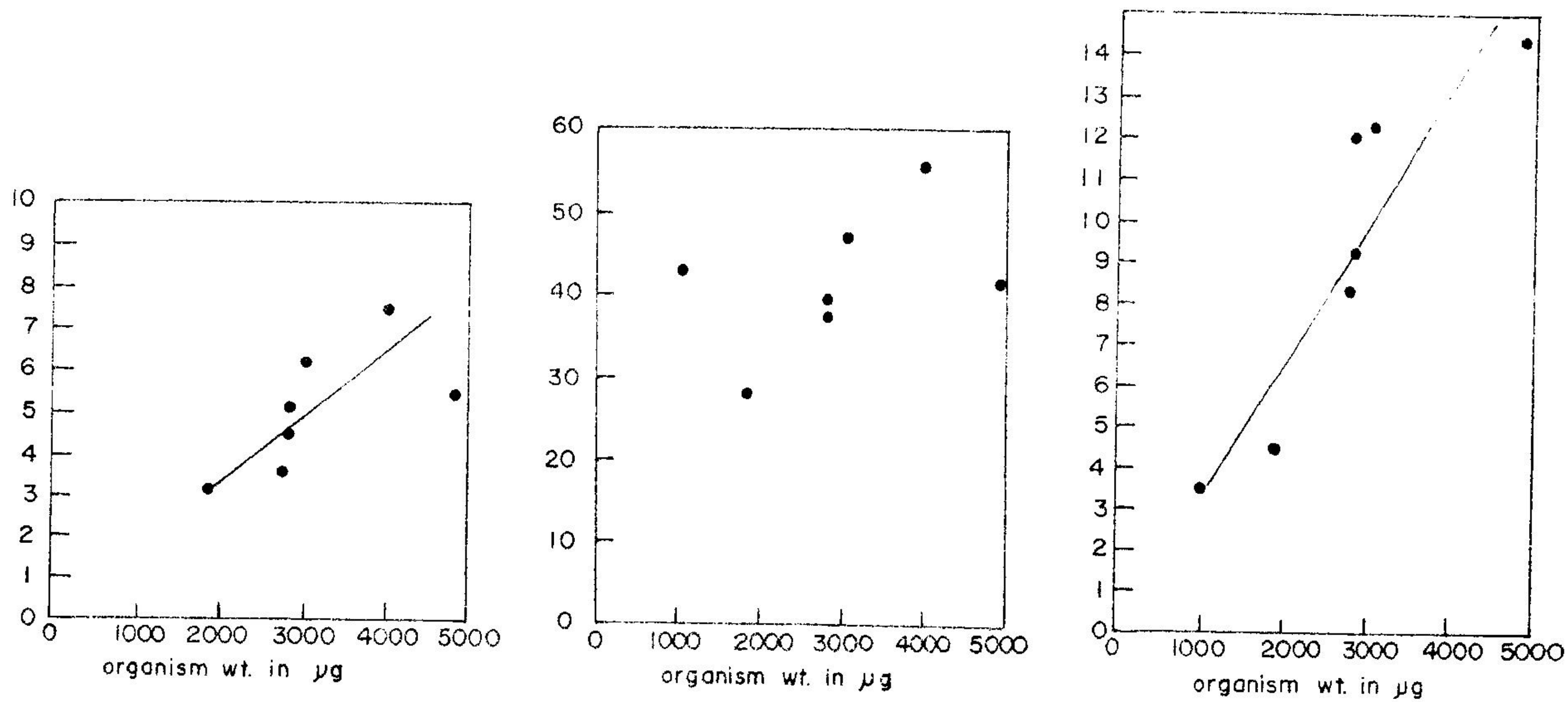


FIG. 32 Relationships of the percentages of hydrogen, carbon and nitrogen (based on dry wt.) to the total dry weights of copepods collected in Añasco Bay.

SEDIMENT INVESTIGATIONS

A preliminary report was made last year on trace element distributions in marine waters and sediments collected in Añasco Bay. Since then the elemental analyses have been completed and the distribution patterns of the elements in the sediments are given in the present report.

The sediment samples were collected in two ways: by an orange peel grab and a piston coring tube. The grab had a capacity of one hundred cubic inches and was used only for collection of sediments in water with depths less than 300 meters. The piston coring tube of the Ewing design was used to collect the sediment cores in a tubular plastic sleeve with inside dimensions of 3.9 cm by 91.5 cm. The cores were removed from the sleeves at the laboratory and divided into three inch (7.62 cm) increments and each section was placed in a polypropylene bottle. The sections were weighed and dried to constant weight at 95°C (subsequent samples have been divided into two fractions - one is frozen and the other dried at room temperature). Aliquots for analysis were taken from the centers of the samples to reduce the possibility of contamination from the sampling device.

A chart of the sampling area and a diagram of a cross section through the area are shown in figure 33. Sediment samples one through six were taken in water less than 100 meters in depth on the sloping island shelf. Samples 7-14 were collected in waters 190 to 370 meters deep on the slope beyond the edge of the shelf. In this area the slope was approximately twice that of the shelf.

During the past year additional sediment samples have been taken in the deeper waters. Further sampling will be continued from the site of sample 14 to Desecheo Island and to Sponge Bank (fig. 1). In addition, a limited coring program is being started off the Culebrinas and Guanajibo Rivers.

Figure 34 shows the distribution patterns of manganese, zinc, chromium and nickel in the sediment cores. The abundance of elements are shown with core depth in the diagrams to depths of 36 inches. Of the four elements, the

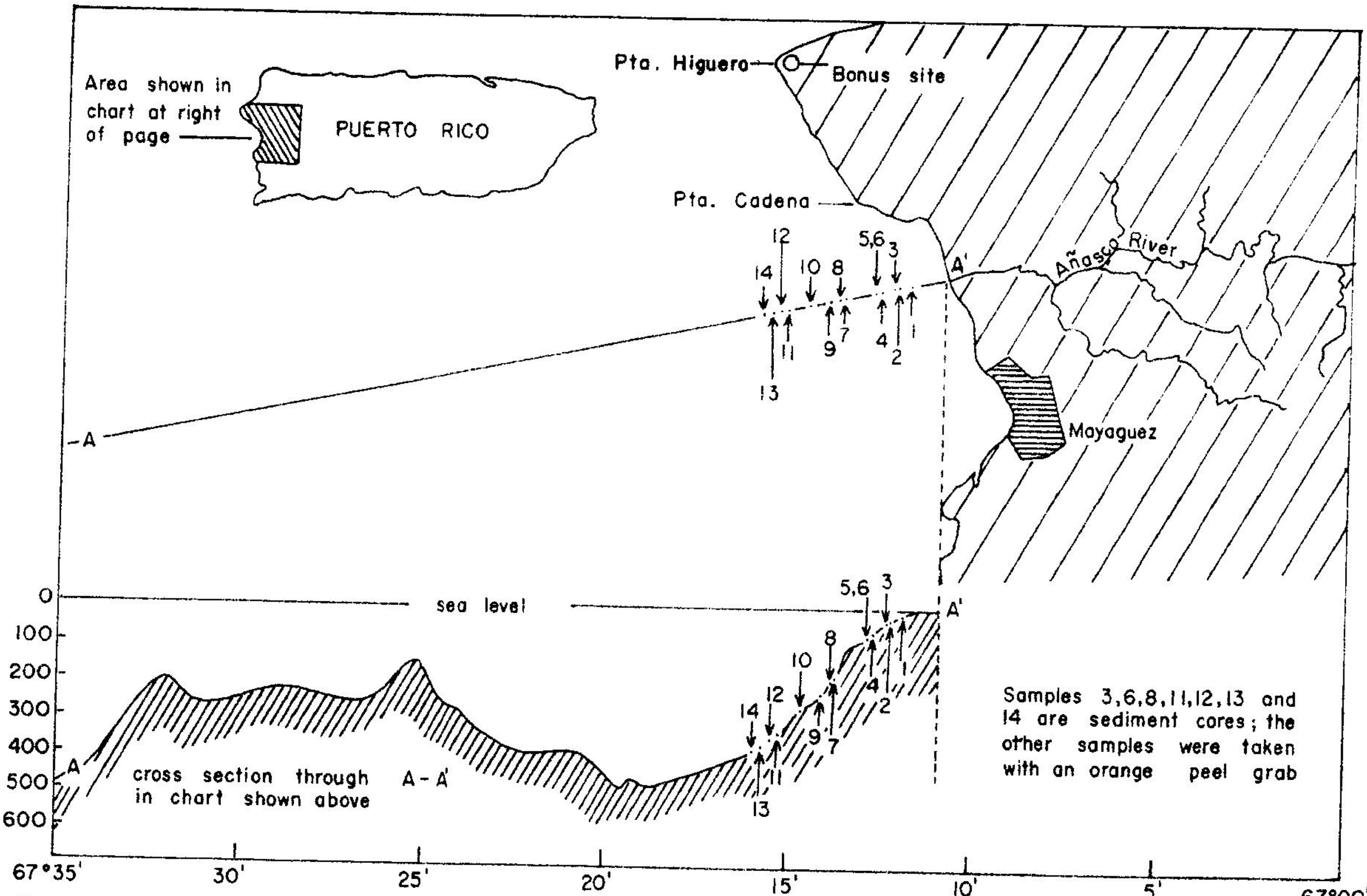


FIG. 33 A chart showing the sites at which marine sediments were collected. Sediments 1–6 were taken in water less than 100 meters deep on a gently sloping island shelf. Sediments 7–14 were collected in water 190 to 370 meters deep in an area with a slope approximately twice as steep as that of the shelf.

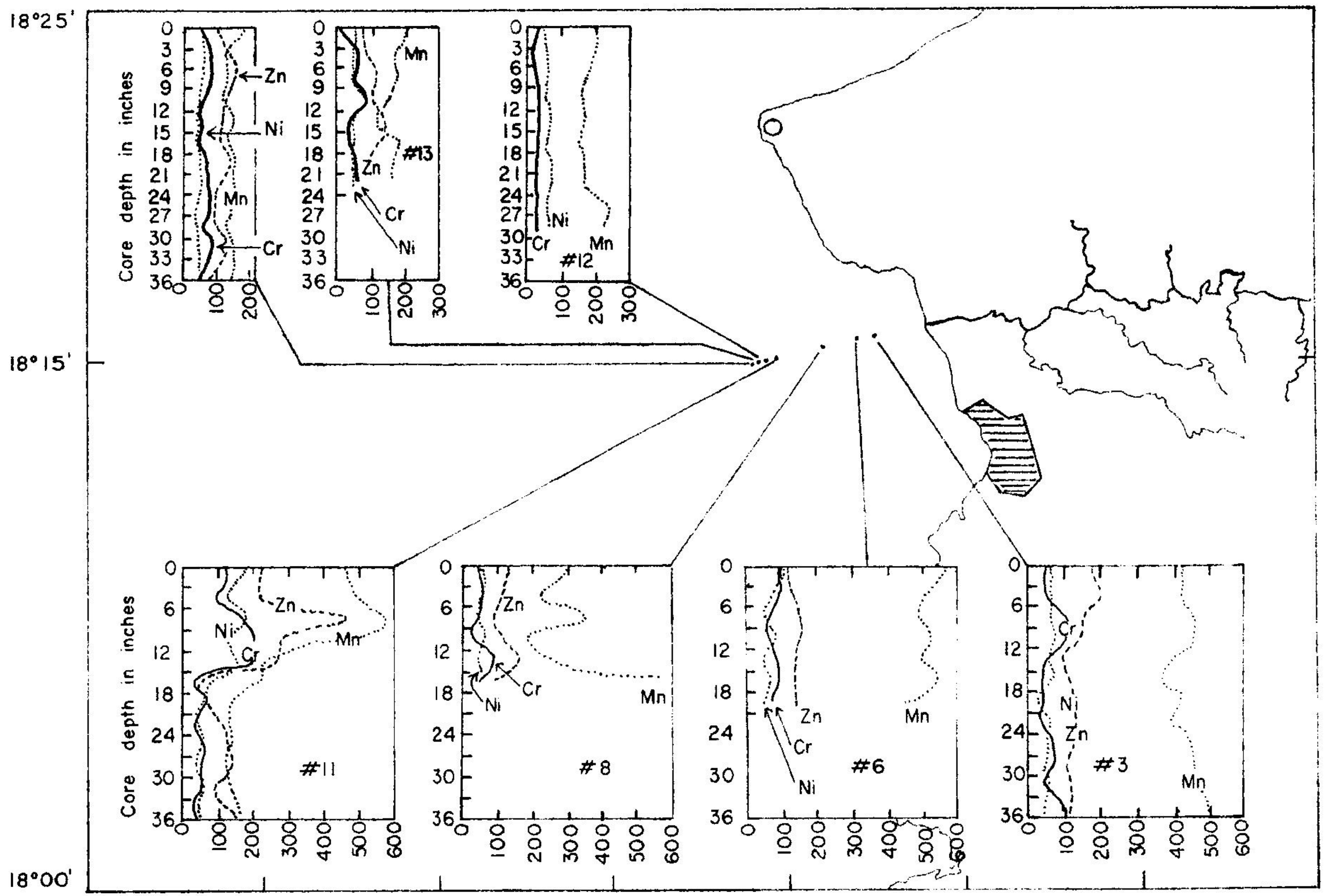


FIG. 34 The distribution patterns of Mn, Zn, Cr and Ni in sediment cores taken off the west coast of Puerto Rico. The amounts of manganese in the sediments were inversely related to distance from shore. The larger amounts of the elements in core #11 probably reflect the effects of a submarine slide upon the sediments in that area.

amounts of chromium, nickel and zinc were not related to distance offshore and they did not exhibit (stratification) with depth within the cores except in core 11. In this core the amounts of the three elements were greater in the top 15 inches than in the lower part of the core. Manganese exhibited a similar pattern of distribution in the same core. However, unlike the other three elements, amounts of manganese decreased with increased distance from shore. The average amount of manganese in the two inshore stations was about 500 micrograms per gram of sediment. At the station farthest from shore the average amount of the same element was about 30 ⁰/₀ of that of the inshore stations.

The distribution patterns of manganese, zinc, chromium and nickel in core number 11 as well as the patterns for iron and magnesium suggest that the top 15 inches of core 11 were deposited from a sediment slide from the nearby island shelf. If this is correct, the sediment scavenged manganese, nickel, chromium, zinc, magnesium and iron from sea water as it moved from the shelf to the site of core 11. Additional sediment samples will be taken in the area in an attempt to explain the anomalous pattern in the core.

Figure 35 shows the distributions of iron and scandium in the same sediment cores. The patterns of distribution of iron and scandium were similar to that of manganese in that they decrease with increased distance offshore. The amounts of iron dropped from an average of 40 mg per gram of sediment at a distance of one mile offshore to a value of about 12 mg per gram at five miles offshore. The scandium levels dropped form an average value of 20 mg per gram at one mile to approximately 8 mg per gram at five miles. Thus the reduction in the amount of scandium in the sediments with increased distance offshore was not as great as that of iron or manganese. In addition, the distribution pattern of scandium was distinguished from that of iron and manganese in that scandium showed no marked decrease with depth in core number 11. If the altered distribution patterns were due to the effects of a submarine slide the amounts of scandium in sediment number 11 would not be expected to be influenced by the slide since the amounts of scandium in the sea water of the area are low. Most of the scandium from the Añasco River is precipitated within the first hour after it mixes with sea water and would probably be deposited near shore on the island shelf.

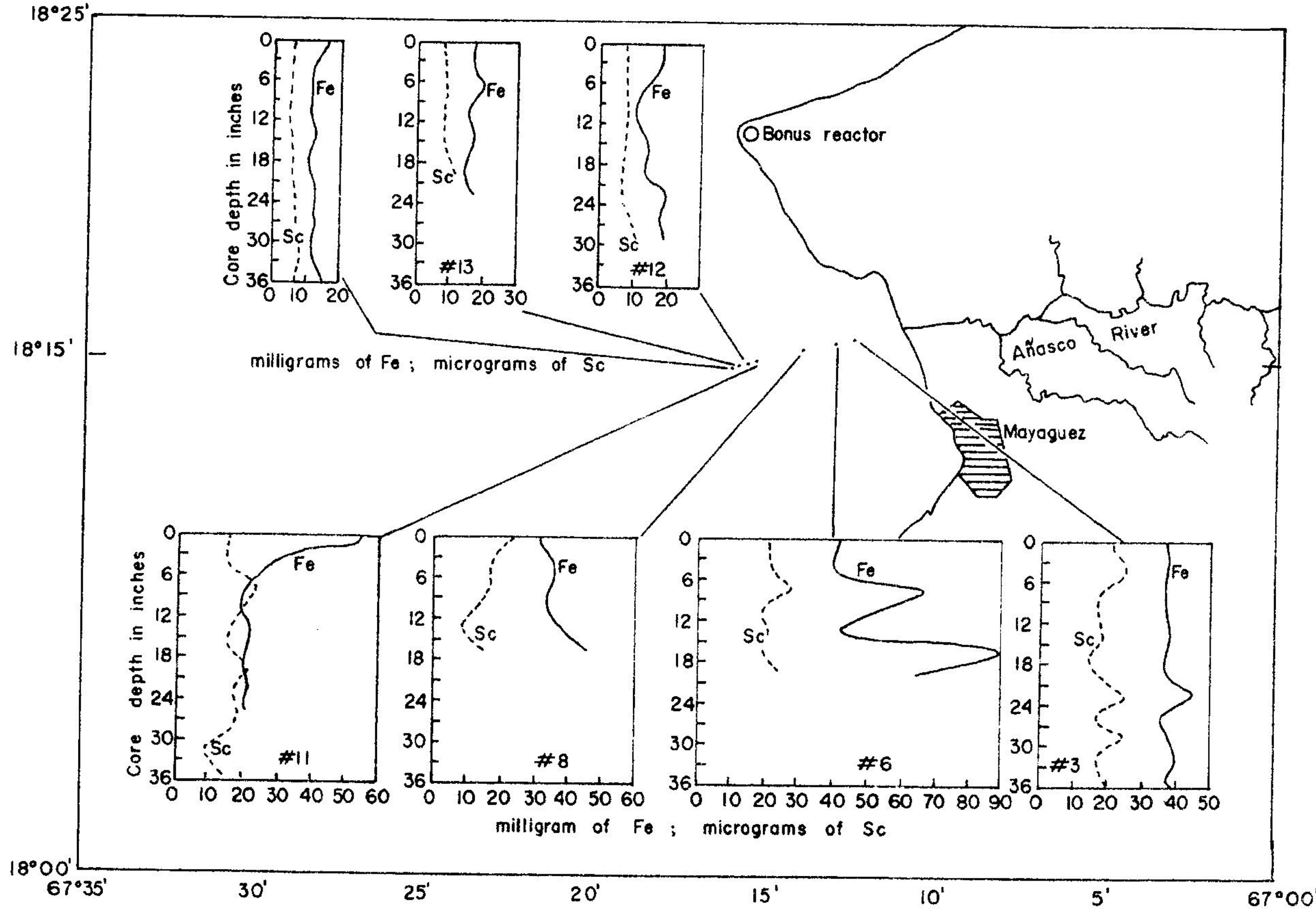


FIG. 35 The distribution of iron and scandium in sediment cores taken off the west coast of Puerto Rico. The amounts of iron and scandium were inversely related to distance from shore.

The distribution pattern of magnesium is shown in figure 36. Except for core number 11, the distribution pattern of magnesium was the same for all cores and was not influenced by depth in the core or distance offshore.

Figure 37 shows the distribution patterns for calcium and strontium in the sediments. The average amounts of calcium and strontium, in contrast to the patterns of iron, manganese and scandium, increased with increased distance offshore. The amounts of strontium and calcium in the cores were covariant. The covariance was especially marked in cores 8, 11, 12, 13 and 14. Neither the rates at which the sediments are deposited are known, nor have the sources of the calcium and strontium been determined. As a result, the mechanisms responsible for the variability in the amounts of the two elements with depth in the cores cannot be defined. However, the variability is much greater than that exhibited by the other elements and may be a direct result of biological activity. Work is now in progress to subdivide duplicate sediment samples, taken in connection with the benthic ecological studies, into biogenous and terrigenous components. The two components will be analyzed separately for strontium and calcium distribution as well as for the trace elements. In addition, work is being done on the sediment samples with X-ray diffraction to determine into which compounds the strontium and calcium are incorporated.

Figure 38 shows the inter relationships of the elements in the sediments. Iron and manganese (Fig. 38 A) were linearly covariant. The atom ratio, manganese to iron, is 1.04×10^{-2} in the sediments whereas in the water of the Añasco River the ratio was 17.5×10^{-2}. Thus, the sediments were enriched with iron in respect to manganese. In figure 38 B the relationships of nickel and zinc to chromium are shown. Both nickel and zinc are related linearly to chromium. These data are supported by the observation that the zinc chromite diffraction peaks occurred in the X-ray diffraction diagrams.

Scandium was not linearly related to any of the other elements analyzed in the samples. However, the amounts of scandium were directly related to the logarithms of the amounts of iron and manganese in the sediments (fig. 38 C, D).

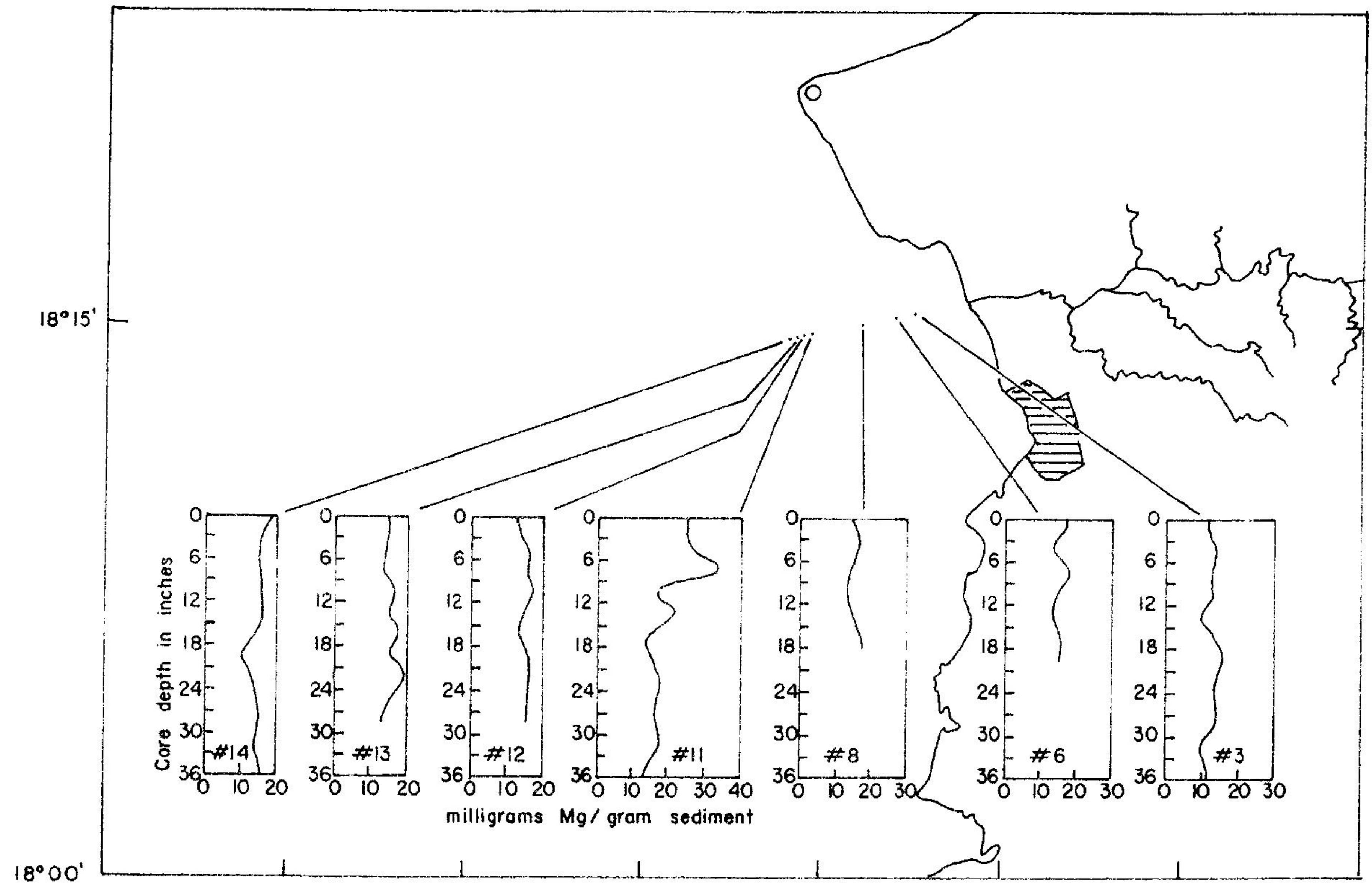


FIG. 36 The distribution pattern in sediment cores taken off the west coast of Puerto Rico.

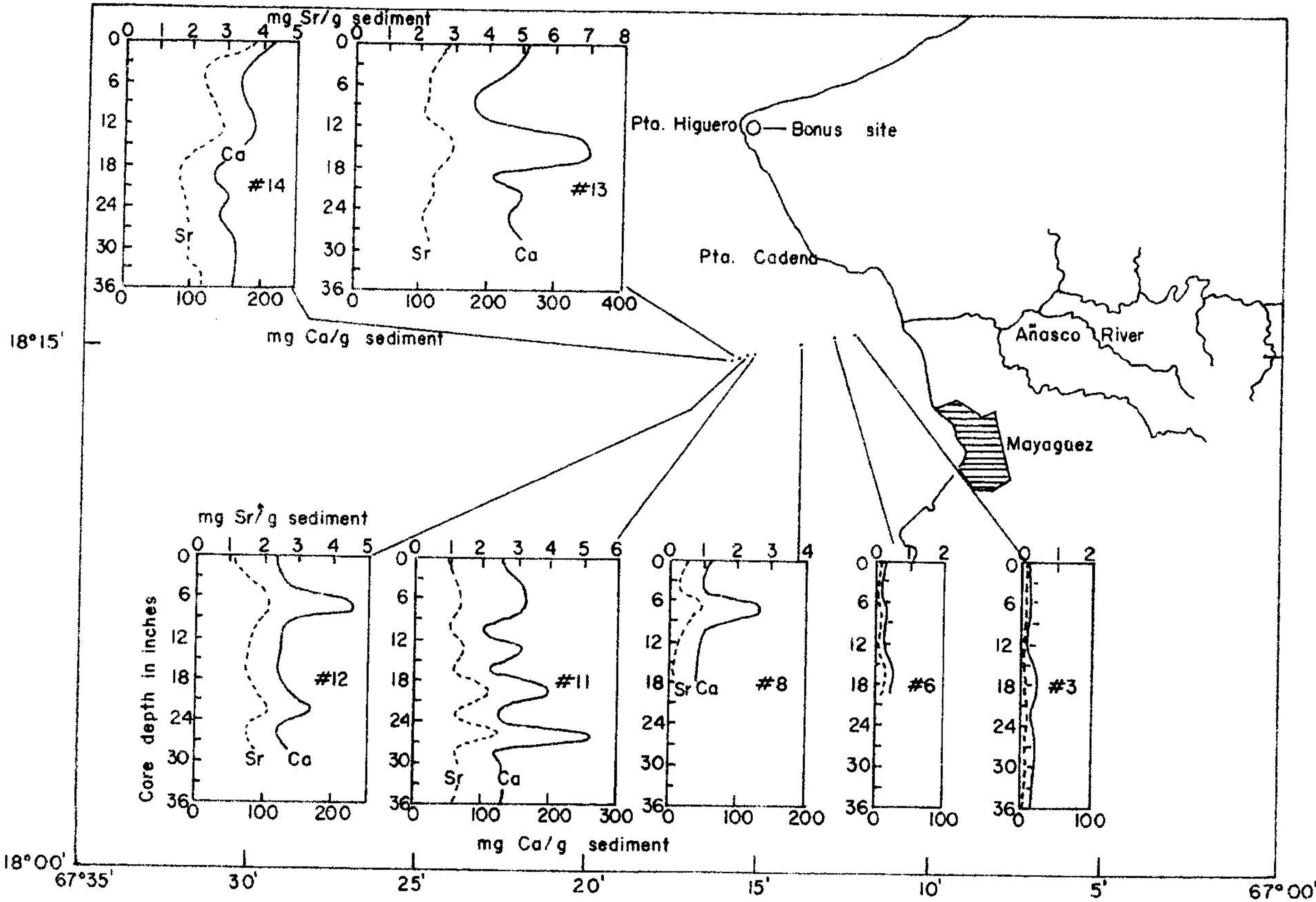


FIG. 37 The distribution of calcium and strontium in the sediment cores. The average amounts of the two elements in the cores are covariant and are directly related to distance from shore.

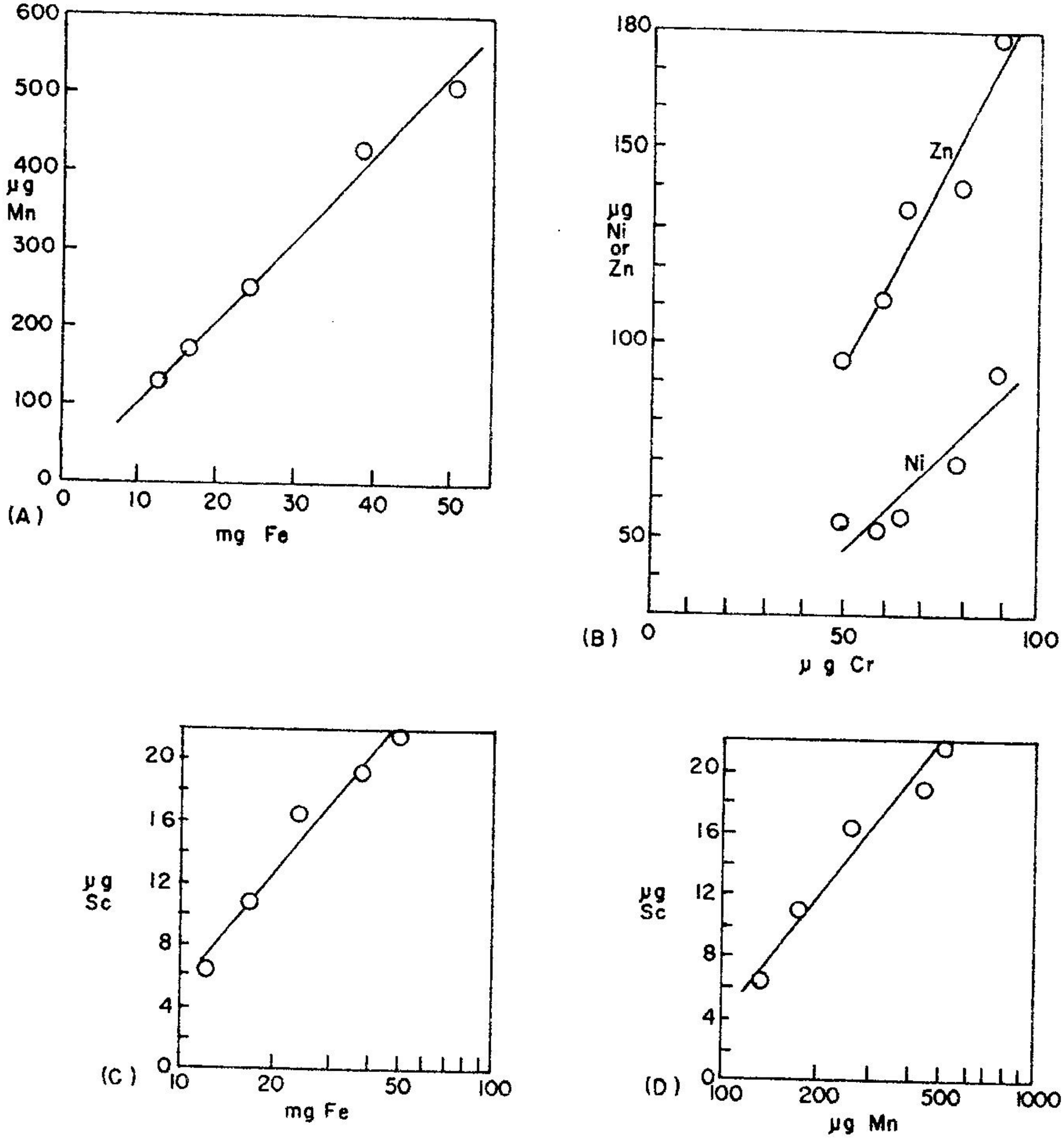


FIG. 38 Relationships of elements in marine sediments off the Añasco River. Iron and manganese (A) exhibit a linear relationship in levels of abundance and are known to coprecipitate in sea water. The amounts of nickel and zinc (B) are linearly related to the amounts of chromium. The levels of scandium exhibit linear relationships with the logarithms of the amounts of iron (C) and manganese (D) in the sediments.

As mentioned before, strontium and calcium exhibited similar patterns of distribution with core depth (Fig. 37). Thus variations in the amounts of calcium in the cores were directly related to variations in the amounts of strontium in the same parts of the samples and the atom ratios strontium/calcium exhibited a direct and positive relationship to distance of sample from the outflow of the Añasco River (Fig. 41 A). The ratio varied from an average value of about 2.7×10^{-3} at one and a half miles offshore to a value of approximately 5.5×10^{-3} at five miles. Thus, the amount of strontium with respect to calcium increased with increased distance from the shore. The atom ratio strontium/calcium also exhibited a direct and positive relationship to the amounts of calcium in the samples (41 B).

Figure 40 presents a summary of relationships of element abundance in the sediments with distance offshore. Although the elements show well defined patterns of distribution, the analyses herein reported are not sufficient to explain the mechanisms responsible for the elemental distributions, or to demonstrate that the Añasco River is the major source of these sediments. Observations made during the past year suggest that a large eddy starting at Punta Higuero often rotates in a counterclock wise direction between the island of Desecheo and sponge bank and re-enters the coastal circulation pattern near Punta Cadena thence to Punta Higuero. The outflow from the Culebrinas River empties to the north of Punta Higuero and usually follows southward along the shore and joins the area of Punta Higuero. It may be that the contributions of calcium and strontium are mainly from this river since it drains an area which is predominantly lime stone. Thus it would explain the increased amounts of strontium and calcium offshore from the Añasco River.

Investigations on the currents of this area have been started and will be continued.

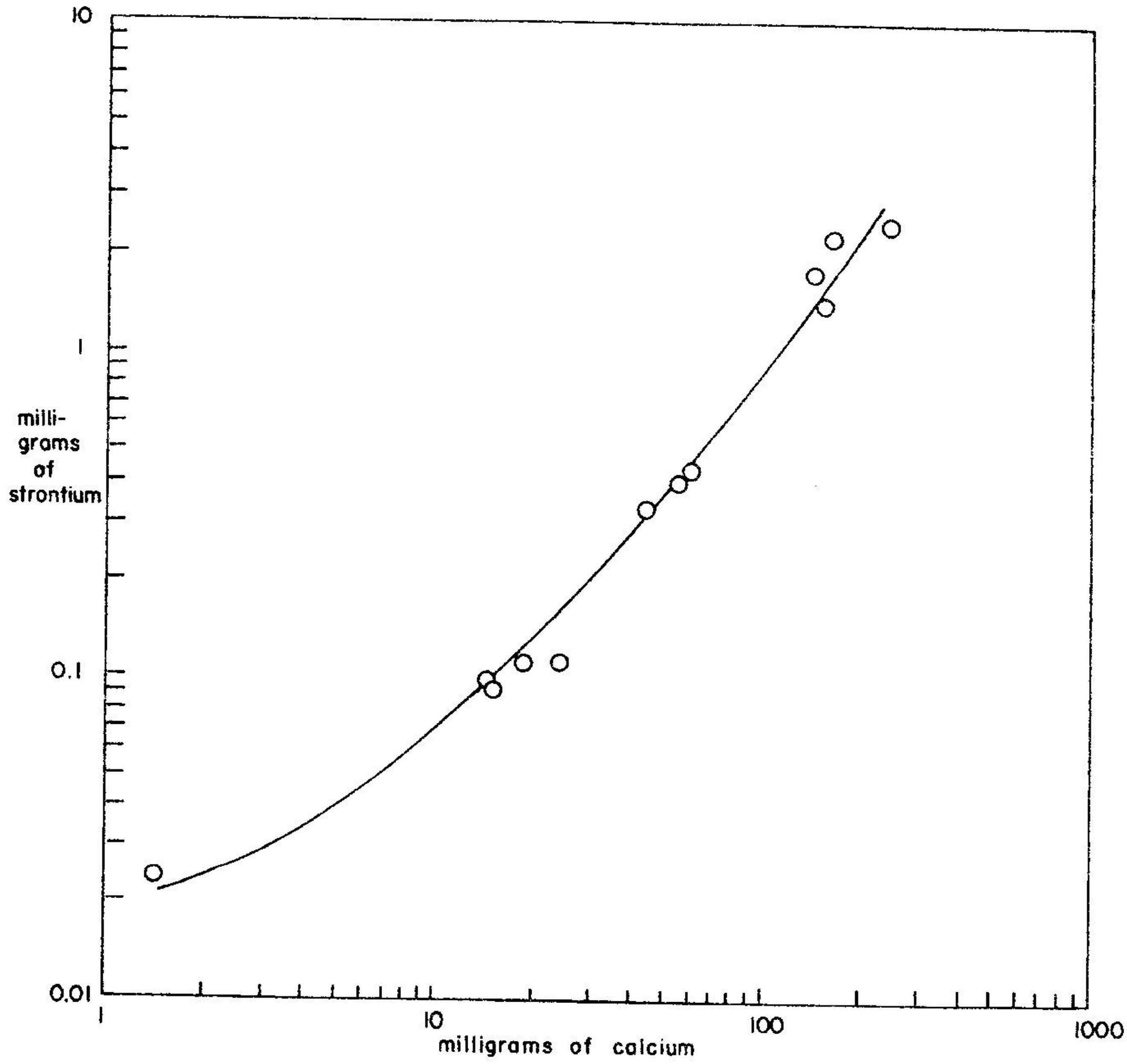


FIG. 39 Relationship of strontium and calcium in marine sediments off the outflow of the Añasco River.

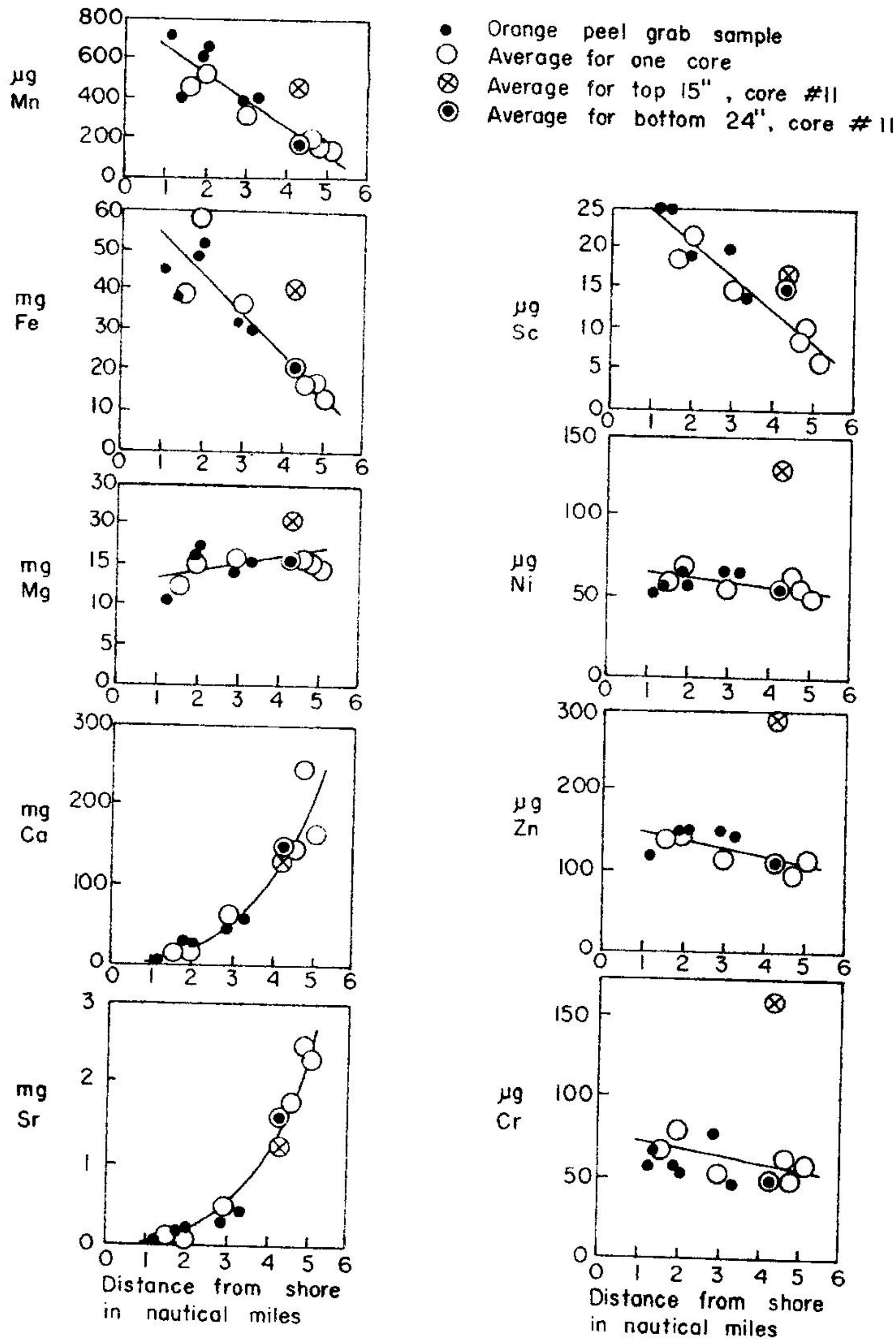
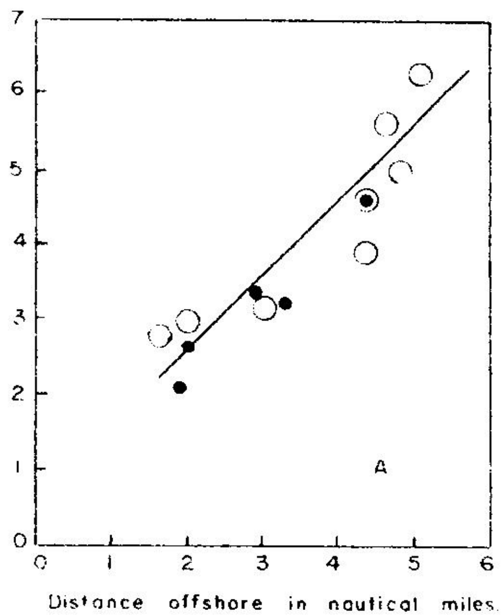


FIG. 40 Amounts of nine elements per gram of sediment related to distance offshore from the outflow of the Añasco River.



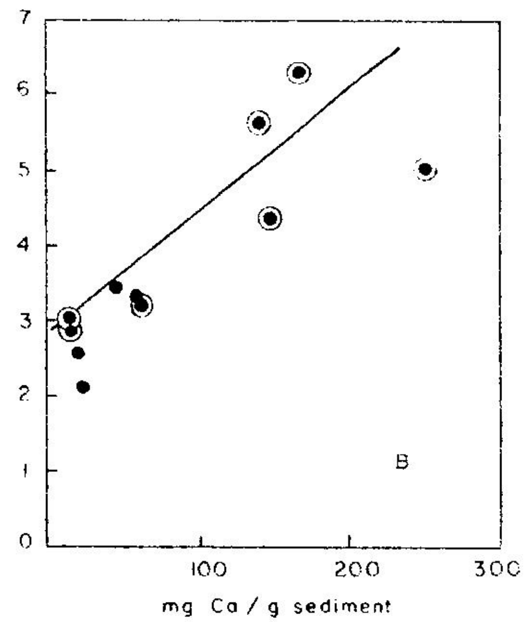


Figure 41. Relationships of the atom ratios, Sr/Ca, in marine sediments with respect to distance offshore from the outflow of the Anasco River (A) and to the average of the amounts of calcium in the sediments (B).

METHODS OF ANALYSIS

Scandium:

The scandium method, developed by members of the marine biology program in late 1963, has been used to analyze amounts of the element in 260 specimens of a wide variety of sample types. The method has been successfully used with river water, rocks, minerals, soils, sands, marine sediments, terrestrial plants, plankton, marine invertebrates and marine vertebrates. The method was described in detail last year and, in summary, consists of: (1) irradiating the sample for four hours in a neutron flux of 2.5 x 10^{12} $n/cm^2/sec$, (2) dissolving the sample in weak acid (after alkali fusion, if necessary), (3) passing through a Dowex-50 column on which the scandium is retained while neutron-induced P^{32} passes through, (4) eluting the Sc^{46} and other cations with 2N HNO_3 (5) coprecipitating the Sc^{46} with zirconium phytate, (6) rinsing the other cations from the precipitate with 0.2N HCl and 4N HNO_3 and (7) measuring the Sc^{46} by gamma spectrometry.

The large number of samples which have been successfully analyzed by the method have confirmed the hopes that the method would be practical and applicable to the work in the marine biology. The reproducibility of the method has been tested with duplicate runs on several types of samples, usually with differences of less than 5%.

The precipitation step does coprecipitate neutron-activated Fe^{59} and Sb^{125} if the two radioisotopes are present. However, the antimony is removed in the ion exchange step and the interference from the Fe^{59} activity may be easily corrected in the counting procedure. This is illustrated in fig. 42 in which the gamma spectrum of the sample was essentially identical with that of the comparator standard after the Fe^{59} component was subtracted.

Scandium in Sea Water:

The scandium method has been adapted to the analysis of the element in sea water. In this analysis the scandium is coprecipitated with scandium-free sodium carbonate. Five precipitations with milligram amounts of carbonate quantitatively remove the scandium from one liter of sea water. The precipitate is then analyzed by the regular scandium analysis. Figure 43 shows the gamma spectra from a neutron activation analysis of scandium in sea water. The separation was contaminated with a trace of Br^{82} and a large amount of Fe^{59}, however, the Sc^{46} was easily determined by analysis of the 2.01 sum peak of the scandium isotope. The values for scandium in sea water samples analyzed thus far range from 0.020 in the open Atlantic Ocean to 0.083 off the west coast of Puerto Rico.

Non-destructive activation analysis:

During November, 1964 a rabbit system was installed in one of the chemistry laboratories of the marine biology program. Preliminary work has been started on a non-destructive neutron activation analysis program. Whether or not an element may be analyzed by the method depends upon its abundance in the samples, the % of the total isotopic abundance of the stable precursor, the neutron cross-section of the precursor, the half-life (ie specific activity)

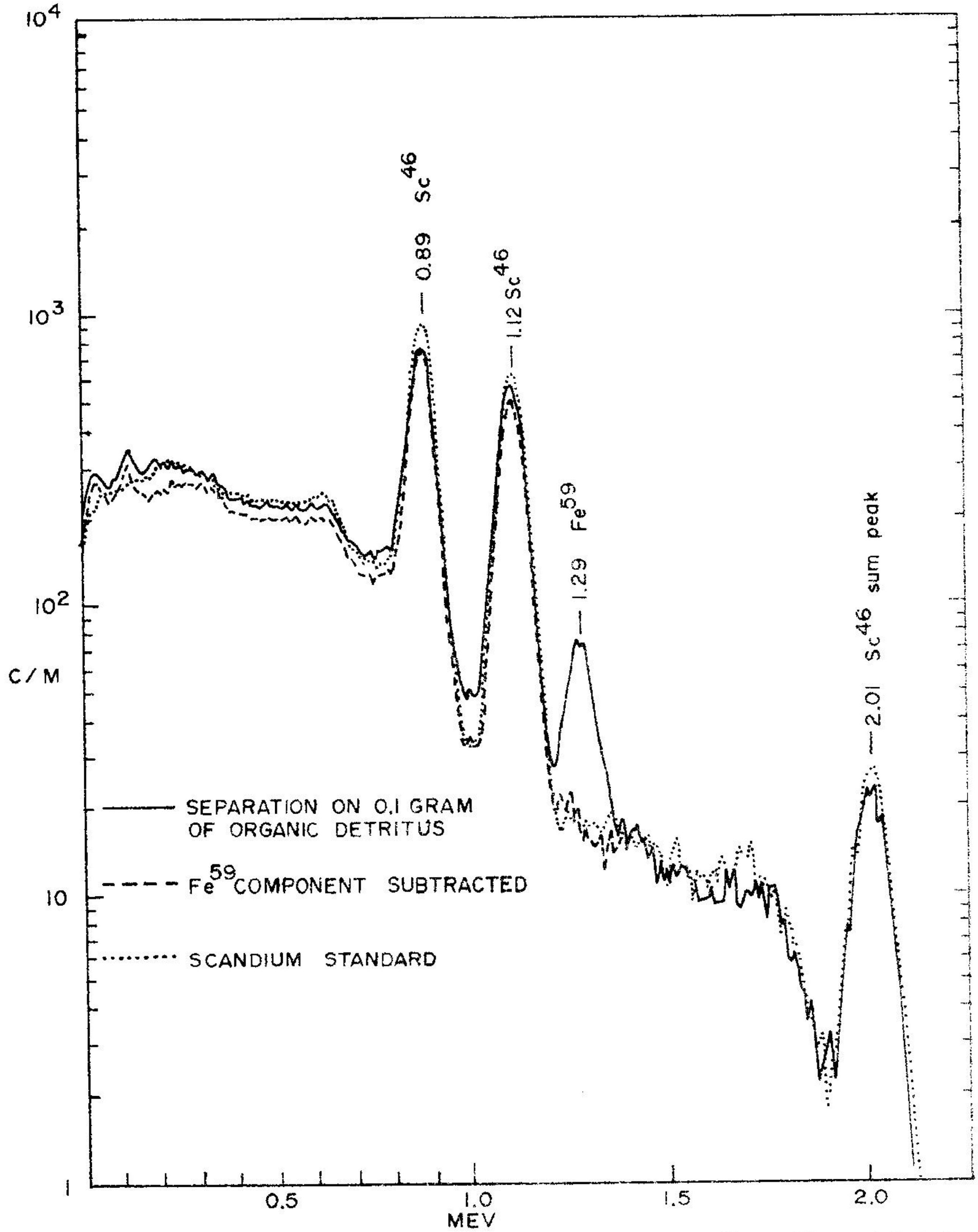


FIG. 42 Gamma spectrum of a phytate precipitate of scandium-46 precipitated from 0.1 gram of organic detritus. The detritus was separated from sediment collected in Añasco Bay. The sample was irradiated four hours in a neutron flux of 2×10^{12} n/cm^2/second. A small amount of activated Fe^{59} was coprecipitated with the scandium phytate. Also shown is the spectrum of the precipitate after the iron component was subtracted as well as that of a 8.4μg standard.

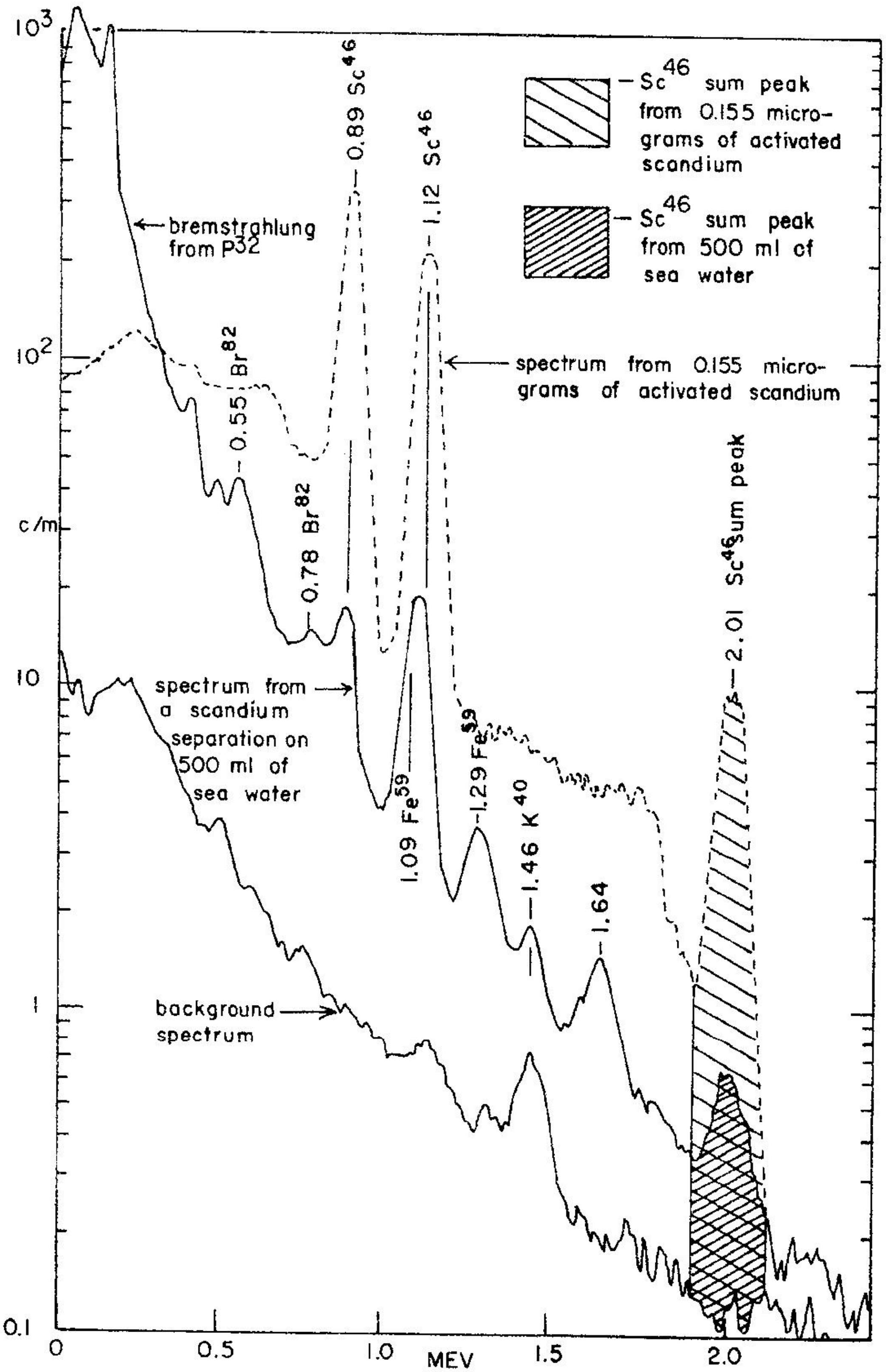


FIG. 43 Gamma spectrum from a neutron activation analysis for stable scandium in 500 ml of sea water previously filtered through a filter of 0.5 micron pore size before the scandium was separated. Also shown is the gamma spectrum from a comparator standard (0.155 micrograms of activated scandium). The water contained 0.0203 ± 0.0016 micrograms of scandium per liter.

of the activation product and the type of radiation emitted by the activation product. Of the elements selected for study, manganese, rubidium, rhodium, silver, indium, europium and dysprosium emit gamma rays in cascade. Coincidence gamma spectrometry may therefore be used to count the radiation from these activated products, thus reducing the interference from other gamma emitters. Other elements which produce activation products which may be analyzed by gamma spectrometry include calcium, cobalt and iodine.

Figure 44 shows the gamma spectra from a non-destructive activation analysis of sandstone from Añasco Valley. The sandstone sample (0.1 g) was put into a polyethylene vial and placed with another vial, containing a comparator standard of 5 ug of Mn, into a polyethylene rabbit. The sample and standard were irradiated with neutrons for 30 seconds, allowed to cool 30 minutes, transfered to new vials and counted at 30, 60 and 85 minutes after irradiation. In this sample the amount of manganese was easily determined from the spectrum. Calcium could have been determined simultaneously had a calcium comparator standard been included with the manganese standard.

Bismuth:

A method for rapid analysis of bismuth is many types of samples has been developed as a result of work done this year in an area of research not directly concerned with the marine biology program. During August 1964 two members of the marine biology program of PRNC, Raúl McClin and Frank G. Lowman participated in a resurvey of the Pacific Proving Ground at Eniwetok and Bikini Atolls in the Marshall Islands. The survey was under direction of the Laboratory of Radiation Biology, University of Washington, Seattle, Washington. Among the samples collected were sediments from the large craters formed in the reefs by the firing of thermonuclear weapons during the weapons-test program. Gamma spectrum analyses of the crater samples showed Co^{60} to be the dominant radiocontaminant and Bi^{107} to be second in disintegration rate (Fig. 45 A). The only reference to the occurrence of Bi^{207} known to the writer is that of Lowman and Palumbo (1962).

Two 20 gram samples of crater sediment were dissolved in aqua regia and dried. One sample was dissolved in 0.2N HCl and the bismuth separated on a Dowex-50 column (Lowman and Palumbo, 1962). A gamma spectrum from the leading fraction of the elution peak is shown in figure 45 (A). The other sample was subjected to the following treatment:

(1) The sample was counted in the gamma spectrometer then redissolved in 100 ml of triple distilled water.

(2) The solution was poured into a separatory funnel and 100 ml of 0.1 M Tri-n-octylphosphine oxide (TOPO) in cyclohexane were added to the funnel.

(3) The separatory funnel was shaken for 15 minutes on a mechanical shaker.

(4) The phases were separated and two more extractions were made with 100 ml of 0.1 M TOPO.

(5) The fractions were counted and a 99.3 % yield was achieved.

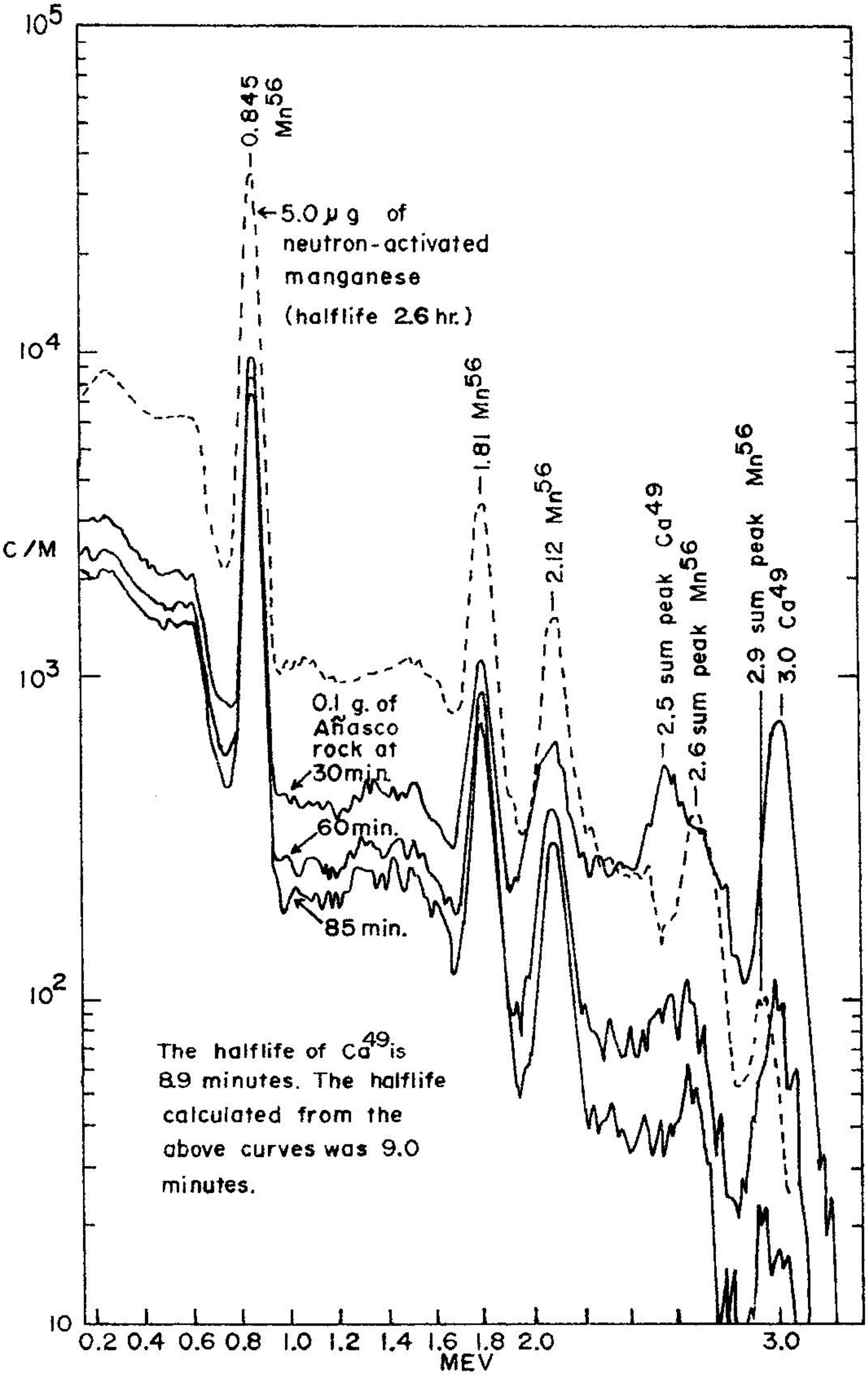


FIG. 44 Gamma spectra from 0.1g of red sandstone made 30, 60 and 85 minutes after irradiation for 30 seconds in a neutron flux of 2.5×10^{12} n/cm^2/second. Also shown is the spectrum of a comparator standard of 5.0 μg of manganese which was activated with the sample.

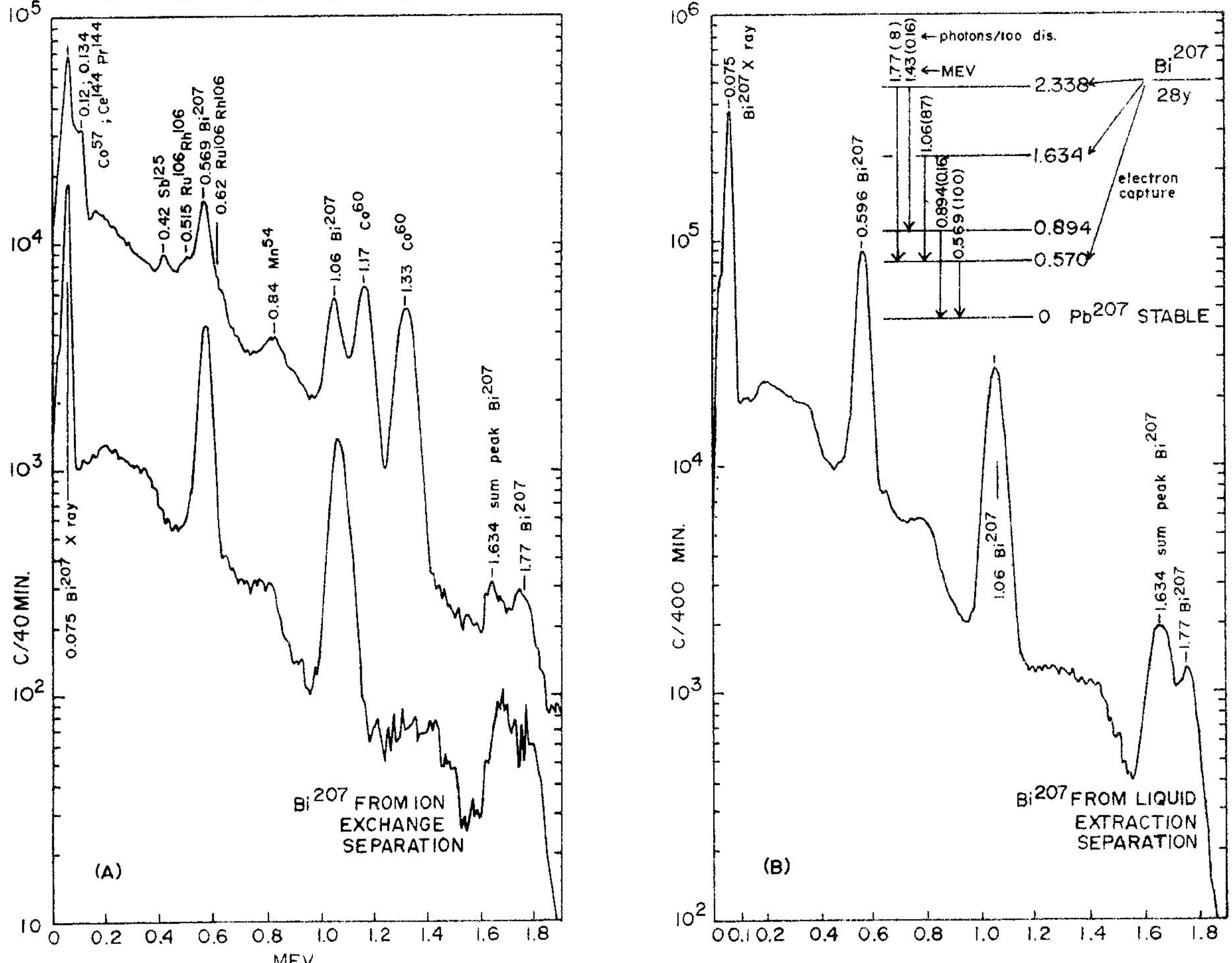


FIG. 45 (A) Gamma spectra of a sample of sediment taken from the Tewa crater at Bikini Atoll and the Bi^{207} separated from the sediment by ion exchange. (B) A gamma spectrum of Bi^{207} separated by liquid-liquid extraction from sediment collected from the Tewa crater in August, 1964. Also shown is the decay scheme for Bi^{207}.

(6) The bismuth was back extracted into 7M HCl for a final overall yield of 99 %.

(7) The bismuth is measured by atomic absorption methods.

The method has been adapted to analyses for bismuth in biological, sediment, and mineral samples. The yield is determined with carrier-free Bi^{207} and the limit of detection ($\pm$ 10% at the 95% confidence level) is 1 ug Bi/g of sample, using one gram samples.

Lithium:

An adaptation of a published method for the analysis of lithium in sea water has been tested and is in use.

The procedure is as follows:

(1) An ion exchange column (1.55 x 40 cm) was prepared from 50-100 mesh Dowex-50 x 8. The column was treated with 100 ml of 6N HCl followed by 200 ml of triple distilled water.

(2) Twenty ml of sea water were added to the column.

(3) The column was eluted at a flow rate of 0.5ml/minute with 25 ml of distilled water and 500 ml of 0.2N HCl. The eluates were discarded.

(4) Five-hundred ml. of 0.5N HCl was added to the column and the first 135 ml of solution collected (this fraction contained the lithium) (Fig. 46).

(5) The solution containing the lithium was dried in a quartz or platinum crucible and the lithium redissolved in one ml of 0.2N HCl.

(6) The lithium content was measured by atomic absorption and flame spectrophotometry.

The lithium in 20 ml of sea water may be measured with an accuracy of $\pm$ 5% (95 % confidence level). Complete separation of lithium from sodium is achieved.

Zinc:

A method for measuring zinc in sea water has been developed for analyzing large numbers of samples collected off the outflow of the Añasco River. The method is amenable to simultaneous analyses on several samples, by one technician . In brief, the method consists of precipitating the zinc from the sea water with a ferric hydroxide scavenge, rinsing the sodium chloride out of the precipitate, separating the zinc from the iron on a Dowex-1 ion exchange column and measuring the zinc by atomic absorption spectrophotometry.

The principal sources of error in the technique are caused by reagent

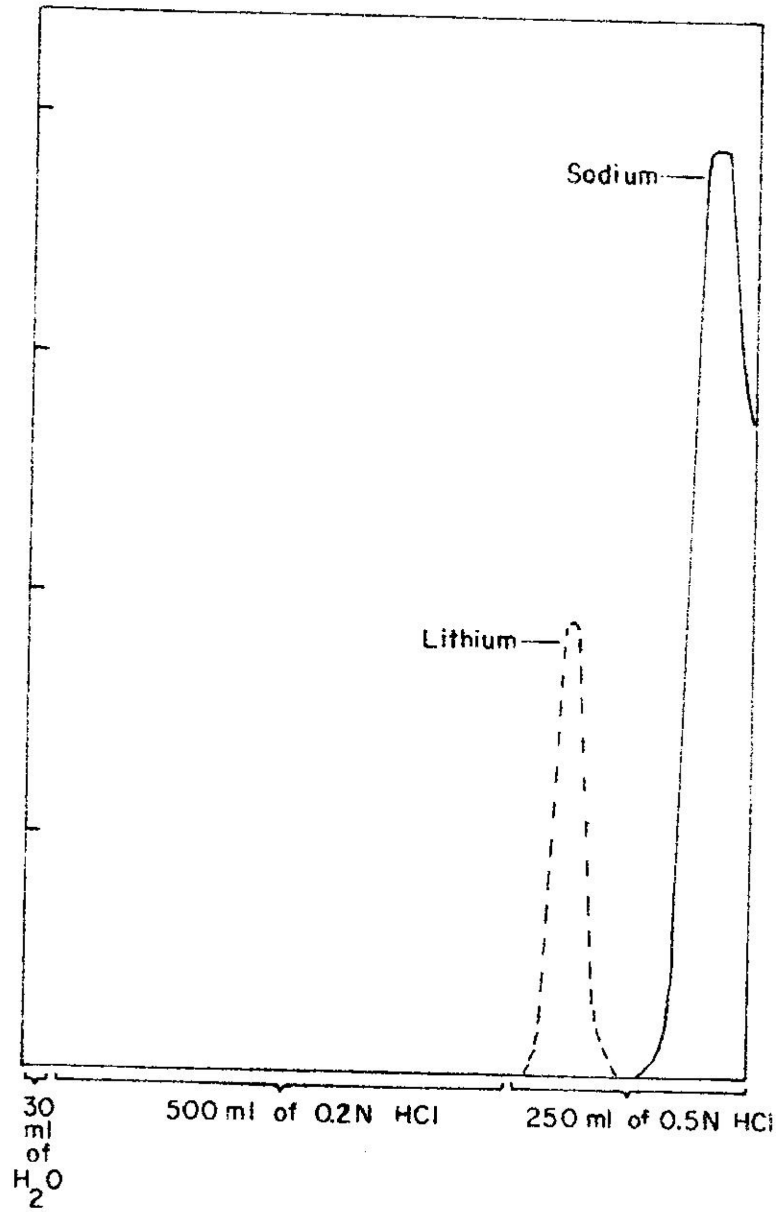


FIG. 46 Elution curves for lithium and sodium from 20ml of sea water separated on a Dowex-50x8 ion exchange column (50-100 mesh; bed dimensions 1.55 x 40 cm).

contamination with zinc. Triple distilled water is used and the last stage of distillation is done with a polyethylene condenser. The iron chloride reagent is freed from zinc by an ion-exchange-chloride complexing method (Kraus and Moore, 1953). HCl and ammonia vapor are used rather than the liquid reagents except in the ion-exchange procedure.

The procedure is as follows:

(1) Zn^{65} tracer (containing less than 0.001 ug of stable zinc) was counted in the gamma spectrometer, then added to 500 ml of sea water in a polyethylene beaker.

(2) The water was acidified to a pH of 2 with HCl vapor and iron chloride (5 mg Fe) was added.

(3) One-half of the water was added to another polyethylene beaker on a magnetic mixer and the solution stirred while ammonia was bubbled into the liquid until a pH of 9 was achieved and the iron was precipitated.

(4) The ferric hydroxide precipitate was centrifuged and the supernate decanted.

(5) The precipitate was redissolved by the addition of HCl vapor and steps 3 and 4 repeated on the remaining one-half of the sea water.

(6) The supernates from steps 4 and 5 were again acidified to a pH of 2 with HCl vapor.

(7) Iron hydroxide (5 mg Fe) was added to one of the acidified supernates and steps 3, 4 and 5 were repeated.

(8) The precipitates were combined and dissolved in 2 ml of redistilled 6N HCl (a quartz condenser was used).

(9) The iron solution was placed on a Dowex-1 (100-200 mesh) ion exchange column (8 mm x 260 mm) which had been previously treated with zinc-free water and 6N HCl.

(10) The column was rinsed with 10 ml of 6N HCl, 20 ml of 0.6N HCl.

(11) The column was eluted with 20 ml of zinc-free water which was collected in one ml aliquors.

(12) Each ml of water was counted for Zn^{65} and the stable zinc was determined by atomic absorption spectrophotometry. The counts from Zn^{65} were plotted against micrograms of stable zinc in each ml (Fig. 47). Any point which fell to the right of the line shown in the figure was considered to have been contaminated by environmental stable zinc.

(13) The total counts of Zn^{65} added to the sea water was equated to the corresponding amounts of stable zinc detected by the atomic absorption method. (Fig. 47).

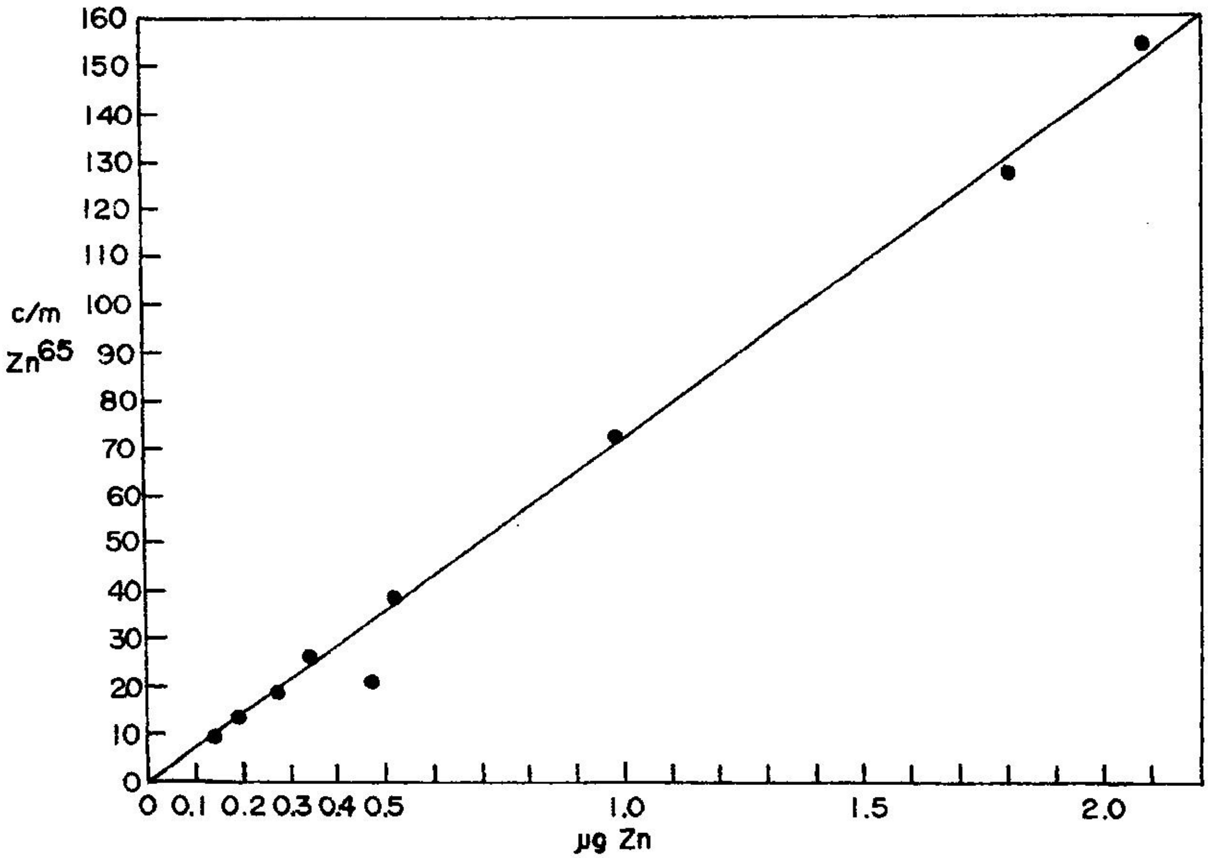


Figure 47. A comparison of the activity of a Zn^{65} tracer and the stable zinc separated from one liter of sea water collected off the west coast of Puerto Rico. The high specific-activity-Zn^{65} (< 0.001 ug of stable Zn in the tracer) was added to the sea water and the stable zinc plus tracer separated by a combination precipitation-ion exchange method. The values shown are those of one ml fractions which were collected from the Dowex-1 ion exchange column.

References

Lowman, F. G. and R. F. Palumbo. 1962. Occurrence of Bismuth - 207 at Eniwetok Atoll. Nature 193:796-797

Kraus, K. A. and G. E. Moore. 1953. Anion exchange studies. VI. The divalent transition elements manganese to zinc in hydrochloric acid. Anal. Chem. 75:1460-1462

DATA STORAGE AND RETRIEVAL

A system for storage and rapid retrieval of data has been initiated in order to handle the volume of information which is being collected by the Marine Biology Program. Information is punched on IBM cards in two forms:

1. Coded descriptors indicating items such as sex, location, date of collection, sample type, species, etc.

2. Raw data such as temperature, salinity, weight of sample, amount of stable element present in ash, wet weight, and dry weight, etc.

A precise location is reserved on each card for a specific piece of information (Fig. 48). Each card has the basic descriptive information pertinent to a sample plus either ecological or stable element data for a given series of elements analyzed from that sample.

By making use of the IBM Sorter and Accounting Machine, this system provides an opportunity to make quick comparisons in addition to a rapid print-out of all data. Gross correlations between amounts of stable elements contained in organisms in relation to gradients of temperature, sediments, or salinity may be quickly ascertained, along with differences in stable element content between geographic locations, or between organs within the same animal; or differences in stable element content between or within species or phyla. In this sense it has a built-in first step toward data reduction.

This system also provides a means for entering data directly into a computer for whatever program may be desired. The multi-use aspect of this method of recording data will greatly facilitate the handling and analyses of information collected for the Marine Biology Program.

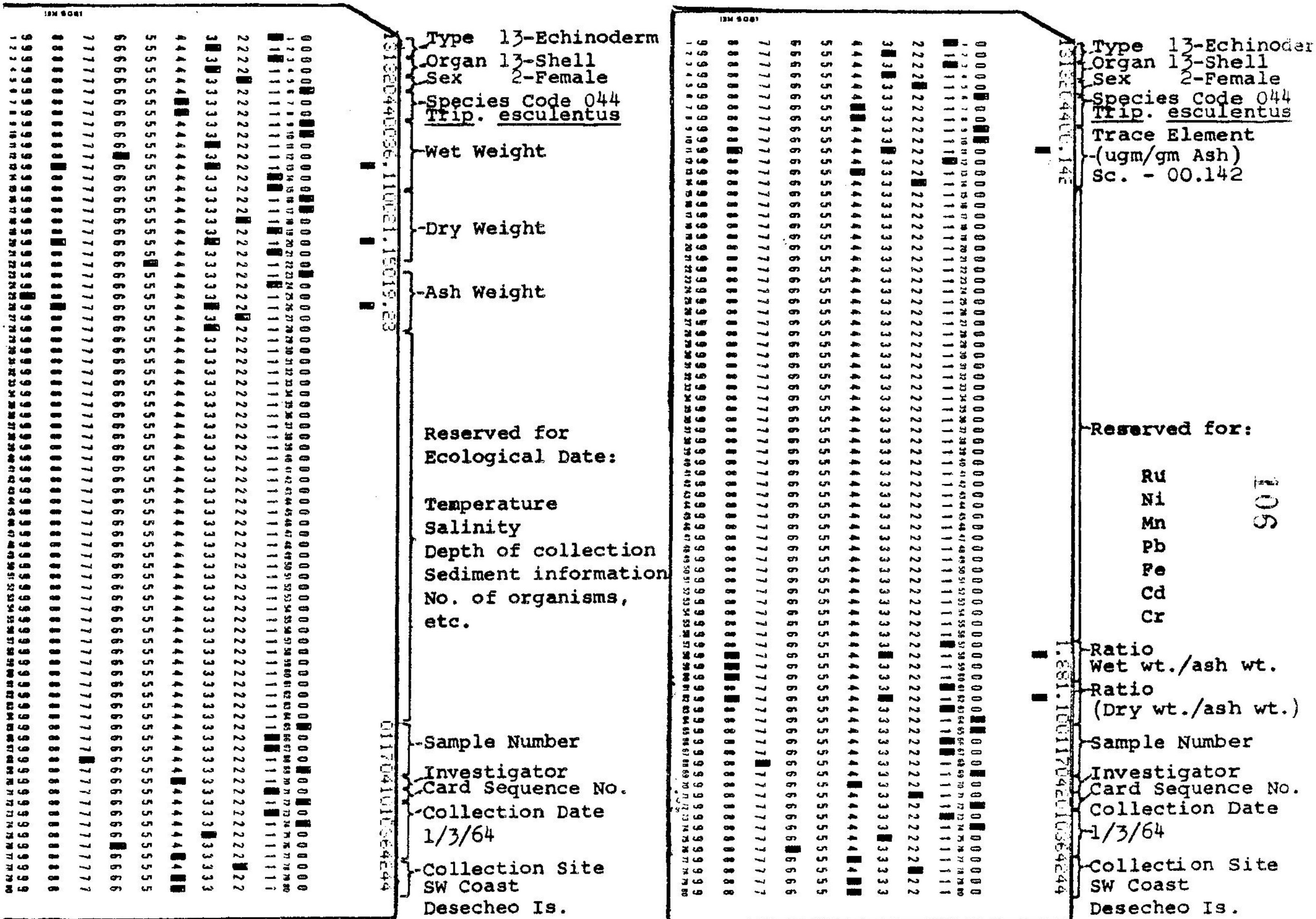


FIG. 48. Illustration of Card Punching System for Storage and Retrieval of Data.

X-RAY DIFFRACTION STUDIES

Marine and terrestrial sediment samples are analyzed for their clastic properties and stable element compositions as described previously. X-ray diffraction diagrams are used to determine in which compounds the elements occur.

The sediment and marine samples are transformed into a fine powder and a diffraction pattern run for each one. The tubes usually employed as targets for the X-rays are Mo and Cu. The voltage used for the first one is 45 KV and the current 17 MA; for the second one 45 KV and 35 MA is used. The diffraction pattern is run from 2θ equals 2° until 2θ equals 80; running it at a chart speed of 1°/minute.

The 2θ angles and intensities are then read from the pattern for each peak that appears. With the 2θ readings, the interplanar spacings or "D" values are determined from tables prepared previously according to the Bragg equation $n = 2d \sin \theta$, where n is considered to be 1, λ is the $K\alpha$, radiation characteristic of the target used, and θ is one-half of the total angle of deviation of the incident X-ray beam.

The "D" values are punched into IBM cards. A computer program is then employed which searches out and defines all of the possible compounds (on the basis of ASTM listings for powdered compounds) which are characterized by the observed "D" values. If two peaks of the compound appear and the given intensities correspond to the observed ones in the graph, a tentative identification is made, since the third peak may be hidden by the background, especially if it is of low intensity. If the three peaks occur and the intensities correspond to the observed ones, a positive identification is made (Fig. 49). The present program utilizes only the observed "D" values. The intensities for each peak must be checked manually. The program is being re-written so that both the observed "D" values and intensities will be checked by the computer. Then, computer printout will include only those peaks and intensities occurring in the prescribed ratios for known compounds.

The spectra of elements are obtained by using X-ray **fluorescence** instead of X-ray diffraction, and elements are identified in the tables for fluorescence using the 2θ angles readings and intensities only. Several elements have been identified and others corroborated using this method.

The more than 50 compounds identified to date, both positively and tentatively, appear in Table IX. The utilization of these techniques should provide basic information as to the compounds through which stable elements are either locked into the physical environment or made available for the diverse biological pathways.

Program card no.	Sample "D" value	Programmed "D" values			Programmed Intensities			ASTM file reference no.	
0317-1	1.97	1.97	3.21	2.79	100	C40	040	9-64	$CuS \cdot Cu_2S$, copper sulfide, Digenite
C317-2	3.21	1.97	3.21	2.79	1C0	C40	040	9-64	
C317-3	2.79	1.97	3.21	2.79	1C0	C40	040	9-64	
0318-1	1.97	1.97	1.68	2.79	1C0	C90	080	4-C861	α $Cu_{1.8}S$, alpha copper sulfide, Digenite
0318-2	1.68	1.97	1.68	2.79	1C0	C90	080	4-0861	
0318-3	2.79	1.97	1.68	2.79	1C0	C90	080	4-0861	
0319-1	3.CC	2.00	2.52	1.62	1C0	100	100	2-0656	
C321-1	2.53	2.53	3.00	1.62	1C0	C80	060	3-0860	
0321-2	3.CC	2.53	3.CC	1.62	1C0	C80	060	3-0860	
0322-1	2.6C	2.60	7.28	2.12	200	100	080	7-172173	
0324-3	1.97	2.05	1.89	1.97	1C0	C70	050	9-333	
0326-2	3.CC	3.74	3.C0	2.70	1C0	C90	080	10-453	$2PbS \cdot As_2S_3$ Dufrenoysite
0326-3	2.7C	3.74	3.C0	2.70	1C0	C90	080	10-453	
0327-1	3.16	3.16	2.87	2.63	1C0	C90	090	6-0317	$CuPbAsO_4OH$ Duftite
0327-2	2.87	3.16	2.87	2.63	1C0	C90	090	6-0317	
0327-3	2.63	3.16	2.87	2.63	1C0	C90	090	6-0317	
0328-2	2.63	3.17	2.63	2.91	100	C90	070	6-0322	
0330-1	2.55	2.55	5.89	5.84	1C0	C90	090	7-7172	$(Al\,Fe)_7\,BSi_3\,O_{18}$ Dumortiertite
0330-2	5.89	2.55	5.89	5.84	1C0	C90	090	7-7172	
0332-1	3.13	3.13	2.86	2.51	1C0	090	090	7-404	
0333-1	3.11	3.11	2.32	2.00	100	C70	070	2-0574	$1/2(2As_2O_5 \cdot 2BaO \cdot 3Fe_2O_3 \cdot 7H_2O)$, Dussertite
0333-2	2.32	3.11	2.32	2.C0	1C0	C70	070	2-0574	
0334-3	1.84	4.40	3.61	1.84	1C0	C85	020	10-377	
0335-1	2.29	2.29	2.42	1.37	1C0	C40	040	10-452	Ag_3Sb, Dyscrasite
0335-3	1.37	2.29	2.42	1.37	1C0	C40	040	10-452	
0336-1	3.13	3.13	8.41	3.27	1C0	C80	040	10-431	
0337-3	3.26	3.12	8.39	3.26	100	C95	035	10-427	
0338-1	3.16	3.16	2.54	1.95	1C0	C70	070	2-0547	
0339-3	1.97	2.86	2.76	1.97	1C0	C60	060	3-07C8	
0340-3	2.34	2.86	2.02	2.34	1C0	100	080	8-70	
0341-1	2.87	2.87	2.03	2.34	1C0	100	080	3-07C1	K_2NaAlF, potassium sodium fluoaluminate
C341-2	2.03	2.87	2.03	2.34	1C0	100	080	3-C7C1	
C341-3	2.34	2.87	2.03	2.34	100	100	080	3-07C1	
C342-1	3.13	3.13	2.86	2.51	1C0	C90	090	7-404	
C343-2	3.23	3.05	3.23	3.13	1C0	C90	070	10-474	$1/2(Cu_2S \cdot Bi_2S_3$, Emplectite?
0343-3	3.13	3.05	3.23	3.13	1C0	C90	070	10-474	
C345-3	3.11	3.22	3.04	3.11	1C0	100	090	2-0516	
C346-1	2.16	2.16	2.55	3.C4	1C0	C50	20#	4-082C	$Ag_{5-x}Te_3$ (x=0.71), silver telluride, Empressite
C346-2	2.55	2.16	2.55	3.C4	1C0	C50	20#	4-082C	
C348-3	2.87	3.22	1.86	2.87	1C0	C90	080	10-436	
C349-3	1.72	9.30	2.86	1.72	1C0	C70	060	2-CC63	
C350-2	2.87	3.17	2.87	2.49	1C0	C87	051	7-216	$MgSiO_3$, Enstatite
C350-3	2.49	3.17	2.87	2.49	1C0	C87	051	7-216	
0351-2	2.4C	2.90	2.40	1.64	1C0	C70	065	9-438	
C353-3	2.68	4.21	5.35	2.68	1C0	C26	024	8-467	
C354-1	2.46	2.46	4.45	3.17	1C0	C80	080	2-1066	
C356-2	3.21	6.69	3.21	2.59	1C0	C75	075	10-480	$[(Y,Er)UTh](Nb,Ta,Ti,Fe)_2O_6$ Eschwegeite
0357-1	2.97	2.97	1.72	1.49	1C0	C80	080	6-03970398	
C357-2	1.72	2.97	1.72	1.49	1C0	C80	080	6-03970398	
C357-3	1.49	2.97	1.72	1.49	1C0	C80	080	6-03970398	

FIG. 49 A sample page of print-out from a computer program written to search out and identify compounds in x-ray diffraction analyses on rocks, minerals, soils and marine sediments.

COMPOUNDS IN AÑASCO SEDIMENTS

1) $(K,Na)Al_3(OH)_6(SO_4)_2$ Alunite
2) Ti_3O_5 Titanium Oxide
3) Cu Fe S_2 Copper Iron Sulfide
4) Cu S Copper Sulfide
5) 2 Pb S. As_2S_3 Dufrenoysite
6) $Na_2Ca(CO_3)_2.SH_2O$ Sodium Calcium Carbonate Hydrate
7) Co Se_2 Cobalt Selenide; Hastite
8) $(Ca,Ce,Na,K)_2(Nb,Fe)_2O_6(O,OH,F)$ Koppite (Pyrochlore)
9) Mn $Fe_2(PO_4)_2(OH)_2.2H_2O$ Basic Mn, Fe (III) Phosphate Hydrate
0) $Al_2O_3.SiO_2$ Kyanite
1) Mo S_2 Molybdenum Di Sulfide
2) 0.85-1.5 $CaO.SiO_2$.N-x H_2O Plombierite (Gel)
3) PbO. $2Fe_2O_3$ Plumboferrite (Lead Iron Oxide)
4) SiO_2 Silicon (IV) Oxide (Alpha Quartz)
5) Saponite
6) Sassolite; H_3BO_3 (Boric Acid)
7) C Diamond
8) Mn_2 TiO_4 Manganese Titanate; Hausmannite
9) $Ca_5(PO_4)_3F$ Calcium Fluoride Phosphate
0) Au - Gold
1) Sodium Calcium Aluminum Silicate Hydrate
2) Hg S Mercury (II) Sulfide (hexagonal)
3) 7 (Mn,Zn,Ca) 0.3 SiO.H O Leucophoenicite
4) $(Ca,Na,Fe)_2Ta_2$ $(O,OH,F)_7$ Microlite
5) Fe_3S_4 Smythite
6) Hg_2O Cl Terlinguaite
7) MnO_2
8) Samarskite
9) Sauconite 3(Zn,Mg,Fe,Al)0.4 $(Si,Al)O_2.2H_2O$
0) Fe S Iron (II) Sulfide
1) $(Zn,Mn,Fe).(Fe,Mn)_2O_4$ Franklinite
2) Mn_3O_4 Manganese Oxide
3) $Pb_5(PO_4)_3$ OH Lead Hydroxide Phosphate
4) HgO Mercury (II) Oxide
35) 0.83 $MaAlSi_3O_8$, 0.16 $CaAl_2Si_2O_8$ - Sodium Ca, Al, Silicate
36) $(Ag,Cu)_{16}$ As_2 S_{11}
37) $MgCo_3$ Magnesium Carbonate
38) $Ca(Mg_2Al)$ $(Al_{2.8}Si_{1.2})O_{10}(OH)_2$ Xanthophillite
39) BeO Beryllium Oxide; Bromellite
40) (Na_2Ca_{10}) $(AlO_2)_{20}(SiO_2)_6(PO_2)_{10}$ $(H_3O_2)_{12}$. $16H_2O$ Viseite
41) (Mg Fe) $(Cr,Al)_2O_4$ Magnesiochromite
42) 2 Fe" Fe_4" $(PO_4)_3$ $(OH)_5$ Basic Iron Phosphate
43) Cu S.4 Cu_2S Copper Sulfide; Digenite
44) Pd Palladium
45) Au Ag Te_4 Sylvanite
46) Bi_4TeS_3 Bismuth Telluride Sulfide; Gruenlingite
47) $(MnFe)_2O_3$ Iron Manganese Oxide
48) 5 $MgO.Al_2O_3$.3 $SiO_2.4H_2O$ Penninite (above 600°C)
49) $Mg_{11}Al_5FeSi_{11}O_{42}.40H_2O$ Vermiculite
50) Ni_2S Nickel Sulfide; Vaesite
51) $FeCO_3$ Iron (II) Carbonate
52) $MgSb_2O_6$ Bystromite
53) $Cu_{2-x}Se$ Berzelianite
54) $Ca(UO_2)_2$ $(PO_4)_2.8\text{-}12H_2O$ Calcium Uranyl Phosphate Hydrate
55) $Mg(OH)_2$ Magnesium Hydroxide
56) $K_2Cu(SO_4)_2.6H_2O$ Potassium Copper (II) Sulfate Hexa Hydrate
57) Ag Fe_2S_3 Silver Iron Sulfide; Argentopyrite
58) Cu_{2-x} Te Copper Telluride (x = 0.6)
59) $CoAs_3$ Cobalt Arsenide; Skutterudite
60) (Fe,Mn) $(Ta,Nb)_2O_6$ Tapiolite
61) FeO. $(Cr,Al)_2O_3$ Chromite
62) (Co,Fe) As S Cobalt Arsenic Sulfide; Cobaltite
63) Cu Copper
64) Cu Cr_2O_4 Copper (II) Chromite
65) CaMg $(SiO_3)_2$ Calcium Magnesium Meta Silicate
66) Mn Fe_2O_4 Manganese Iron Oxide; Jacobsite (synthetic)

Table 9. Compounds tentatively or positively identified in Añasco Bay Sediments.

New Facilities

During April, 1965 two buildings for use in the Marine Biology Program will be completed. A new building, located on the grounds of the Puerto Rico Nuclear Center, Mayaguez, is a two-floor structure and will house an instrument laboratory (including a low-background facility) on the first floor and two chemistry laboratories on the second floor to be used for trace element analysis of sea water. The other building is located on the BONUS site at Pta. Higuero and is being converted into a marine biological laboratory.

The building at the BONUS site was purchased from the U. S. Navy by the U. S. Atomic Energy Commission. The AEC also allowed $4000 for conversion of the building for use in the marine biology program. The building, as purchased, was 40 by 20 feet in length and width, and 13 feet high with a pitched roof. It was constructed on a concrete slab with steel framing covered by 1/2 inch thick asbestos-cement pannels. It was completely insulated with fiberglass batts, was wired for laboratory use with 110 and 220 volt outlets and contained shower and toilet facilities. One end of the building was provided with sliding garage-type doors.

The conversion work on the building is almost completed and includes the following projects:

(1) Furring strips were bolted to the inside of the steel frame and the interior of the building was paneled with sheet rock.

(2) A stairway was built to the space over the shower and toilet for access to storage area.

(3) The garage-type doors were removed, steel framing installed in the opening and the opening was paneled on the outside with asbestos-cement board and on the inside with sheet rock. A regular exterior door was installed in this wall.

(4) An instrument laboratory 12' x 12' was constructed in one corner of the building and an air conditioner was installed. The walls between the instrument laboratory and the main laboratory were provided with windows.

(5) Sleeping and cooking accomodations for four researchers were constructed. Because the building will be used for uptake experiments and other marine biological work which often require 24 hours attention, these facilities are necessary.

(6) A salt water system was installed with pumps, a settling tank, a salt water table and running salt water.

(7) A total of 60 feet of laboratory benches were constructed in the two laboratory rooms.

(8) A protective cover was built for the air conditioner.

(9) The building was painted.

Early in 1965 construction was started at the Puerto Rico Nuclear Center, Mayaguez on a new building for use as a chemistry and instrument laboratory in the marine biology program. The structure is built of reinforced concrete, is thirty two by twenty feet in length and width and is two stories high. The new building is located 300 feet northeast of the main PRNC building.

The new building is constructed in the side of a hill. The second floor of the building coincides with the outside ground level on the side facing the main PRNC building - on the opposite side of the new building the lower floor is at ground level. Thus the radiation counting equipment, which will be placed on the first floor, will be shielded from the research reactor and; Co^{60} gamma source in the main PRNC building by more than 300 feet of soil. Entry to the instrument room is gained through an office with dimensions of approximately nine by twelve feet.

The second floor of the building contains a central office and storage room with dimensions of approximately thirteen by twenty feet. A lavatory and toilet is built into one corner of this room. On opposite sides of the office are two chemistry laboratories to be used for trace element analyses of sea water. Each laboratory has dimensions of nine by twenty feet. The entrances from the office to the chemistry laboratories are fitted with sliding doors. Entry to the laboratories is gained by passing through the length of the office from the outside office door. The laboratories are thus isolated from direct entry from outside the building.

The two chemistry laboratories and the central office are serviced by separate air conditioners and the outside air which is supplied to the laboratories is subjected to special filtration. Each laboratory is supplied with a stainless steel hood and the ordinary chemistry laboratory furniture.

STABLE ELEMENT ANALYSES

The following tables list the samples for which trace element analyses have been made and corrected for wet, dry and ash weights. Analyses which have been made on other samples are not included because the calculations are not yet completed.

The values presented were intended to present only two significant figures. In some instances, the final calculations in these tables were not rounded to two significant figures. This does not signify confidence in the third figure and these values should be rounded to two places.

The analyses were made in two ways - scandium and rubidium by activation analysis and the remainder by atomic absorption or flame spectrophotometric measurements. The activation analysis methods are described elsewhere in this report.

Samples are prepared for emission and absorption spectrophotometry in the following manner: (If necessary, specimens are frozen until processed). The specimens are wet weighed, dried and then ashed at a temperature of 450°C. An aliquot of 0.25 gram of ash is dissolved in agua regia and warmed on a hot plate. It is filtered by vacuum through two thickness of glass filter paper and washed three times with 0.2N HCl. The filtrate is brought to a final dilution of 1/100 (weight/volume) by adding distilled water. The filtered sample is analyzed for content of stable elements.

The atomic absorption analyses for the elements reported in these tables (Ni, Zn, Cr, Mn, Co, Cd) have been tested for possible interference errors in the types of samples used in the present work. Interference effects have not been found. However, this method is also used for the determination of magnesium, calcium and strontium and, for these elements, interferences do exist if large amounts of phosphate, silicate, or aluminum are present in the sample. These effects may be eliminated by the addition of excess lanthanum to the samples.

Type of sample	Scientific name	Collection site	ug Ca/gram Wet x 10^3	ug Ca/gram Dry x 10^3	Type of sample	Scientific name	Collection site	ug Ca/gram Wet x 10^3	ug Ca/gram Dry x 10^3
Terrestrial	Piston Core sed. T-16 A	343m. depth off Añasco	7.3	130	Terrestrial	Piston Core Sed. T-19 A	31m. depth off Añasco	5.5	10
"	" T-16 B	"	88	160	"	" T-19 B	"	5.9	11
"	" T-16 C	"	89	160	"	" T-19 C	"	6.2	11
"	" T-16 D	"	58	100	"	" T-19 D	"	5.6	10
"	" T-16 E	"	94	160	"	" T-19 E	"	2.9	5.3
"	" T-16 F	"	67	110	"	" T-19 F	"	12	22
"	" T-16 G	"	120	200	"	" T-19 G	"	13	23
"	" T-16 H	"	73	120	"	" T-19 H	"	9.3	16
"	" T-16 I	"	160	260	"	" T-19 I	"	11	19
"	" T-16 J	"	76	120	"	" T-19 J	"	13	21
"	" T-16 K	"	80	130	"	" T-19 K	"	11	17
"	" T-16 L	"	82	130	"	" T-19 L	"	11	17
"	" T-16 M	"	84	130	"	" T-19 M	"	9.0	14
"	" T-17 A	Off Añasco River	120	200	"	" T-20 A	351m. depth off Añasco	67	120
"	" T-17 B	"	97	120	"	" T-20 B	"	81	140
"	" T-17 C	"	100	170	"	" T-20 C	"	140	230
"	" T-17 D	"	110	180	"	" T-20 D	"	77	130
"	" T-17 E	"	110	190	"	" T-20 E	"	76	122
"	" T-17 F	"	94	160	"	" T-20 F	"	88	120

Type of sample	Scientific name	Collection site	ug Ca/gram Wet x 10^3	ug Ca/gram Dry x 10^3
Terrestrial	Piston Core Sed. T-17 G	Off Añasco River	80	130
"	" T-17 H	"	94	150
"	" T-17 I	"	80	140
"	" T-17 J	"	99	160
"	" T-17 K	"	100	160
"	" T-17 L	"	100	160
"	" T-18 A	64m. depth off Añasco	5.2	8.2
"	" T-18 B	"	3.7	5.5
"	" T-18 C	"	11	15
"	" T-18 D	"	8.5	12
"	" T-18 E	"	8.8	13
"	" T-18 F	"	18	26
"	" T-18 G	"	16	23

Type of sample	Scientific name	Collection site	ug Ca/gram Wet x 10^3	ug Ca/gram Dry x 10^3	Ash x 10^3
Terrestrial	Piston core Sed. T-20 G	351m. depth off Añasco	83	130	
"	" T-20 H	"	120	170	
"	" T-20 I	"	78	120	
"	" T-20 J	"	87	130	
"	" T-21 A	"	26	54	
"	" T-21 B	"	27	48	
"	" T-21 C	"	7.9	130	
"	" T-21 D	"	33	55	
"	" T-21 F	"	27	39	
"	Sea Bottom sed. T-3	"	190	260	270
"	" T-13	"	24	47	50
"	" T-12	"	12	18	19
"	" T-14	190m. depth Añasco R.	22	42	44
"	" T-9	St.2 8m. depth mouth Añasco	.75	1.3	1.4
"	" T-6	20m. depth Enriquez Pass	16	240	
"	" T-11	St.4 60m. depth mouth Añasco R.	11	23	24

Type of sample	Scientific name	Collection site	ug Ca / gram		
			Wet $\times 10^3$	Dry $\times 10^3$	Ash
Terrestrial	Sea bottom sed. T-7	20 m. depth Enriquez Pass	148	220	
"	" T-4	20 ft. depth Inside cat Is.	200	260	
"	" T-15	230 depth Añasco River	21	40	57
"	" T-22 A	358 m. depth off Añasco R.	150	250	
"	" T-22 B	"	140	230	
"	" T-22 C	"	110	180	
"	" T-22 D	"	110	190	
"	" T-22 E	"	200	330	
"	" T-22 F	"	200	350	
"	" T-22 G	"	120	210	
"	" T-22 I	"	130	230	
"	" T-22 J	"	130	250	
Water	Añasco River Water	Añasco		35 ug/ml	

Type of sample	Scientific name	Collection site	ug Cd / g Wet	Dry	Ash
Terrestrial	Piston core sed. T-18 G	64 m. depth off Añasco R.	3.4		5.0
"	" T-18 E	"	1.8		2.7
"	Sea bottom sed. T-12	65 m. off Añasco R.	5.8	8.7	9
"	" T-3	20 ft. depth Inside cat Is.	3.9	5.4	5.5
"	" T-15	230 m. depth Añasco R.	1.4	2.7	3.8
"	" T-14	190 m. depth Añasco R.	2.6	4.9	5.2
"	" T-5	20 m. depth Enriquez's Pass	3.6	5.6	5.8
"	" T-7	"	2.7		4
"	" T-10	St.3, 22m. depth mouth Añasco R.	1.7	3.6	4
"	" T-9	St.2, 8m. depth mouth Añasco R.	9.7	17	18
"	" T-6	20m. depth Enriquez Pass	5.1		7.8
"	" T-11	St. 60m. depth mouth Añasco R.	1.9	3.4	3.6
"	" T-17 H	Off Añasco R.	4.3	6.8	
"	" T-17 L	"	3.3	5.2	
"	" T-17 G	"	2.6	4.2	
"	" T-17 F	"	2.0	3.5	
"	" T-17 E	"	2.9	4.8	
"	" T-17 K	"	2.5	3.9	
"	" T-17 J	"	2.2	3.5	
"	" T-17 I	"	1.1	1.9	
"	" T-17 A	"	2.8	4.6	

Type of sample	Scientific name		Collection site	ug Cd / g		
				Wet	Dry	Ash
Fish	Cetengraulis edentulus		South of La Boquilla			
		F-5		0.24	0.72	3.1
"	"	F-7	"	0.22	0.82	2.9
"	"	F-3	"	0.21	0.91	2.8
"	"	F-2	"	0.50	2.2	6.8
"	"	F-4	"	0.28	2.0	3.6
"	"	F-6	"	0.29	0.96	3.9
"	"	F-52	"	0.38	0.85	2.7
"	"	F-36	"	0.34	1.2	4.3
"	"	F-41	"	0.29	1.1	3.1
"	"	F-38	"	0.23	0.89	3.1
"	"	F-1	"	0.21	0.80	3.5
"	"	F-19	"	0.25	0.88	3.1
"	"	F-12	"	0.38	1.5	4.5
"	"	F-34	"	0.29	1.1	3.4
"	"	F-29	"	0.54	1.8	6.5
"	"	F-48	"	0.55	2.2	6.1
"	"	F-31	"	0.25	1.0	3.0
"	"	F-30	"	0.52	2.0	6.4
"	"	F-18	"	0.25	1.0	3.0
"	"	F-16	"	0.52	1.4	4.3
"	"	F-8	"	0.29	1.1	3.1
"	"	F-45	"	0.25	0.9	3.4
"	"	F-44	"	0.39	1.4	4.4
"	"	F-11	"	0.36	1.4	5.2
"	"	F-13	"	0.23	1.5	4.2

Type of sample	Scientific name		Collection site	ug Cd / g		
				Wet	Dry	Ash
Fish	Cetengraulis edentulus	F-33	South of La Boquilla	0.24	0.98	3.1
"	"	F-17	"	0.28	1.0	3.1
"	"	F-39	"	0.33	1.3	3.5
"	"	F-9	"	0.37	0.90	3.0
"	"	F-28	"	0.15	0.59	1.8
"	"	F-49	"	0.34	1.1	4.1
"	"	F-35	"	0.20	0.74	2.5
"	"	F-32	"	0.24	0.91	2.6
"	"	F-43	"	0.28	1.2	4.1
"	"	F-25	"	0.27	1.1	3.5
"	"	F-51	"	0.43	0.95	3.7
"	"	F-20	"	0.36	1.4	4.1
"	"	F-22	"	0.29	0.98	4.1
"	"	F-46	"	0.40	1.4	4.8
"	"	F-24	"	0.62	2.5	6.7
"	"	F-6	"	0.69	2.5	9.4
"	"	F-15	"	0.75	2.6	7.0
"	"	F-5	"	0.43	1.7	5.3
"	"	F-27	"	0.41	1.6	5.3
"	"	F-10	"	0.37	1.4	4.7
"	"	F-40	"	0.47	1.3	4.1
"	"	F-14	"	0.40	1.4	4.1
"	"	F-4	"	0.43	1.6	4.1
"	"	F-3	"	0.47	1.2	4.0
"	"	F-2	"	0.41	1.6	4.4
"	"	F-7	"	0.29	1.1	5.4

Type of sample	Scientific name	Collection site	ug Cd / g Wet	Dry	Ash
Fish	Chloroscombrus crysurus F-0008	South of La Boquilla	0.17	0.83	3.1
"	" F-22	"	0.19	1.0	3.5
"	" F-11	"	0.15	0.83	2.7
"	" F-25	"	0.16	0.74	3.0
"	" F-8	"	0.12	0.68	1.7
"	" F-20	"	0.14	0.64	2.7
"	" F-7	"	0.16	0.92	2.8
"	" F-26	"	0.12	0.94	1.8
"	" F-19	"	0.23	0.95	4.1
"	" F-12	"	0.42	0.87	3.4
"	" F-15	"	0.22	1.0	4.2
"	" F-24	"	0.15	0.68	2.8
"	" F-4	"	0.10	0.48	1.8
"	" F-5	"	0.12	0.49	2.2
"	" F-10	"	0.14	0.58	2.9
"	" F-13	"	0.20	0.92	3.4
"	" F-14	"	0.06	0.54	2.2
"	" F-16	"	0.21	0.58	4.1
"	" F-17	"	0.19	0.87	3.4
"	" F-21	"	0.15	0.75	2.5
"	" F-27	"	0.20	0.92	4.1
"	" F-2	"	0.16	0.71	2.9
"	" F-1	"	0.21	0.97	2.7
Fish	Cetengraulis edentulus F-0006	"	0.50	2.0	6.5
"	" F-1	"	0.20	0.88	3.8

Type of sample	Scientific name	Collection site	ug Cd / g Wet	Dry	Ash
Fish	Harengula F-37	South of La Boquilla	0.23	0.78	3.2
"	" F-23	"	0.28	1.0	3.7
"	" F-50	"	0.31	0.98	2.9
"	" F-21	"	0.44	1.7	4.2
"	" F-26	"	0.33	1.1	3.6
"	" F-47	"	0.25	0.90	2.6
"	Opisthonema oglinum F-1	"	0.17	0.71	3.0
"	" F-4	"	0.15	0.62	2.5
"	" F-10	"	0.14	0.74	2.8
"	" F-7	"	0.10	0.39	1.8
"	" F-3	"	0.16	0.55	1.8
"	" F-9	"	0.16	0.66	3.2
"	" F-8	"	0.19	0.76	2.9
"	" F-6	"	0.15	0.60	2.8
"	" F-2	"	0.16	0.63	2.9
"	" F-5	"	0.12	0.52	2.4
"	Caranx (food) Latus F-8	"	0.21	0.87	3.2
"	" F-3	"	0.09	0.44	1.9
"	" F-11	"	0.12	0.55	2.1
"	" F-5	"	0.11	0.52	1.9
"	" F-6	"	0.17	0.99	3.3
"	" F-14	"	0.15	0.63	3.2
"	" F-9	"	0.29	1.3	5.9
"	" F-12	"	0.17	0.67	2.8

Type of sample	Scientific name	Collection site	ug Cd / g Wet	Dry	Ash
Fish	Caranx (food) latus F-2	South of La Boquilla	0.29	1.2	6.2
"	" F-7	"	0.19	0.87	4
"	" F-15	"	0.15	0.62	2.8
"	" F-16	"	0.33	1.3	4.1
"	" F-1	"	0.12	0.57	1.8
"	" F-13	"	0.16	0.72	3.1
Algae	Laurencia obtusa A-5	Cayo Enriquez	0.21	2.5	4.7
"	Halimeda opuntia A-4	"	1.6	3.6	3.9
"	A-0026 A-1	Cayo Turremote	0.22	2.7	7.2
"	Codium Taylorii A-7	Guanica	0.26	3.0	6.2
"	Hypnea musciformis A-15	"	0.27	0.68	6.4
"	Enteromorpha	Cayo Enriquez	0.10	2.4	5.7
"	Gracilaria mammilaris	Guanica	0.27	2.5	5.7
"	Thalassia	Belvedere	0.10	0.91	3.4
"	Acantophora spicifera	Cayo Enriquez	0.08	1.8	4.7
"	Valonia ventricosa A-3	"	0.22	4.1	5.9
"	Laurencia papillosa A-17	Guanica	0.17	1.2	5.7
"	Lyngbia mayuscula A-2	Cayo Turremote	0.15	2.1	4.3

Type of sample	Scientific name	Collection site	ug Cd / g Wet	Dry	Ash
Algae	Gracilaria caudata A-10	Guanica	0.15	1.4	2.9
"	Mixture of Acantophora spicifera & Spyridia filamentosa	Cayo Enriquez	0.39	3.9	8
"	Not Known	"	0.39	2.1	4.5
Terrestrial	Mango leaves	PRNC	0.14	0.27	3
"	Pueraria hirsuta	"	0.21	0.63	9.2
"	Mangrove leaves	Parguera	0.10	0.23	1.8
"	Sugar cane stems	Coconut area Rincon	0.052	0.13	5.4
"	Tamarindo leaves	PRNC	0.17	0.60	8
"	Chucho	Coconut area Rincon	0.04	0.49	2.8
"	Pajuil rojo	PRNC	0.42	0.61	5.8
"	Coconut hard shell & meat	Coconut area Rincon	0.065	0.16	3.8
"	Mangrove subt. roots	La Parguera	0.38	0.39	5.4
"	Sugar cane leaves	Coconut area Rincon	0.20	0.30	3.0
"	Almonds	"	0.044	0.069	4.8
"	Brazil rubber	PRNC	0.61	0.82	11.3
"	Mangrove aereal roots	La Parguera	0.018	0.075	3.5
"	Piston core sed. T-20 E	351 m. depth off Añasco R.	2.2		3.5
"	" T-19 L	31 m. deep off Añasco R.	2.2		3.5

Type of sample	Scientific name	Collection site	ug Cd / g Wet	Dry	Ash
Terrestrial	Piston core sed. T-17 B	Off Añasco River	1.1	1.9	
"	" T-17 C	"	1.4	2.4	
"	" T-17 D	"	1.6	2.8	
	Piston core sed. T-16 M	343 m. deep off Añasco R.	1.8	2.8	
"	" T-16 F	"	2.5	4.2	
"	" T-16 H	"	2.1	3.4	
"	" T-16 J	"	2.2	3.5	
"	" T-16 K	"	2.2	3.5	
"	" T-16 L	"	2.4	3.8	
"	" T-16 A	"	2.8	5.0	
"	" T-16 G	"	2.1	3.5	
"	" T-16 I	"	2.1	3.5	
"	" T-16 B	"	2.9	5.2	
"	" T-16 C	"	3.9	7.0	
"	" T-16 D	"	3.7	6.4	
"	" T-16 E	"	2.0	3.4	
"	" T-20 F	351 m depth off Añasco R.	2.2	2.9	
"	Sea bottom sed. T-4	20 ft. depth inside cat Is.	2.9	3.9	
Plankton	Mixture P-21	South of Vieques	0.74	5.8	14
"	" P-18	3 mi. south of Desecheo	0.96	8.4	21
"	" P-20	Sponge bank	0.26	4.0	7.0
"	" P-13	Añasco R. mouth	1.4	10	24

Type of sample	Scientific name	Collection site	ug Cd / g		
			Wet	Dry	Ash
Plankton	Mixture P-23	Fern Point south of Vieques	3.3	20	38
"	" P-22	"	1.8	24	56
"	" P-24	2 1/2 mile off Point Brea Parguera	0.083	3.3	23

Type of sample	Scientific name	Collection site	ug of Co/g		
			Wet	Dry	Ash
Fish	Makaira nigricans (gonads)	Virgin Gorda Island S. E. end	0.34	1.2	20
"	" (liver)	"	0.42	1.2	52
"	" (GI tract)	"	0.53	3.3	52
"	" (spleen)	"	1.4	5.2	35
"	" (gonads)	Arecibo	0.37	1.5	22
"	" (GI tract)	"	0.54	3.9	50
Invertebrate (sponge)	Damiriella	Negro Reef	2.2	13	24

Type of sample	Scientific name	Collection site	ug Co / g			ug Mn / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Detritus		Añasco Bay	17	34	41	15	29	35
"		"	87	31	58	83	30	55
"		"	11	31	48	163	460	700
Mollusc	Anadara sp.	"	34	44	48	28	36	39
"	Pitar sp.	"	56	58	58	37	38	38
"	"	"	22	55	59	17	43	46
Echinodermata	Luidia senegalensis	"	13	27	36	48	100	130
"	"	"	12	35	46	26	74	98

Type of sample	Scientific name	Collection site	ug Cr / g Wet	Dry	Ash
Plankton	Mixture	Mona Isl.	0.52	4.2	48
"	Lot of phytoplankton	5 min. west of Mayaguez	2.3	26	67
"	Mixture	78 mi. depth Añasco R. mouth	0.70	5.2	12
"	"	3 m. south of Desecheo Isl.	0.32	2.8	7
"	"	Sponge bank	1.2	18	32
"	"	South of Vieques	4.9	38	93
"	"	"	60	760	1,800
"	"	Fern point south of Vieques	33	200	380
"	"	2 1/2 ml. off Point Brea, Parguera	0.43	17	120
Invertebrate (sponge)	Ircinia fasciculata	Pta. Higuero			44
"	Purple sponge	"			750
Invertebrate (Gorgonium)		"			41
Invertebrate (sponge)	Haliclona	Negro Reef	6.9	15	37
"	Small grey sponge	"	6.4	28	57
"		Mona Isl.			50
Invertebrate (gorgonium)	Eunicea	Pta. Higuero			37
"	Pterogorgia	"			75
Algae	Dyctiopteris justii	"	4.9	35	78
"	Coralline	"			49
"	Padina				42

Type of sample	Scientific name	Collection site	ug Cr / g Wet	Dry	Ash
Algae	Sargassum				39
Fish	Thunnus albacore (skin & scales)	Ghana, Africa	7.5	27	75
Algae	Gracilaria	"	1.0	11	18
"	Bryothamnion triquetrum	"	0.80	5.0	9
"	Coddum taylorii	"	NOT DETECTED		
"	Galaxaura cylindrica	"	"	"	
"	Laurentia papillosa	"	"	"	
Invertebrates	Panulirus argus I-18	Joyuda beach	0.66	2.7	29
" (sponge)	Species 774	1/2 mi. off Pta. Higuero	0.48	2.3	9
Invertebrate jellyfish		3 mi. from Pta. Arenas Mayaguez	0.32	7.2	9
Invertebrate sponge	Species 744	1/2 mile off Pta. Higuero	1.5	8.8	18
"	Species 767	1/2 mile off Pta. Higuero	NOT DETECTED		
Invertebrate sponge	Species 727	"	1.3	7.7	15
"		Cayo Turremote	NOT DETECTED		
Invertebrate	White sea urchin	Cayo Turremote	11	11	13
" sponge	Species 732	1/2 mile off Pta. Higuero	7.6	12	16
Invertebrate	Brittle star	Cayo Turremote	6.2	12	14
"	Acanthopleura granulata Hard tissue 6 H	Bonus Nuclear Plant	11	16	19

Type of sample	Scientific name	Collection site	ug Cr / g		
			Wet	Dry	Ash
Invertebrate	Chiton Squamosus 18 H	Bonus Nuclear Plant	14	18	20
"	Panulirus argus 245	Joyuda beach	NOT DETECTED		
Fish	Harengula F-15	South of La Boquilla	0.96	3.4	9
Terrestrial	Piston core sed. T-22 G	358m. off Añasco River	17	31	
"	" T-22 H	"	17	31	
"	" T-22 A	"	17	27	
"	" T-22 B	"	12	20	
"	" T-22 C	"	19	32	
"	" T-22 D	"	21	36	
"	" T-22 E	"	21	36	
"	" T-22 F	"	18	31	
"	" T-22 I	"	16	27	
"	" T-22 J	"	14	27	
Invertebrate (sponge)	Species 728	1/2 mile of Pta. Higuero	0.49	2.2	9
"	" 772	"	NOT DETECTED		
"	" 767	"	NOT DETECTED		
"	" 736	"	8.4	13	16
Invertebrate (mollusc)	Acanthopleura granulata (hard tissue)	Bonus Nuclear Plant	9.1	12	14
"	"	"	10	14	16
Invertebrate	Brown sea urchin	Cayo Turremote	6.3	13	15
"	Panulirus argus	Joyuda beach	0.66	2.7	29

Type of sample	Scientific name	Collection site	ug Cr / g			ug Fe / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Tripneustes esculentus	Bonus Site	16	38	42	18	43	48
"	"	"	16	44	53	16	42	50
"	"	"	20	46	52	26	59	66
"	"	"				25	59	66
"	"	"	32	78	87	25	59	66
"	"	"				26	63	71
"	"	"	47	110	130	26	60	69
"	"	"	44	110	120	23	55	62
"	"	"	36	87	97	39	94	110
"	"	"	47	110	120	32	77	85
"	"	"				40	97	110
"	"	"	42	95	110	28	63	69
"	"	"	20	52	60	18	46	53
"	"	"	18	52	60	29	84	98
"	"	"				29	73	120
"	"	"	17	46	52	36	99	110
"	"	"	38	97	110	28	73	83
"	"	"	26	74	84	34	97	110
"	"	"	39	110	130	30	84	98
"	"	"	42	110	130	30	77	90
"	"	Parguera	41	100	120	17	44	52
"	"	"	35	84	95	19	46	52
"	"	"	34	86	100	18	45	52
"	"	"	24	64	72	25	65	74
"	"	"	28	73	95	22	58	76
"	"	"	44	110	130	26	67	76

Type of sample	Scientific name	Collection site	ug Fe/g			ug Cr/g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Tripneustes esculentus	Rincon	120	150	170	250	310	350
"	"	"	80	92	100	190	220	250
"	"	"	330	480	540	210	310	350
"	"	"	65	100	110	200	300	340
"	"	"	120	140	150	260	300	340
"	"	"	160	160	180	300	300	340
"	"	"	140	140	160	250	270	300
"	"	"	110	150	160	210	290	320
"	"	"	78	88	100	260	290	330
"	"	"	100	100	110	300	300	340
"	"	"	150	190	210	180	230	250
"	"	"	150	220	240	210	310	340
"	"	"	280	280	320	240	240	270
"	"	"	660	680	760	230	240	260
"	"	"	150	180	200	200	230	260
"	"	"	53	100	110			
"	"	"	24	47	500			
"	"	"	82	150	160			
"	"	"	71	133	140			
"	"	"	81	170	190			
"	"	"	60	100	110			
"	"	"	37	72	76			
"	"	"	31	59	63			
"	"	"	55	100	110			
"	"	"	43	88	93			
"	"	Parguera	52	100	110	160	310	340

Type of sample	Scientific name	Collection site	ug Fe/g			ug Cr/g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Tripneustes esculentus	Parguera	29	58	63	120	230	250
"	"	"	140	240	260	160	260	290
"	"	"	32	64	71	160	320	350
"	"	"	35	70	76	140	280	310
"	"	"	31	55	61	150	260	290
"	"	"	54	100	110	140	270	300
"	"	"	65	120	130	150	270	300
"	"	"	40	77	90	160	300	340
"	"	"	30	57	65	110	200	230
"	"	"	31	60	66	120	240	260
"	"	"	51	91	100	150	260	290
"	"	"	45	87	100	130	250	270
"	"	"	30	54	60	190	350	390
"	"	"	46	85	95	120	210	240
"	Echinometra lucunter	Parguera	120	160	180	35	49	54
"	"	"	62	80	90	23	30	35
"	"	"	40	59	65	24	36	39
"	"	"	48	75	84	29	45	50
"	"	"	80	110	120	35	47	52
"	"	"	49	81	87	28	46	50
"	"	"	110	170	190	21	33	37
"	"	"	74	130	140	19	33	37
"	"	"	40	64	71	31	49	54
"	"	"	45	72	78	21	34	37
"	"	"	37	57	63	22	34	37
"	"	"	38	64	70	28	47	52

Type of sample	Scientific name	Collection site	ug Fe/g			ug Cr/g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Echinometra lucunter	Parguera	95	140	160	28	42	46
"	"	"	49	78	87	22	35	39
"	"	"	44	72	77	19	31	33
"	"	"	170	180	200	28	29	33
"	"	"	81	110	120	28	38	42
"	"	"	120	190	210	29	47	52
"	"	"	110	110	120	40	41	46
"	"	"	100	100	110	40	41	46
"	"	"	39	57	63	38	55	61
"	"	"	46	64	71	37	50	56
"	"	"	430	470	520	83	91	100
"	"	"	94	110	120	30	35	39
"	"	"	57	58	65	32	33	37
"	"	"	190	200	220	40	41	46
"	"	"	21	36	40	15	25	29
"	"	"	64	69	77	24	25	29
"	"	"	180	180	200	28	29	33
"	"	"	33	56	63	26	45	50

Type of sample	Scientific name	Collection site	ug Cr /g			ug Fe / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Tripneustes esculentus	Parguera	33	91	110	17	46	54
"	"	"	27	77	95	18	50	62
"	"	"	45	110	120	26	61	70
"	Echinometra lucunter	Pta. Higuero	36	40	46			
"	Eucidaris tribuloides	"	24	30	32	110	130	140

Type of sample	Scientific name	Collection site	ug Cr / gm Wet	Dry	Ash
Invertebrate coelenterate	Eunicea	Pta. Higuero	29	58	80
Invertebrate sponge	Ircinia fasciculata	Pta. Higuero	7.3	33	44
"	Small grey sponge	Negro Reef	6.2	27	56
Invertebrate coelenterata	Pterogorgia		22	47	75
"	Plexaurella	Pta.Higuero	23	42	50
Invertebrate sponge	Haliclona	Negro Reef	14	30	75
Fish	Thunnus albacores skin & scales		7.5	27	75
Terrestrial	Plant ash		1.3	3.3	39

Type of sample	Scientific name	Collection site	ug Mn / gm Wet	Dry	Ash
Fish	Makaira nigricans liver	Virgin Gorda Island	0.33	0.89	40
"	" Spleen	"	0.62	2.2	15
"	" GI Tract	"	0.27	1.6	26
"	" Gonads	"	0.18	0.65	11
"	Makaira nigricans gonads	Arecibo	0.24	0.94	14
"	"	"	0.15	1.1	14
"	Ablennes hians muscle	Culebrinas Bay	0.60	2.6	360
"	" Gills	"	26.	110	360
"	Caranx lugubris muscle	Grappler's Bank	0.50	2.8	310
Invertebrate	Acanthopleura granulata H-6	Bonus Nuclear Plant	7.2	12	120
Invertebrate coelenterate	Medusa I-48	Parguera	3.0	10	93

Type of sample	Scientific name	Collection site	ug Cr / g			ug Ni / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Alga	Padina	Pta. Higuero	8.5	27	43			
"	Padina gymnospora	"	3.8	21	59			
"	Penicillus	"	6.1	30	43			
"	Dictyosphaeria favulosa	"	5.1	35	48			
"	Cymopolia	"	11	41	54			
"	Dictyopteris justii	"	8.5	33	54			
"	Dictyophaeria	"	10	39	44	10	37	41
"	Amphiroa	"	29	34	39			
"	Codium	"	440	700	1100	20	32	57
"	Penicillus	"	12	27	33	18	40	49
"	Cymopolia	"	12	34	44	9.1	27	34
"	Caulerpa	"	17	28	41	26	43	63
"	Dictyota dentata	"	17	53	98	38	120	220
"	Bryothamnion	"	110	180	230	45	72	92
"	Amphiroa	"	33	35	42	34	36	43
Miscelaneous sediment & alga		"	42	58	65	62	85	96
Alga	Penicillus	"	19	35	46	10	19	25
Marine angiosperm	Thalassia	"	12	65	85	7	37	49
Alga	Sargassum	"				5	25	42
"	Dictyota dentata	"				4	24	40
"	Amphiroa	"				16	33	41
"	Dictyopteris justii		3	18	33			

Type of sample	Scientific name	Collection site	ug Cr / g			ug Ni / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Marine angiosperm	Thalassia testidunum	Pta. Higuero				4.7	21	46
Alga	Sargassum lendigenum	"	3.4	18	48	4.0	21	56
"	Sargassum sp.	"	4.0	18	54	3.7	16	49
"	Bryothamnion triquetrum	"	4.7	22	41	4.8	22	42
"	Penicillus	"	7.2	31	44	9.0	39	55
"	Dictyopteris	Rincon	1.8	16	30	3.9	35	66
"	Amphiroa fragilissima	"	13	32	40	12	31	38
"	Padina	"	.93	9.0	35	2	19	15
"	Dictyota	"	.49	6.9	35	.97	14	69
Alga	Padina	Bonus Site				5.1	37	64
"	"	"				5.6	33	79
"	"	"				7.0	33	57
"	"	"				5.7	37	71
"	"	"				4.2	30	57
Marine angiosperm	Thalassia testudinum	Parguera				2.3	15	84
"	"	"				2.8	21	79
"	"	"				7.2	38	100
"	"	"				4.5	32	96
"	"	"				6.4	35	97
"	"	"				4.2	33	100
"	"	"				6.0	39	100

Type of sample	Scientific name	Collection site	ug Cr/gm Wet	Dry	Ash
Alga	Coralline amphiroa & sed.	Pta. Higuero	19	54	60
"	Halimeda opunctia A-0056-A-31	Magueyes	23	60	66
"	Sargassum A-0054	Guanica	5.2	27	57
"	Padina	Guanica	8.5	42	67
"	Dyctiota	Bonus	4.3	28	88
"	Sargassum	"	3.4	30	73
"	Mixed cora-lline alga	Pta. Higuero	11	40	48
"	Padina	Bonus	2.4	20	41
"	Dyctiopteris Justii	Pta. Higuero	4.9	35	78
"	Sargassum	Pta. Higuero	1.8	16	39
Invertebra-te sponge	Grey sponge	"	3.7	20	60
"	Ircinia strobilina	Negro Reef	11	41	57
"	Species #2 I-0051	Desecheo	4.0	15	69
"	I-00050	Desecheo	6.1	38	75
"		Mona	11	49	73

Type of sample	Scientific name	Collection site	ug Ni/gm Wet	Dry	Ash
Fish	Makaira nigricans gonads	Arecibo	0.36	2.7	34
"	" gonads	Arecibo	0.34	1.4	20
"	" Spleen	Virgin gorda Is.	1.2	4.5	30
"	" GI Tract	"	0.39	2.4	38
"	" Liver	"	0.21	0.58	26
"	" Gonads	"	0.32	1.1	19
Invertebrate	Damiriella	Negro Reef	5.1	31	56

Type of sample	Scientific name	Collection site	ug Ni/g Wet	ug Ni/g Dry	ug Ni/g Ash	ug Cr/g Wet	ug Cr/g Dry	ug Cr/g Ash
Echinoderm	Tripneustes esculentus	Pta. Higuero	16	36	41	19	42	47
"	"	"	8.6	34	38	15	31	35
"	"	"	17	36	42	14	30	35
"	"	"	20	41	45	22	45	49
"	"	"	14	28	31	19	38	42
"	"	"	12	24	27	14	29	31
"	"	"	14	28	31	21	42	50
"	"	"	29	49	54	24	42	50
"	"	"	21	36	40	20	35	41
"	"	"	24	42	47	25	44	50
"	"	"	17	33	37	17	34	73
"	"	"	16	34	37	19	40	48
"	"	"	15	31	35	22	47	52
"	"	"	17	29	33	26	47	50
"	"	"	20	37	42	17	31	35
"	"	"	16	27	30	23	39	50
"	"	"	22	36	40	13	23	25
"	"	"	15	32	35	19	39	43
"	"	"	20	37	42			
"	"	"	23	38	42			
"	"	"	24	38	42			
"	"	"	21	33	37	26	41	46
"	"	"	21	37	42			
"	"	"	23	38	42			
"	"	"	18	31	35	23	41	46

Type of sample	Scientific name	Collection site	ug Cr/g			ug Ni/g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Echinometra lucunter	Salt Key	26	44	49	18	30	33
"	"	"	26	45	50	16	27	30
"	"	"				19	30	32
"	"	"				16	29	32
"	"	"				16	29	31
"	"	"	24	47	51	15	29	32
"	"	"				14	24	26
"	"	"				18	27	29
"	"	"	37	59	65	33	52	57
"	"	"				18	29	32
"	"	"	28	45	50	18	30	33
"	"	"				17	26	28
"	"	"	26	41	45	17	26	29
"	"	"	29	46	49	17	27	29
"	"	Desecheo	28	45	49	17	27	30
"	"	"				21	34	37
"	"	"				15	26	28
"	"	"	25	44	49	18	31	34
"	"	"				18	29	32
"	"	"	29	46	50	20	31	34
"	"	"	26	43	46	17	29	31

Type of sample	Scientific name	Collection site	ug Ni / g			ug Cr / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Coelenterate	Eunicea laciniata	Pta. Higuero	20	34	66			
"	"	"	39	73	89	40	75	92
"	Pseudptero-sorgia americana	"	30	65	92	25	55	78
"	"	"	9.2	25	38			
"	Euhicea calyculata	"	22	41	48	19	35	41
"	Eunicea mammosa	"	27	60	81	22	49	67
"	"	"	13	27	37			
"	"	"	13	27	38			
"	"	"	13	25	33			
"	"	"	13	25	34			
"	Plexaurella sp.	"	14	29	34			
	Muricea atlantica	"	14	26	33	32	60	78
"	"	"	13	25	33			
"	Eunicea asperula	"	26	45	57	26	46	57
"	Eunicea tourneforti	"	16	28	34			
"	"	"	19	33	37	29	49	56
Optriuroid		Pta Higuero	24	56	66	25	57	67
"		"	50	110	140	46	110	130
"		"	14	32	41	26	60	76
"		"	14	31	37	29	65	78
"		"	13	27	34	30	64	78
"		"	15	35	42			

Type of sample	Scientific name	Collection site	ug Ni / g			ug Cr / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Ophiuroid								
		Pta. Higuero	12	27	33			
"	"	"	12	28	34			
"		"	14	30	37	15	33	41
Ophiuroid		"	10	28	33			
"		"	16	30	37	22	41	50
"		"	12	30	36			
"		"	12	27	33			
"		"	13	28	33			
"		"	11	31	38	13	34	43
"		"	12	27	33			

Type of sample	Scientific name	Collection site	ug Fe / g Wet	Dry	Ash
Terrestrial Plants	Jaboncillo	PRNC	72	150	1,200
"	Pueraria hirsuta	"	36	110	1,600
Plankton	12-S	S. of Vieques	67	860	21,000
"	Mixture	Sponge bank	72	1,100	1,900
"	"	3 mi. south of Desecheo Isl.	8	74	180
Invertebrate (sponge)	Damiriella	Negro Reef	12	740	1,300
"	Species 727	1/2 mile of Pta. Higuero	130	790	1,500
"	" 744	"	330	1,900	3,900
"	" 774	"	57	270	1,100
"	" 765	"	8	31	200
"	" 747	"	710	2,900	4,400
"	" 728	"	170	750	3,100
"	" 748	"	270	1,200	3,300
"	" 766	"	NOT DETECTED		
"	" 731	"	59	120	240
"	" 772	"	48	180	500
"	" 768	"	6	26	170
"	" 791	"	41	230	720
"	" 750	"	490	1,700	3,400
"	" 767	"	22	100	290
"	" 736	"	32	51	60
"	" 745	"	150	790	2,300
"	" 769	"	71	260	890
"	" 732	"	110	180	240

Type of sample	Scientific name	Collection site	ug Fe / g Wet	Dry	Ash
Invertebrate (sponge)	Species 738	1/2 mile of Pta. Higuero	83	160	250
"	" 749	"	3.6	17	24
"	" 754	"	140	570	800
"	" 792	"	33	90	204
"	" 740	"	88	140	200
"		Parguera	100	580	1,500
"		Cayo Turremote	27	250	480
"	Black sponge	Desecheo	130	820	1,600
"	Orange sponge	"	12	48	220
Invertebrate	Nudibranch	Cayo Turremote	15	88	460
Invertebrate (mollusc)	Chiton squamosus (hard tissue)	Bonus Nuclear Plant	27	35	39
"	"	"	38	47	52
"	Acanthopleura granulata (hard tissue)	"	48	64	72
"	"	"	33	45	52
Invertebrate	Acanthopleura granulata	"	28	38	46
"	"	"	33	44	51
"	Panulirus argus (gills)	Joyuda beach	1.7	13	13
"	Panulirus argus	"	27	50	99
"	Panulirus argus (abdominal muscle)	"	130	540	4,200
"	Panulirus argus	"	4	16	130
"	"	"	3.4	15	79
"	Brittle star	Cayo Turremote	23	44	53

Type of sample	Scientific name	Collection site	ug Fe / g Wet	Dry	Ash
Invertebrate	Brown sea urchin	Joyuda beach	35	75	84
"	White sea urchin	"	59	61	72
"	Crab	"	81	230	410
"	Medusa	3 miles from Pta. Arenas	1.2	27	34
Algae	Codium taylorii	Guanica	7.3	94	140
"	Gracilaria	"	7.7	80	140
"	Hypnea musciformis	"	26	300	410
"	Spatoglossum schroederi	"	84	710	1,500
"	Penicillus capitatus	"	190	750	1,000
"	Ulva lactuca	"	24	210	400
"	Not Known	Cayo Enriquez	280	1,500	3,200
"	Bryothamnion triquetrum	Guanica	57	360	640
"	Galaxaura cylindrica	"	61	250	310
"	Laurencia papillosa	"	22	170	300
"	Laurencia obtusa	Cayo Enriquez	13	150	290
"	Valonia ventricosa	"	99	1,900	2,700
"	Halimeda opuntia	"	96	220	240
"	Laurentia papillosa	Guanica	34	240	1,200
"	Hypnea musciformis	"	80	200	1,900

Type of sample	Scientific name	Collection site	ug of Fe/g		
			Wet	Dry	Ash
Algae	Codium taylorii	Cayo Henriquez	16	32	200
"	Gracilaria mammillaris	"	36	340	760
Plankton	20-S	2 1/2 mile off Point Brea	9.6	390	2,700
"	6-S	Fern point S. of Vieques	1,300	8,100	15,000
Terrestrial plants	Mangrove subt. roots	Parguera	23	24	330
Fish	Makaira nigricans (gonads)	Virgin Gorda Isl. S. E. end	16	51	880
"	"(liver)	"	20	56	2,500
"	"(G.I. tract)	"	14	87	1,400
"	" (spleen)	"	350	1,200	8,500
"	" (gonads	Arecibo	25	100	1,500
"	" (GI tract)	"	13	170	1,600
"	Harengula F-34	S. of La Boquilla	100	400	1,200
"	" F-44	"	370	1,300	4,100
"	" F-38	"	93	130	1,300
"	" F-15	"	700	2,500	6,600
"	Opisthonema oglinum F-3	"	420	1,500	5,000
"	Harengula F-36	"	190	680	2,400
"	" F-39	"	330	1,300	3,500
"	" F-41	"	240	940	2,600
"	" F-12	"	260	1,000	3,000

Type of sample	Scientific name	Collection site	ug Fe / g		
			Wet	Dry	Ash
Plankton		South of Vieques	200	1,600	3,900
Fish	Caranx latus	S. of La Boquilla	270	1,100	4,200
"	" F-13	"	30	130	580
"	" F-5	"	120	600	2,200
"	" F-7	"	100	470	2,100
"	" F-14	"	110	470	2,400
"	" F-9	"	140	640	2,900
"	" F-6	"	310	1,800	6,000
"	" F-1	"	150	690	2,200
"	" F-12	"	62	240	1,000
"	" F-15	"	55	230	1,000
"	" F-11	"	34	160	600
"	" F-2	"	300	1,300	6,600
"	" F-3	"	140	680	3,000
"	" F-37	"	110	380	1,500
"	" F-49	"	670	2,200	8,200
"	" F-48	"	430	1,700	4,800
"	" F-32	"	370	1,400	4,000
"	" F-11	"	160	620	2,200
"	" F-8	"	310	1,200	3,400
"	" F-33	"	180	730	2,300
"	" F-14	"	430	1,500	4,400
"	" F-22	"	66	220	930
"	" F-1	"	95	360	1,600
"	" F-7	"	57	220	1,000
"	" F-25	"	300	1,200	3,900

Type of sample	Scientific name	Collection site	ug Fe / g Wet	Dry	Ash
Fish	Caranx F-27	S. of La Boquilla	200	800	2,600
"	Chloroscombrus chrysurus	S. of La Boquilla	120	670	2,300
"	" F-21	"	280	1,400	4,700
"	" F-17	"	68	320	1,200
"	" F-19	"	25	107	460
"	" F-14	"	35	330	1,300
"	" F-20	"	110	505	2,100
"	" F-16	"	76	210	1,500
"	" F-15	"	88	430	1,700
"	" F-13	"	160	730	2,700
"	" F-4	"	140	640	2,400
"	" F-7	"	94	560	1,700
"	" F-5	"	170	700	3,100
"	" F-8	"	90	500	1,300
"	" F-10	"	67	270	1,400
"	" F-12	"	230	480	1,900
"	" F-9	"	72	340	1,300
"	" F-11	"	82	470	1,500
"	" F-27	"	32	150	660
"	" F-26	"	70	560	1,100
"	" F-25	"	100	460	1,900
"	" F-24	"	140	607	2,500
"	Caranx latus F-16	"	120	480	1,500
"	Harengula (F-31)	"	230	920	2,800
"	" F-29	"	150	520	1,900

Type of sample	Scientific name	Collection site	ug Fe / g		
			Wet	Dry	Ash
Fish	Harengula F-30	S. of La Boquilla	250	920	3,000
"	" F-52	"	240	540	1,700
"	" F-19	"	180	630	2,200
"	" F-10	"	190	700	2,300
"	" F-20	"	170	660	2,000
"	" F-40	"	100	280	900
"	" F-21	"	430	1,700	4,100
"	" F-28	"	50	190	590
"	" F-9	"	300	730	2,400
"	" F45	"	88	320	1,200
"	" F-47	"	480	1,700	4,900
"	" F-26	"	210	730	2,400
"	" F-17	"	230	1,100	3,400
"	" F-46	"	190	670	230
"	" F-5	"	94	380	1,200
"	" F-18	"	140	590	1,700
"	" F-3	"	390	990	3,400
"	" F-51	"	250	550	2,100
"	" F-16	"	160	430	1,300
"	" F-4	"	220	820	2,100
"	" F-43	"	120	530	1,800
"	" F-13	"	72	470	1,300
"	" F-23	"	94	340	1,200
"	" F-35	"	50	180	620
"	" F-6	"	370	1,500	5,000
"	" F-2	"	500	1,900	5,400

Type of sample	Scientific name	Collection site	ug Fe / g		
			Wet	Dry	Ash
Fish	Harengula F-24	S. of La Boquilla	340	1,400	3,700
"	" F-50	"	120	380	1,100
"	Cetengraulis edentulus F-1	"	34	150	650
"	" F-6	"	260	880	3,600
"	" F-7	"	500	1,800	6,500
"	" F-2	"	700	3,100	9,900
"	" F-3	"	520	2,300	7,000
"	" F-4	"	340	2,500	4,400
"	" F-8	"	470	1,800	6,000
"	" F-5	"	590	1,800	7,500
"	Opisthonema oglinum F-1	South of La Boquilla	270	1,100	4,700
"	" F-2	"	160	630	2,900
"	" F-6	"	180	700	3,300
"	" F-9	"	28	120	560
"	" F-10	"	400	2,100	8,200
"	" F-7	"	260	1,000	4,000
"	" F-4	"	260	1,100	4,400
"	" F-5	"	110	470	2,100
"	" F-8	"	410	1,600	6,200
"	Chloroscombrus chrysurus F-2	"	150	670	2,700
"	" F-1	"	59	270	760
Terrestrial Plants	Sugar Cane stems	Coconut area Rincon	4	10	400

Type of sample	Scientific name	Collection site	ug Fe / g		
			Wet	Dry	Ash
Terrestrial Plants	Mangrove leaves	La Parguera	12	29	220
"	Mango leaves	PRNC	63	120	1,400
"	Tamarindo leaves	"	50	170	2,300
"	Coconut hard shell & meat	Coconut area Rincon	20	48	1,100
"	Mangrove aereal roots	Parguera	2	9	400
"	Pajuil Rojo	PRNC	84	120	1,200
"	Chucho	Coconut area Rincon	14	150	860
"	Brazil rubber	PRNC	55	74	1,000
"	Almonds	Coconut area Rincon	2	4	250
"	Sugar cane leaves	"	57	85	840
Algae	Enteromorpha	Cayo Enriquez	9	220	510
"	Acanthophora spicifera	"	50	1,100	3,000
"	Mixture of Acanthophora spicifera & Spyridia filamentosa	"	200	1,900	3,900
"	Gracilaria caudata	Guanica	8	76	160
"	Codium taylorii	"	11	130	270
"	Thalassia	Hacienda Belvedere	29	260	480
"	Spyridia filamentosa	Cayo Enriquez	71	760	1,600
"	Nor identified	"	180	960	2,100

Type of sample	Scientific name	Collection site	ug Fe/g Wet	Dry	Ash
Echinoderm	Echinometra lucunter	Salt Key	34	59	64
"	"	"	32	55	60
"	"	"	38	59	65
"	"	"	61	110	120
"	"	"	42	72	78
"	"	"	43	77	84
"	"	"	36		68
"	"	"	77	120	130
"	"	"	78	130	140
"	"	"	89	140	150
"	"	"	82	130	150
"	"	"	74	120	130
"	"	"	73	120	130
"	"	"	88	140	150
"	"	Desecheo	69	110	120
"	"	"	90	140	160
"	"	"	70	130	140
"	"	"	91	150	160
"	"	"	68	120	130
"	"	"	84	130	140
"	"	"	87	140	160
"	"	"	71	120	130
"	"	"	91	150	160
"	"	"	84	130	140
"	"	"	85	140	160
"	"	"	83	130	140

Type of sample	Scientific name	Collection site	ug Fe / g		
			Wet	Dry	Ash
Echinoderm	Echinometra lucunter	Desecheo	70	110	130
"	"	"	88	140	160
"	"	"	82	130	140
"	"	"	80	130	140

Type of sample	Scientific name	Collection site	µg Fe/gm			µg Mn/gm			µg Ni/gm			µg Cr/gm		
			Wet	Dry	Ash	Wet	Dry	Ash	Wet	Dry	Ash	Wet	Dry	Ash
Mollusc soft body	Tectarius muricatus	Bonus	11	180	300	.14	34	58	11	29	49	9.1	23	39
"	"	"	11	37	110	30	100	300	6.2	21	61	3.0	10	30
"	"	"	47	170	510				10	37	110	5.9	21	64
"	"	"	78	260	620	13	43	100	27	92	220	12	42	100
"	"	"				21	72	170	5.4	19	45	5.7	13	51
"	"	"	61	200	500	20	65	150	12	42	97			
(shell)	"	"				28	30	31				30	36	37
"	"	"				122	130	130				190	210	211
"	"	"	67	72	74	20	21	22	54	58	60	60	65	67
"	"	"	33	36	37	16	17	18	27	29	30	36	39	40
"	"	"	33	35	36	23	25	25	27	28	29	45	48	49
"	"	"	62	67	68	19	21	21	28	30	31	45	48	49

Type of sample	Scientific name	Collection site	K (ug K/gram) Wet	Dry x 10^3	Ash x 10^4
Inverte-brate sponge	Orange sponge I-50 A	Desecheo Island	1500	5.5	250
"	Black sponge I-49	"	3800	23	460
"	Orange sponge I-2	Desecheo	1700	6.7	300
"	Gray sponge	Pta. Higuero	2200	12	360
"	Ircinia fas-ciculata	Pta. Higuero	830	3.8	50

Type of sample	Scientific name	Collection site	K (ug K/gram) Wet	Dry x 10^3	Ash x 10^3
Inverte-brate sponge	Species 748 I-31	1/2 mile of Pta. Higuero	2200	11	28
"	Species 772 I-33	"	1300	4.8	14
"	Species 765 I-35	"	720	2.8	18
"	Sponge I-0001	Parguera	680	3.9	10
"	Species 791 I-36	1/2 mile of Pta. Higuero	990	5.6	18
"	Species 769 I-43	"	3300	12	41
Alga	Padina	Bonus	2500	17	32
"	"	"	1400	82	20
"	"	"	3200	23	40
"	"	"	1500	11	21
"	"	"	2500	12	20
"	"	"	3600	23	45
"	"	"	2900	17	41
Marine angiosperm	Thalassia testudinum	Parguera	670	5.3	20
"	"	"	1400	10	31

Type of sample	Scientific name	Collection site	(ug K/gram) Wet	Dry $\times 10^3$	Ash $\times 10^3$	Type of sample	Scientific name	Collection site	(ug K/gram) Wet	Dry $\times 10^3$	Ash $\times 10^3$
Mollusk soft body	Strombus pugilis	Off Culebrinas R.	3100	12	57	Mollusk (shell)	Strombus pugilis	Off Culebrinas R.	570	.59	.60
" (shell)	"	"	320	.32	.33	"	"	Villa Cofresi	310	.32	.33
"	"	"	310	.32	.33	"	"	"	210	.22	.22
"	"	Cofresi Villa	250	.26	.26	" soft body	Strombus costatus	Cofresi	2100	7.9	51
" soft body	"	"	2500	9.0	32	Shell	Strombus costatus	"	250	.26	.26

Type of sample	Scientific name	Collection site	K (ug K/gram) Wet	Dry x 10^3	Ash x 10^3
Marine angiosperm	Thalassia testudinum	Parguera	870	6.8	21
"	"	"	1200	8.1	21
"	"	"	1200	7.4	21
"	"	"	1500	7.9	21
"	"	"	2000	11	30
"	"	"	810	5.3	30
"	"	"	800	6.0	23
Crustacea	Pagurestes sericeus	Off Culebrinas River		6.0	1.2
Sponge w/spicules	Ircinia Strobilina	Negro Reef	740	4.0	5.3
"	"	Parguera	1800	11	25
"	Brittle cup sponge	Off Culebrinas R.	1300	5.6	10
Sponge	"	"	2900	13	24
"	"	Off Añasco River	1900	7.8	12
"	"	"	2100	7.2	10

Type of sample	Scientific name	Collection site	K (ug K/gram) Wet	Dry	Ash x 10^3
Crustacea	Pagunstes sericeus	Villa Cofresi			19
"	"	"	2900	8900	27
"	"	"	2700	7700	17
Coelenterate	Meandrina	Off Añasco R.	380	380	.39
"	Meandrina meandrites	"	290	320	.33
"	"	"	380	390	.40
"	"	Off Culebrinas R.	340	340	.38
"	Eusmilia fastigiata	"	250	250	.26
"	"	Off Añasco R.	360	380	.39
Echinoderm	Oreaster reticulatus	Off Guanajibo Pt.	440	1100	1.5
"	"	Parguera	520	850	1.8
"	"	Negro Reef	610	1500	1.9
Sponge	Ircinia strobilina	"	460	2500	3.3
Sponge w/spicules	Pliable cup sponge	Off Añasco River	1800	7200	23

Type of sample	Scientific name	Collection site	K (ug K/gram) Wet	Dry x 10^3	Ash x 10^4
Invertebrate sponge	Species 749 I-28	1/2 mile of Pta. Higuero	1100	5.1	70
"	Species 732 I-41	"	2600	4.3	56
"	Species 792 I-37	"	2500	6.6	150
Invertebrate mollusc	Nudibranch aplysia (I-00012 I-4A	Cayo Turremote Parguera	260	2.5	83
Invertebrate mollusc	Acanthopleura granulata H-6	Bonus Nuclear Plant	540	.75	9
Invertebrate sponge	Black sponge I-49 A	Desecheo Island	7400	54	900
Invertebrate ceelenterate	Medusa I-10	3 miles from Pta. Arenas	470	11	140
Invertebrate sponge	Species 766 I-45	1/2 mile of Pta. Higuero	2200	9.8	280
"	Species 773 I-47	"	770	4.6	110

Type of sample	Scientific name	Collection site	K (ug K/gram) Wet	Dry x 10^3	Ash x 10^3
Invertebrate sponge	Porifera I-00002	Parguera	560	7.9	14
Invertebrates coelenterate	Coelenterata I-00005	Belvedere	42	.17	11
"	Panulirus argus(gonad) I-19 I-00023	Joyuda beach	2600	7.4	38
Invertebrate sponge	Species 750 I-30	1/2 mile of Pta. Higuero	2400	8.6	17
Invertebrate coelenterate	Panulirus argus muscle 24 S	Joyuda beach	3300	15	78
Invertebrate sponge	Species 766 I-45	1/2 mile of Pta Higuero	1800	7.9	23
"	Species 738 I-40	"	5500	10	17
"	Species 774 I-42	1/2 mile of Pta. Higuero	2000	9.6	38
Invertebrate coelenterate	Panulirus argus I-22 gills	Joyuda beach	1000	7.8	80

Type of sample	Scientific name	Collection site	K (ug K/gram) Wet	Dry x 10^3	Ash x 10^3
Sponge	Pliable cup sponge	Off Culebrinas River	1900	9.1	36
"	Ircinia strobilina	Parguera	3600	21	50
Crustacea	Petrochirus diogenes	Guanajibo Pt.	2600	6.8	16
Echinoderm	Tripneustes esculentus	Rincon	130	.28	.31
"	"	"	170	.32	.34
"	"	"	290	.30	.31
Alga	Chondria littoralis	Bonus	9900	.86	160
"	Sargassum	"	9700	.59	.17
Echinoderm	Echinometra lucunter	Parguera	.77	1.1	1.2
"	"	"	.75	1.2	1.3
"	"	"	.62	1.0	1.1
"	"	"	1.1	1.5	1.7
"	"	"	1.4	1.4	1.6
"	"	Rincon	860	1.4	1.6
"	"	"	840	1.4	1.6
"	"	"	1400	1.4	1.6

Type of sample	Scientific name	Collection site	K (ug K/gram) Wet	Dry x 10^3	Ash x 10^3
Sponge w/spicules	Pliable cup sponge	Off Añasco River	1700	7400	23
"	Brittle cup sponge	"	1500	5000	7.2
Echinoderm	Echinometra lucunter	Parguera	.80	1.0	1.1
"	"	"	.79	1.3	1.4
"	"	"	.61	1.0	1.1
"	"	"	.84	1.3	1.5
"	"	"	.75	1.1	1.2
"	"	"	.79	1.0	1.1
"	"	"	.60	.90	1.0
"	"	"	.57	1.0	1.1
"	"	Rincon	1.3	1.4	1.6
"	"	"	1.8	1.8	2.1
"	"	"	1.3	1.3	1.4
"	"	"	1100	1.6	1.8
"	"	"	1200	1.3	1.5
Mollusc soft body	Strombus pugilis	Off Culebrinas R.	3100	12	57

Type of sample	Scientific name	Collection site	K (ug of K/gram) Wet	Dry x 10^3	Ash x 10^4	Type of sample	Scientific name	Collection site	K (ug of K/gram) Wet	Dry x 10^3	Ash x 10^4
Terrestrial plants	Species-man grove aereal roots (TP-14	Parguera	510	2.1	10	Inverte-brate sponge	Species 769 (I-43)	1/2 mile of Pta. Higuero	3300	12	4.1
"	Species-tamarindo leaves (TP-16)	PRNC Mayaguez	1700	5.8	.77	Inverte-brate Echinoder-mata	Tripneustes esculentus (White sea urchin I-00019 I-12	Cayo Turremote La Parguera	3400	3.5	.40
"	Species-almonds (TP-4)	Coconut area Rincon	2600	4.0	2.8	Inverte-brate crustacea	Cirripedia I-00017 21 S	Cayo Turremote Parguera	22	.17	.061
"	Species Chucho (TP-12)	Coconut area Rincon	4800	52	30	Inverte-brate mollusca	Acanthopleu-ra granulata I-00006 H-6	Bonus Nuclear Plant	540	.75	.09
"	Species-cascara y cachipa de coco(TP-18)	Coconut area Rincon	4800	12	28	Inverte-brate sponge	I-26 Species 747	1/2 mile of Pta. Higuero	1300	5.1	.77
"	Pueraria hirsuta Kudzu (TP-3)	PRNC Mayaguez	4200	1.3	18	Inverte-brate Echinoder-mata	Tripneustes esculentus white sea urchin I-00019 I-11	Cayo Turremote Parguera	5300	5.5	.65
"	Mangrove leaves (TP-17)	Parguera	2100	5.1	3.9	Inverte-brate mollusc	Acanthopleu-ra granulata I-00006 H-7	Bonus Nuclear Plant	480	.65	.075
"	Sugar cane stems (+-8)	Coconut area Rincon	3300	8.3	34	Inverte-brate Porifera	I-00014 I-7 Sponge	Cayo Turremote Parguera	210	2.0	.38

Type of sample	Scientific name	Collection site	mg K / g Wet	mg K / g Dry	mg K / g Ash	Type of sample	Scientific name	Collection site	mg K / g Wet	mg K / g Dry	mg K / g Ash
Terrestrial	Piston core sed. T-16 G	343 m. deep off Añasco	1.2	2.0		Terrestrial	Piston core sed. T-16 K	343 m. deep off Añasco	2.2	3.6	
"	Pajuil rojo TP-9	PRNC Mayaguez	9.8	14	140	"	" T-16 J	"	2.8	4.4	
"	Subt. Mangrove roots TP-13	Parguera	6.5	6.6	92	"	" T-16 H	"	1.5	2.4	
"	Sea bottom sed. T 4	Inside Cat Isl. 20 ft depth	.35	.46		"	" T-16 L	"	1.7	2.7	
"	Piston core sed. T-22 C	358 m off Añasco R.	1.2	2.1		"	" T-16 E	"	1.8	3.1	
"	Sea bottom sed. T-6	20 m. depth Enriques P.	.45	.70		"	" T-16 D	"	1.9	3.3	
"	" T-7	"	.18	.27		"	" T-16 C	"	1.6	2.9	
"	" T-12	65 m off Añasco R.	1.5	2.2	2.3	"	" T-16 B	"	1.8	3.3	
"	" T-14	190 m depth Añasco R.	1.5	2.9	3.1	"	" T-16 A	"	2.6	4.7	
"	" T-5	20 m. depth Enriques P.	.67	1.0	1.1	"	" T-16 F	"	2.6	4.2	
"	" T-15	230 m depth Añasco R.	1.2	2.4	3.4	"	" T-17 B	Off Añasco	1.2	2.1	
"	" T-3	20 ft. depth Inside Cat.I.	.25	.35	.36	"	" T-17 C	"	.95	1.6	

Type of sample	Scientific name	Collection site	mg K / g Wet	Dry	Ash	Type of sample	Scientific name	Collection site	mg K / g Wet	Dry	Ash
Terrestrial	Piston core sed. T-17 K	Off Añasco River	1.1	1.8		Terrestrial	Piston core sed. T-17 D	Off Añasco River	1.2	2.0	
"	" T-18 F	64 m. deep off Añasco	2.7	3.9		"	" T-17 H	"	2.0	3.2	
"	" T-19 B	31 m. deep off Añasco	3.5	6.5		"	" T-17 A	"	1.7	2.8	
"	" T-16 M	343 m. deep off Añasco	1.7	2.7		"	" T-17 F	"	1.4	2.4	
"	" T-18 A	64 m. deep off Añasco	3.2	5.1		"	" T-19 J	31 m. off Añasco R.	2.6	4.2	
"	" T-18 B	"	2.6	3.9		"	" T-19 K	"	3.7	5.7	
"	" T-18 C	"	4.0	5.8		"	" T-19 F	"	2.0	3.7	
"	" T-18 E	"	2.5	3.7		"	" T-19 I	"	2.6	4.5	
"	" T-18 G	"	1.4	2.1		"	" T-19 L	"	2.3	3.7	
"	" T-19 A	31 m. deep off Añasco	3.6	6.6		"	" T-19 M	"	2.4	3.8	
"	" T-19 C	"	3.1	5.4		"	" T-20 C	351 m deep off Añasco	2.0	3.4	
"	" T-19 D	"	2.3	4.1		"	" T-20 E	"	1.6	2.5	
"	" T-19 E	"	3.4	6.2		"	" T-20 G	"	1.4	2.3	
"	" T-19 G	"	1.9	3.3		"	" T-20 H	"	3.2	4.4	
"	" T-19 H	"	2.3	4.0		"	" T-20 I	"	1.3	2.0	

Type of sample	Scientific name	Collection site	mg K / g Wet	Dry	Ash	Type of sample	Scientific name	Collection site	mg K/ g Wet	Dry	Ash
Terrestrial	Piston core sed. T-22 I	358 m. off Añasco R.	1.8	3.1		Terrestrial	Piston core sed. T-21 A	200 m. deep off Añasco	2.4	5.0	
"	" T-21 C	200 m. deep off Añasco	1.3	2.3		"	" T-21 D	"	2.1	3.5	
"	" T-20 D	351 m. deep off Añasco	1.7	2.7		"	" T-21 B	"	2.6	4.7	
"	" T-17 L	Off Añasco River	1.0	3.6		"	" T-17 E	Off Añasco River	.52	.90	
"	" T-22 D	358 m. off Añasco R.	1.2	2.0		"	" T-20 F	351 m. deep off Añasco	2.1	2.9	
"	" T-22 E	"	1.3	2.2		"	" T-20 J	"	2.2	3.4	
"	" T-22 F	"	.82	1.4		Fishes	Harengula F0004-F-43	South of La Boquilla	3.2	15	47
"	" T-22 A	"	1.5	2.5				Henriquez P. Parguera	.43	2.3	5.0
"	" T-22 H	"	1.0	1.8		"	Sargassum A0054-A-29	Guanica	10	53	110
"	" T-22 J	"	1.4	2.6		"	Padina A0055-A-30	Guanica	6.4	32	50
"	" T-22 G	"	.93	1.7		Algae	Dyctiopteris justii A0038-A-13	"	4.0	23	83
"	" T-20 A	351 m deep off Añasco	1.7	3.1		"	Halimeda opuntia A0056-A-31	Magueyes	.59	1.5	1.7

Type of sample	Scientific name	Collection site	K (ug of K/gram) Wet	Dry x 10^3	Ash x 10^4	Type of sample	Scientific name	Collection site	K (ug K/gram) Wet	Dry x 10^3	Ash x 10^4
Terrestrial plants	Brazil rubber goma de Brazil (TP-5)	PRNC Mayaguez	6200	8.3	11.	Inverte-brate crustacea	Crab I-00016 I-9	Cayo Turremote Parguera	1100	3.2	.56
"	Jaboncillo (TP-7)	PRNC Mayaguez	13000	26	22	Inverte-brate mollusc	Squamosus linne I-00008 H-18	Bonus Nuclear Plant	490	.60	.067
"	Mango Leaves (TP-20)	PRNC Mayaguez	4400	8.7	9.7	Inverte-brate echinoderm	Brittle star I-00010 I-1	Cayo Turremote Parguera	690	1.3	.16
Marine sed.	Piston core sed. T-17 i	Añasco R. (373 M deep)	2000	3.6	.1	"	Species 736 I-00040 I-39	1/2 mile of Pta. Higuero	1400	2.3	.27
"	Piston core sed. T-17 J	"	1600	2.7	---	Inverte-brate Echinoderm	Brown sea urchin I-00020 I-13	Cayo Turremote Parguera	970	2.0	.23
"	Piston core sed. T-18 D	64 meters deep off Añasco R.	1800	2.5	---	Inverte-brate mollusc	Acanthopleu-ra granulata I-00006 H-4	Bonus Nuclear Plant	540	.70	.08
Inverte-brate sponge	Species 740 I-44	1/2 mile of Pta. Higuero	3500	5.5	80	Inverte-brate Porifera	Species 767 I-46	1/2 mile of Pta. Higuero	600	2.8	.80
Invente-brate mollusc	Squamosus linne H-16	Bonus Nuclear Plant	46	.18	6.6	Inverte-brate sponge	Small gray sponge	Negro Reef	1100	4.8	9.7
Inverte-brate sponge	Species 738 I-40	1/2 mile of Pta. Higuero	7400	4.2	230	"	Purple sponge	Pta. Higuero	2400	9.2	15
Inverte-brate mollusc	Acanthopleu-ra granulata H-3	Bonus Nuclear plant	350	.47	5.4	"	Ircinia strobilina	Pta. Higuero	830	5.0	6.9

Type of sample	Scientific name	Collection site	mg K / g Wet	Dry	Ash	Type of sample	Scientific name	Collection site	mg K / g Wet	Dry	Ash
Algae	Lyngbia mayuscula A0027	Cayo Turre-mote Parguera	.37	5.4	11	Algae	Dictyota	Bonus	2.0	13	42
"	Halimeda opuntia A0004	Belvedere	.64	1.7	1.9	"	Sargassum	"	3.4	30	72
"	Codium isthmocladum A0012	Henriques P. Parguera	.30	4.8	9.1	"	Padina	"	1.6	13	27
"	Penicillus capitatus A0024	Hacienda Belvedere	.14	.76	1.1	"	Coralline and Amphiroa + Sediment	Pta. Higuero Rincon	2.2	6.1	6.8
Invertebrate coelenterata	Pterogorgia	Pta. Higuero Rincon	.72	1.5	2.5	"	Mixed Coralline	"	2.7	10	12
"	Haliclona sponge	Negro Reef	2.3	12	30	"	Caulerpa ra-cemosa A0001	La Parguera	.25	4.4	14
"											
coelenterata	Plexaurella	Pta. Higuero Rincon	1.1	2.1	2.5	"	Caulerpa racemosa A003	Belvedere	.19	1.4	12
"	Eunicea	Pta. Higuero	.90	1.8	2.6	"	Galaxaura marginata A-006	Belvedere	32	42	63
Plankton	Plankton 6S P-18	3 miles S. of Desecheo Isl.	1.2	5.7	14	"	Acantophora spicifera A-007	Belvedere	32	45	99
"	Plankton 6S P-23	Feln point S. of Vieques	.16	.98	1.8	"	Dictyota Divaricata A-0010	"	1.4	11	98

Type of sample	Scientific name	Collection site	mg K / g Wet	Dry	Ash
Plankton	Plankton 12S P-20	Sponge bank	.66	10	18
"	Plankton 12 S P-22	South of Vieques 30' haul	.11	1.4	3.2
"	Plankton 20S P-24	2 1/2 mile off Pt. Brea Parguera	.044	1.8	12
"	Plankton 12S P-13	78 m. depth Añasco R. mouth 30' haul	.36	2.7	6.2
"	Mostly iso-pods P-26	Mona Isl.	1.6	3.0	36

Type of sample	Scientific name	Collection site	mg K / g Wet	Dry	Ash
Alga	Thalassia A-0011	Belvedere	.98	7.2	44
"	Dictyota divaricata A-0022	"	2.7	30	78
Plankton	Plankton P-21	S. of Vieques	.37	2.9	7.0
"	Mixed plankton Lot of Phyto-plankton P-25	5 mile w. of Mayaguez	1.1	13	32
"	Plankton & River sed. P-00004 P-4	Pta. Arenas Mayaguez	.51	8.1	10

Type of sample	Scientific name	Collection site	mg K/g		
			Wet	Dry	Ash
Fish (2077)	Symphurus plaguisa 130 cm.	Añasco Bay	2.7	11	43
" (2085)	" 118 cm.	"	2.2	9.4	53
" (2086)	" 131 cm.	"	2.0	8.5	44
" (2081)	" 132 cm.	"	2.2	9.1	43
" (2030)	Larimus Breviceps	"	2.1	8.4	31
" (2037	" 80 cm.	"	1.7	6.8	27
" (2052)	" 110 cm.	"		7.7	31
" (2053)	" 121 cm.	"	1.8	9.1	27
" (2054)	" 126 cm.	"	1.6	6.8	26
" (2046)	" 144 cm.	"	1.9	8.0	33
" (2043)	" 149 cm.	"	2.7	10	40
" (2042)	" 166 cm.	"	2.3	8.4	39
" (2050)	"	"	2.2	9.5	38

Type of sample	Scientific name	Collection site	mg K / g Wet	mg K / g Dry	mg K / g Ash	mg Fe / g Wet	mg Fe / g Dry	mg Fe / g Ash
Detritus (2017)		Añasco Bay	2.2	4.5	5.4	1.8	3.5	4.2
" (2016)		"	.80	2.9	5.4	9.6	35	64
Mollusc (2011)	Anadara sp.	"	.22	.28	.30	.24	.31	.34
" (2002)	Pitar sp.	"	.20	.21	.21	.11	.11	.11
" (2013)	"	"	.13	.32	.34	.12	.30	.32
" (2007)	"	"	.24	.24	.24	.082	.083	.085
Echinodermata (2001)	Luidia senegalensis	"	.52	1.1	1.5	3.0	6.4	8.5
" (2014)	"	"	.39	1.1	1.4	1.4	4.1	5.4
" (2061)	"	"	.90	2.5	3.7	.42	1.2	1.7
" (2063)	"	"	1.2	3.3	4.8	.23	.64	.94
" (2060)	Clathrata	"	1.2	3.2	4.6	.29	.78	1.1
" (2064)	"	"	1.5	4.0	6.0	.29	.79	1.2
Polychaeta ampharete sp	Crustacea Shrimp	"	3.2	13	60			
" (2066)	Crustacea	"	2.1	8.4	37			
" (2065)	"	"	2.0	8.3	37			
" (2068)	"	"	2.1	8.1	8.5			
" (2090)	"	"	2.9	11	53			
" (2111)	"	"	2.3	9.6	44			
" (2069)	"	"	2.7	9.7	57			
Fish (2073)	Symphurus plaguisa	"	2.8	11	54			
" (2074)	" 111 cm.	"	2.3	9.1	55			
" (2076)	" 125 cm.	"	2.0	8.0	40			
" (2075)	" 126 cm.	"	3.1	12	62			
" (2080)	" 126 cm.	"	2.3	9.6	52			

Type of sample	Scientific name	Collection site	ug Li / gm.	
			Wet	Dry
Terrestrial	Piston core sed. T-16 A	343 m. depth off Añasco River.	65	120
"	" T-16 B	"	120	220
"	" T-16 C	"	83	150
"	" T-16 D	"	91	160
"	" T-16 E	"	120	210
"	" T-16 H	"	120	190
"	" T-16 J	"	100	160
"	" T-16 K	"	100	160
"	" T-16 L	"	120	190
"	" T-16 M	"	110	170

Type of sample	Scientific name	Collection site	Mg Wet x 10^3	Mg Dry x 10^3
Terrestrial	Piston core sed. T-16 A	343 m. depth off Añasco River	14	25
"	" T-16 B	"	14	26
"	" T-16 C	"	19	34
"	" T-16 D	"	9.3	16
"	" T-16 E	"	13	22
"	" T-16 F	"	8.5	14
"	" T-16 G	"	9.0	15
"	" T-16 H	"	10	17
"	" T-16 I	"	10	17
"	" T-16 J	"	10	16
"	" T-16 K	"	11	17
"	" T-16 L	"	8.9	14
"	" T-16 M	"	9.0	14
"	" T-17 A	Off Añasco R.	10	17
"	" T-17 G	"	5.8	10
"	" T-17 C	"	9.0	15
"	" T-17 D	"	9.3	16
"	" T-17 E	"	9.6	16
"	" T-17 F	"	8.2	14

Type of sample	Scientific name	Collection site	ug Mg/gm Wet x 10^2	ug Mg/gm Dry x 10^3
Terrestrial	Piston core sed. T-17 H	Off Añasco River	82	13
"	" T-17 I	"	80	14
"	" T-17 J	"	93	15
"	" T-17 K	"	89	14
"	" T-17 L	"	96	15
"	" T-18 A	64 m. depth off Añasco R.	100	16
"	" T-18 B	"	88	13
"	" T-18 C	"	120	17
"	" T-18 D	"	99	14
"	" T-18 F	"	100	15
"	" T-18 G	"	100	15
"	" T-19 A	31m. depth off Añasco	66	12
"	" T-19 B	"	65	12
"	" T-19 C	"	79	14
"	" T-19 D	"	79	12
"	" T-19 E	"	47	8.6
"	" T-19 F	"	72	13

Type of sample	Scientific name	Collection site	ug Mg / gm Wet x 10^2	ug Mg / gm Dry x 10^3
Terrestrial	Piston core Sed. T-20 I	351m. depth off Añasco R.	91	14
"	" T-20 J	"	84	13
"	" T-21 A	"	71	15
"	" T-21 B	"	89	16
"	" T-21 C	"	82	14
"	" T-21 D	"	84	14
"	" T-21 F	"	120	17
"	" T-22 A	358m. depth off Añasco	80	13
"	" T-22 B	"	99	16
"	" T-22 C	"	94	16
"	" T-22 D	"	100	17
"	" T-22 E	"	83	14
"	" T-22 G	"	87	16
"	" T-22 I	"	92	16
"	" T-22 F	"	80	14
"	" T-22 J	"	79	15
"	Sea bottom sed. T-3	20 ft. depth Inside cat Island	69	9.8

Type of sample	Scientific name	Collection site	ug Mg/gm Wet $\times 10^2$	ug Mg/gm Dry
Terrestrial	Piston core sed. T-19 G	31m. depth off Añasco	86	15
"	" T-19 H	"	76	13
"	" T-19 I	"	77	13
"	" T-19 J	"	81	13
"	" T-19 K	"	64	10
"	" T-19 L	"	70	11
"	" T-19 M	"	64	10
"	" T-20 A	251m. depth off Añasco	77	14
"	" T-20 B	"	83	14
"	" T-20 C	"	79	13
"	" T-20 D	"	98	16
"	" T-20 E	"	9.4	15
"	" T-20 F	"	130	17

Type of sample	Scientific name	Collection site	ug Mg/gm Wet $\times 10^2$	ug Mg/gm Dry $\times 10^3$	ug Mg/gm Ash $\times 10^3$
Terrestrial	Sea bottom sed. T-12	65m. depth off Añasco	110	16	17
"	" T-7	20m. depth Enriquez Pass	87	13	
"	" T-9	St.2 8 m depth mouth Añasco R.	54	9.3	10
"	" T-11	St.4 60 m. depth mouth Añasco R.	88	15	16
"	" T-6	20m. depth Enriquez Pass	91	14	
"	" T-13	28m. depth off Añasco	76	15	16
"	" T-15	230m. depth off Añasco	54	11	15
"	" T-14	190m. depth Añasco R.	70	13	14
"	" T-4	20ft. depth Añasco R.	55	72	
"	" T-5	20m. depth Enriquez Pass	59	11	11
Water	Añasco River Water				9.5 ug/ml of river water

Type of Sample	Scientific name	Collection site	ug Mg / gm		
			Wet x 10^2	Dry x 10^3	Ash
Terrestrial	Piston core sed. T-20 G	351 m. depth off Añasco	96	15	
"	" T-20 H	"	150	20	

Type of sample	Scientific name	Collection site	μg Mg / g		
			Wet	Dry	Ash
Alga	Dictyota dentata	Pta. Higuero	5.4	17	32
"	Bryothamnion	"	27	22	13
"	Amphiroa	"	27	22	21
Miscelaneous sediment & algae		"	31	27	2.0
Alga	Penicillus	"	18	14	7.5
Marine angiosperm	Thalassia	"	5.5	4.1	.79
Alga	Sargassum	"	30	17	3.2
"	Dictyota dentata	"	24	14	2.3

Type of sample	Scientific name	Collection site	mg Mg / g			ug Sr / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Alga	Dictyosphaeria	Pta. Higuero	5.3	20	23			
Marine angiosperm	Thalassia testudinum	Parguera	.74	6.0	22	11	84	320
"	"	"	2.0	12	31	38	250	640
"	"	"	1.4	11	32	32	230	680
"	"	"	2.0	11	31	48	260	720
"	"	"	1.3	11	32	32	280	760
"	"	"	2.3	13	33	68	360	960
"	"	"	2.0	11	31	54	330	920
"	"	"	1.0	7.0	40	36	340	1300
"	"	"	1.1	8.0	32	48	360	1400
Alga	Padina	Bonus Site	1.8	13	24	89	640	1200
"	"	"	2.9	20	36	130	870	1600
"	"	"	2.9	19	36	130	820	1600
"	"	"	2.0	12	30	110	650	1600
"	"	"	3.2	15	26	170	790	1400
"	"	"	3.3	20	46	96	570	1400
"	"	"	2.9	21	36	110	780	1300
"	"	"	3.3	22	42	230	1500	2800
"	Dictyota	"	1.6	9.1	24	95	550	1500
"	Sargassum	"	2.3	14	40	130	800	2400
"	Chondria littoralis	"	1.2	10	19	NOT DETECTED		
"	Codium	Pta. Higuero	3.7	5.8	9.4			
"	Penicillus	"	9.0	21	26			
"	Cymopolia	"	3.6	11	14			
"	Caulerpa	"	10	17	24			

Type of sample	Scientific name	Collection site	mg Mg / g			mg Sr / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderms	Echinometra lucunter	Rincon	20	21	23	1.3	1.4	1.5
"	"	"	20	21	24	1.3	1.3	1.5
"	"	"	21	22	24	1.2	1.3	1.5
"	"	"	19	20	22	1.4	1.4	1.6
"	"	"	18	20	22	1.3	1.5	1.6
"	"	"	18	20	22	1.3	1.5	1.6
"	"	"	15	20	22	.97	1.3	1.5
"	"	"	12	20	22	.79	1.3	1.5
"	"	"	12	20	22	.81	1.4	1.5
"	"	"	13	21	23	.90	1.5	1.6
"	"	"	15	22	24	.94	1.4	1.5
"	"	"	21	21	24	1.3	1.3	1.5
"	"	"	21	21	24	1.5	1.5	1.7
"	"	"	18	21	24	1.3	1.5	1.6
"	"	"	15	21	23	1.1	1.5	1.7
"	"	Parguera	13	21	22	.87	1.3	1.5
"	"	"	13	20	22	.83	1.3	1.5
"	"	"	13	21	22	.84	1.4	1.5
"	"	"	12	20	22	.71	1.2	1.3
"	"	"	14	22	25	.86	1.3	1.5
"	"	"	15	23	26	.79	1.3	1.4
"	"	"	15	22	25	.89	1.4	1.5
"	"	"	17	22	24	.98	1.3	1.4
"	"	"	4.0	22	24	.88	1.4	1.5
"	"	"	15	22	24	1.9	1.5	1.6
"	"	"	14	22	24	.80	1.3	1.4

Type of sample	Scientific name	Collection site	mg Mg / g			mg Sr / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderms	Echinometra lucunter	Parguera	15	21	24	.90	1.3	1.4
"	"	"	16	22	24	.91	1.2	1.3
"	"	Rincon	11	20	22	.71	1.2	1.3
"	"	"	14	22	24	.89	1.4	1.5
"	Tripneustes esculentus	Rincon	9.0	19	21	.76	1.6	1.8
"	"	"	11	20	2.1	.98	1.8	1.9
"	"	"	10	19	20			
"	Echinometra lucunter	Pta. Higuero	19	21	24			
"	Eucidaris tribuloides	"	11	13	14			

Type of sample	Scientific name	Collection site	mg Mg/g Wet	Dry	Ash	mg Sr/g Wet	Dry	Ash
Echinoderm	Tripneustes esculentus	Rincon	15	19	22	1.1	1.4	1.6
"	"	"	16	20	22	1.1	1.4	1.5
"	"	"	13	20	23	.92	1.4	1.6
"	"	"	15	20	22	1.0	1.4	1.5
"	"	"	19	22	25	1.3	1.5	1.6
"	"	"	18	21	24	1.2	1.4	1.6
"	"	"	19	21	24	1.2	1.4	1.5
"	"	"	15	22	24	.89	1.3	1.4
"	"	"	21	21	24	1.2	1.3	1.5
"	"	"	13	14	15	1.4	1.5	1.6
"	"	"	19	20	22	1.3	1.3	1.5
"	"	"	17	20	22	1.3	1.4	1.6
"	"	"	18	19	22	1.3	1.4	1.5
"	"	"	14	20	22	.92	1.3	1.5
"	"	"	19	20	22	1.3	1.3	1.5
"	"	Parguera	10	20	21	.73	1.5	1.6
"	"	"	11	20	23	.74	1.4	1.5
"	"	"	11	19	22	.80	1.5	1.6
"	"	"	10	20	22	.58	1.1	1.2
"	"	"	11	22	24	.68	1.3	1.5
"	"	"	11	22	24	.69	1.3	1.5
"	"	"	10	19	21	.78	1.5	1.6
"	"	"	11	20	22	.84	1.5	1.7
"	"	"	12	22	24	.67	1.2	1.3
"	"	"	11	22	24	.67	1.3	1.4
"	"	"	11	19	22	.78	1.5	1.6

Type of sample	Scientific name	Collection site	mg Mg/g Wet	mg Mg/g Dry	mg Mg/g Ash	mg Sr/g Wet	mg Sr/g Dry	mg Sr/g Ash
Echinoderm	Tripneustes esculentus	Parguera	9.9	20	22	.64	1.3	1.4
"	"	"	11	19	21	.77	1.3	1.4
"	"	"	10	20	22	.66	1.3	1.4
"	"	"	8.9	17	19	.83	1.6	1.7
"	Oreaster reticulatus	Parguera	7.5	12	26	.45	.75	1.6
"	"	Negro Reef	7.7	19	24	.51	1.2	1.6
"	"	Off Guanajibo Pt.	7.7	20	26	.49	1.3	1.7
Coelenterate	Meandrina meandrites	Off Añasco River	1.4	1.5	1.5	4.9	5.2	5.2
"	"	"	.77	.86	.88	5.1	5.7	5.8
"	Meandrina sp.	"	.84	.86	.88	6.0	6.0	6.0
"	Meandrina meandrites	Off Culebrinas River	.71	.73	.80	5.2	5.3	5.8
"	Eusmilis fastigiata	Off Añasco River	1.2	1.3	1.3	5.0	5.3	5.4
"	"	Off Culebrinas River	1.0	2.0	2.0	5.2	5.2	5.4
Mollusk	Strombus pugilis	Villa Cofresi	.22	.23	.24	1.2	1.2	1.2
"	"	"	.24	.25	.26	1.1	1.1	1.2
"	"	"	.23	.24	.24	1.2	1.3	1.3
"	"	80' depth, off Culebrinas R	.27	.27	.28	1.2	1.2	1.2
"	"	"	.30	.30	.30	1.0	1.1	1.1
"	"	"	1.9	2.0	2.0	.96	.99	1.0
"	Strombus costatus	"	1.7	1.7	1.8			
Crustacea	Paguristes sericeus	Villa Cofresi	---	---	24	---	---	2.5

Type of sample	Scientific name	Collection site	mg Mg/g			mg Sr/g		
			Wet	Dry	Ash	Wet	Dry	Ash
Crustacea	Paguristes sericeus	Villa Cofresí	2.5	7.8	24	.18	.56	1.7
"	"	"	4.4	13	28	.37	1.1	2.4
Mollusk	Paguristes sericeus	Off Culebrinas River	--	10	22	--	1.2	2.6
"	Petrochirus diogenes	"	3.2	8.5	20	.39	1.1	2.5
Porifera	Pliable cup sponge w/ spicules dissolved	Off Añasco River	.25	1.1	3.4	NOT DETECTED		
"	"	"	.026	.10	.33	"	"	
"	"	Off Culebrinas R.	.11	.54	2.1	"	"	
"	Brittle cup sponge w/ spicules dissolved	"	.35	1.6	2.8	"	"	
"	"	Añasco R.	.26	1.1	1.6	"	"	
"	"	"	.62	2.1	3.0	"	"	
"	Spheciospongia vesparia w/ spicule dissolved	Negro Reef	.66	3.6	4.7	"	"	
"	Ircinia strobilina w/spicules dissolved	Parguera	.67	3.9	9.2	.038	.22	.52
"	Spheciospongia vesparia	Off Añasco River	.062	.37	1.1	NOT DETECTED		
"	Pliable cup sponge	Off Culebrinas River	1.5	7.0	2.8	"	"	
"	Brittle cup sponge	"	1.2	5.3	9.6	"	"	
"	"	Off Añasco R.	1.9	7.6	1.1	"	"	
"	"	"	1.6	5.3	7.6	"	"	

Type of sample	Scientific name	Collection site	mg Mg/g			mg Sr/g		
			Wet	Dry	Ash	Wet	Dry	Ash
Porifera	Ircinia strobilina	Parguera	1.1	6.3	15	.15	.84	2.0
"	Spheciospongia vesparia	Negro Reef	.87	4.7	6.2	.060	.32	.42
"	Ircinia strobilina	Parguera	1.1	6.3	15	.15	.84	2.0

Type of sample	Scientific name	Collection site	ug Mn / g Wet	Dry	Ash
Fishes	Chloroscombrus crysurus F-20	South of La Boquilla	1.7	7.9	33
"	" F-22	"	2.3	12	42
"	" F-4	"	2.1	10	38
"	" F-11	"	1.6	9.3	30
"	" F-17	"	1.1	5.1	20
"	" F-19	"	0.72	3.0	13
"	" F-24	"	2.0	8.9	37
"	" F-26	"	1.3	11	21
"	" F-12	"	3.1	6.4	25
"	" F-9	"	1.1	5.3	20
"	" F-13	"	3.3	15	55
"	" F-7	"	1.5	8.9	27
"	" F-8	"	1.5	8.3	21
"	" F-10	"	1.3	5.0	25
"	" F-15	"	1.3	6.2	25
"	" F-21	"	3.9	20	65
"	" F-16	"	1.1	3.1	22
"	" F-27	"	0.84	3.8	17
"	" F-14	"	0.46	4.3	17
"	" F-25	"	1.10	10	41
"	" F-5	"	2.8	12	53
"	" F-1	"	1.2	5.4	15
"	" F-2	"	1.9	8.6	35
"	Opisthonema oglinum F -7	"	5.7	22	87
"	" F-6	"	3.3	13	62

Type of sample	Scientific name		Collection site	ug Mn / g		
				Wet	Dry	Ash
Fishes	Opisthonema oglinum	F-3	South of La Boquilla	11	41	134
"	"	F-5	"	2.9	13	59
"	"	F-10	"	9.4	50	190
"	Cetengraulis edentulus	F-7	"	12	42	150
"	"	F-6	"	12	39	160
"	"	F-4	"	11	77	140
"	"	F-1	"	1.4	6.5	28
"	"	F-8	"	13	51	170
"	"	F-3	"	19	81	250
"	"	F-5	"	14	43	180
"	"	F-2	"	12	70	220
"	Caranx latus	F-16	"	2.9	12	37
"	"	F-5	"	1.7	8.2	39
"	"	F-9	"	2.5	11	50
"	"	F-3	"	2.0	9.7	42
"	"	F-15	"	1.1	4.9	22
"	"	F-8	"	4.4	19	71
"	"	F-6	"	4.7	28	92
"	"	F-14	"	2.0	8.3	42
"	"	F-12	"	1.6	6.3	26
"	"	F-11	"	1.0	4.7	18
"	"	F-7	"	1.9	8.7	40
"	"	F-2	"	3.4	14	72
"	"	F-1	"	2.9	13	42

Type of sample	Scientific name	Collection site	ug Mn / g		
			Wet	Dry	Ash
Fishes	Caranx litus F-13	South of La Boquilla	1.0	4.6	20
"	Harengula F-10	"	3.0	11	38
"	" F-1	"	5.6	21	93
"	" F-49	"	9.7	34	110
"	" F-4	"	5.7	21	54
"	" F-7	"	2.2	8.2	40
"	" F-25	"	5.2	20	66
"	" F-14	"	9.0	32	92
"	" F-26	"	6.8	24	76
"	" F-17	"	6.6	25	74
"	" F-35	"	3.4	12	42
"	" F-38	"	3.9	21	52
"	" F-3	"	9.2	23	80
"	" F-5	"	3.5	14	44
"	" F-31	"	5.3	21	63
"	" F-22	"	2.9	9.5	40
"	" F-30	"	5.4	20	66
"	" F-49	"	7.6	25	93
"	" F-6	"	5.5	23	86
"	" F-40	"	4.3	12	38
"	" F-24	"	7.2	29	78
"	" F-44	"	7.4	26	83
"	" F-47	"	11	39	110
"	" F-20	"	7.0	26	80
"	" F-2	"	17	64	180

Type of sample	Scientific name	Collection site	ug Mn / g		
			Wet	Dry	Ash
Fishes	Harengula F-45	South of La"Boquilla	3.8	14	52
"	" F-21	"	16	64	160
"	" F-9	"	9.9	24	80
"	" F-50	"	7.5	24	70
"	" F-19	"	4.7	17	59
"	" F-46	"	4.9	18	59
"	" F-39	"	11	46	120
"	" F-28	"	3.4	13	40
"	" F-33	"	4.5	18	58
"	" F-10	"	4.5	18	58
"	" F-37	"	2.9	9.7	40
"	" F-16	"	6.3	17	52
"	" F-27	"	4.5	18	58
"	" F-41	"	8.3	33	90
"	" F-43	"	5.3	23	78
"	" F-36	"	5.7	20	71
"	" F-32	"	7.8	30	86
"	" F-15	"	17	60	160
"	" F-34	"	3.0	11	35
"	" F-29	"	5.7	19	68
"	" F-8	"	5.6	20	60
"	" F-23	"	2.7	9.6	35
"	" F-51	"	7.0	15	60
"	" F-52	"	5.9	13	42
"	" F-48	"	3.2	13	36
"	" F-11	"	2.5	10	36

Type of sample	Scientific name	Collection site	ug Mn / g Wet	Dry	Ash
Fishes	Harengula F-13	South of La Boquilla	2.7	18	49
"	" F-18	"	4.8	20	58
"	" F-12	"	6.7	27	80
Invertebrates sponge	I-7	Cayo Turremote	1.5	14	27
"	Species 747 I-26	"	27	110	160
"	Species 749 I-28	1/2 mile of Pta. Higuero	15	72	100
"	Species 769 I-43	"	3.2	12	40
"	Species 736 I-39	"	5.8	9.2	11
Invertebrate	Brown sea urchin I-13	Cayo Turremote	5.5	12	13
"	Brittle star I-1	"	9.3	18	12
Invertebrate sponges		Parguera	98	850	1,500
Invertebrate	Chiton Squamosis 16 H	Bonus Nuclear Plant	12	15	17
" sponges	Species 728 I-23	1/2 mile of Pta. Higuero	5.4	24	99
"	Species 768 I-34	"	1.0	4.5	29
Invertebrate	Acanthopleura granulata 6 H	Bonus Nuclear Plant	6.6	9.2	11
"	Panulirus argus I-17	Joyuda beach	2.3	9.3	72
" sponges	Species 732 I-41	1/2 mile of Pta. Higuero	6.6	11	14
Invertebrate	Nudibranch I-4	Cayo Turremote	0.51	4.9	16

Type of sample	Scientific name	Collection site	ug Mn / g Wet	Dry	Ash
Invertebrate sponge	Species 745 I-24	1/2 mile off Pta. Higuero	6.5	34	100
"	Species 744 I-29	"	12	69	140
"	Species 792 I-37	"	1 6	4.4	10
"	Species 773 I-47	"	0.73	4.3	10
Invertebrate	Acanthopleura granulata 4H	Bonus Nuclear Plant	8.7	12	13
Invertebrate sponge	Species 767 I-46	1/2 mile off Pta. Higuero	0.97	4.5	13
"	Species 774 I-42	"	2.5	12	46
"	Species 754 I-27	"	17	67	94
Invertebrate	Species 727 I-32	"	2.5	15	30
"	Species 791 I-36	"	1.5	8.7	27
"	Species 748 I-31	"	9.0	42	112
Invertebrate Jellyfish	I-10	3 min. from Pta. Arenas	0.14	3.2	4
Invertebrate	Acanthopleura granulata 7 H	Bonus Nuclear Plant	77	10	12
" sponge	Species 772 I-33	1/2 mile from Pta. Higuero	1.9	7.0	20
Invertebrate sponge	Species 766 I-45	"	2.0	8.6	25
"	Species 738 I-40	"	5.5	11	17
Invertebrate	White sea urchin I-11	Cayo Turremote	9.8	10	12

Type of sample	Scientific name	Collection site	ug Mn / g Wet	Dry	Ash
Invertebrate	Panulirus argus I-18	Joyuda beach	0.30	1.2	13
"	Chiton squamosus linne	Bonus Nuclear Plant	8.7	11	12
"	Panulirus argus 24H	Joyuda beach	33	6.1	12
"	Acanthopleura granula H3	Bonus Nuclear Plant	6.5	8.7	10
"	Panulirus argus 24 S	Joyúda beach	0.35	1.6	8
Invertebrate sponge	Species 750 I-30	1/2 mile of Pta. Higuero	63	230	430
"	Species 731 I-38	"	3	7	13
"	Species 765 I-35	"	0.64	2.5	16
"	Black sponge I-49 a	Desecheo	4.0	25	49
"	Orange sponge I-50	"	0.70	2.7	12
Algae	Not Known A-1	Cayo Túrremote	2.9	35	95
"	Laurencia obtusa A-5	Cayo Enriquez	1.4	16	30
"	Gracilaria caudata A-10	Guanica	1.5	13	28
"	Gracilaria mammilaris A-14	"	27	250	560
"	Acantophora spicifera A-0014	Cayo Enriquez	1.7	38	99
"	Halimeda opuntia A-4	"	17	39	42
"	Mixture of Acantophora specifera Spyridia filamentosa	"	8.7	83	180

Type of sample	Scientific name	Collection site	ug Mn / g		
			Wet	Dry	Ash
Algae	Lyngbia mayuscula A-2	Cayo Turremote	4.8	69	140
"	Valonia ventricosa A-3	Cayo Enriquez	4.1	79	110
"	Hypnea musciformis A-15	Guanica	1.7	4.2	40
"	Spyridia filamentosa	Cayo Enriquez	4.1	44	95
"	Acantophora specifera	"	1.9	42	110
"	Mixture of Acanthophora specifera & spyridia filamentosa	"	10	100	210
"	Thalassia A-20	Belvedere	7.7	70	260
"	Enteromorpha	Cayo Enriquez	0.25	6.0	14
"	Not Known	"	0.87	4.5	10
Plankton	Mixture P-18	3 mi. south of Desecheo Isl.	0.83	7.2	18
"	" P-22	South of Vieques	2.7	34	81
"	" P-23	"	14	84	160
"	" P-13	78 m. depth Añasco R. mouth	1.2	9.1	21
"	" P-24	2 1/2 mile off Pta. Brea	0.06	2.6	18
"	" P-20	Sponge bank	2.1	32	56
"	" P-21	South of Vieques	4.5	35	85
Terrestrial	Sugar cane stems	Coconut area Rincon	12	17	170

Type of sample	Scientific name	Collection site	μg Mn / g Wet	Dry	Ash
Terrestrial	Brazil rubber	PRNC	71	95	1,300
"	Chucho	Coconut area Rincon	1.0	11	64
"	Pajuil rojo	PRNC	6.2	89	850
"	Mangrove leaves	Parguera	11	26	200
"	Coconut hard shell & meat	Coconut area Rincon	0.86	2.1	50
"	Mangrove aereal roots	Parguera	1.5	6.2	290
"	Tamarindo	PRNC	10	36	480
"	Mangrove subt. roots	Parguera	4.0	4.1	56
"	Almonds	Coconut area Rincon	0.57	0.90	62
"	Pueraria hirsuta	PRNC	35	100	1,500
"	Sugar cane leaves	Coconut area Rincon	27	41	410
"	Jaboncillo	PRNC	84	170	1,500
"	Piston core sed. T-22 A	358 m off Añasco R.	120	200	
"	" T-22 B	"	120	200	
"	" T-22 C	"	100	180	
"	" T-22 D	"	94	160	
"	" T-22 E	"	98	170	
"	" T-22 F	Añasco R.	88	160	
"	" T-22 G	"	92	170	
"	" T-22 H	"	94	170	
"	" T-22 I	"	140	240	
"	" T-22 J	"	118	230	

Type of sample	Scientific name	Collection site	ug Mn / gm		
			Wet	Dry	Ash
Invertebrate sponge	Species 740 I-44	1/2 mile of Pta. Higuero	9.7	15	220
"	Species 765 I-35	"	0.97	3.7	240
" mollusc	Purpura Patula 23 H	Cayo Turremote	110	120	120
Plankton	P-28 Euphausid shrimps Isopods	Mona Island	12	29	300
"	P-26 Isopods	"	12	23	280
"	P-27 Euphausid shrimps	"	12	26	320
Invertebrate	Damiriella	Negro Reef	5.2	32	57

Type of sample	Scientific name	Collection site	ug Mn/g			ug Fe/g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Tripneustes esculentus	Pta. Higuero	7	15	17	43	92	110
"	"	"	8.2	13	14	89	179	200
"	"	"	8.7	16	18	57	125	150
"	"	"	4.4	9.2	10	63	130	140
"	"	"				38	76	85
"	"	"	5.2	11	12	33	69	76
"	"	"	4.5	9	10	41	88	90
"	"	"	13	18	24	48	74	90
"	"	"	9.4	16	18	41	61	78
"	"	"	12	19	24	65	113	130
"	"	"	12	21	25	46	92	100
"	"	"	7.6	15	17	31	63	69
"	"	"	9.7	21	23	39	84	93
"	"	"	9.6	17	23	40	75	78
"	"	"	11	19	22	48	88	99
"	"	"	11	19	21	47	82	90
"	"	"	12	20	24	59	99	110
"	"	"	9.9	17	25	36	73	86
"	"	"	10	20	22	57	96	110
"	"	"	11	19	21	49	81	90
"	"	"	10	16	17	97	150	170
"	"	"	11	19	20	53	82	93
"	"	"	11	19	22	46	82	92
"	"	"	11	19	21	59	98	110
"	"	"	11	18	21	45	83	91

Type of sample	Scientific name	Collection site	ug Mn / g			ug Fe / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Coelenterate	Eunicea laciniata	Pta. Higuero	4.3	7.1	14	83	140	270
"	"	"	16	29	36	68	130	160
"	Pseudoptero-gorgia americana	"	12	26	37	65	130	250
"	"	"	3.5	9.4	14	37	100	150
"	Eunicea calyculata	"	9.6	18	21	52	100	110
"	Eunicea mammosa	"	11	24	32	54	120	160
"	"	"	6.6	14	19	58	120	170
"	"	"	5.0	10	15	58	120	170
"	"	"	5.5	11	15	58	110	150
"	"	"	4.9	9.5	13	52	100	140
"	Plexaurella sp.	"	5.1	10	12	39	78	92
"	Muricea atlantica	"	13	25	32	69	130	170
"	"	"	4.2	8.2	11	53	100	140
"	Muricea muricata	"	6.8	12	15	75	130	170
"	Eunicea asperula	"	9	15	19	120	200	250
"	Eunicea tourneforti	"	67	12	14	43	75	92
"	"	"	8.9	15	17	79	130	150
Ophiuroids		Pta. Higuero	16	37	44	56	350	430
"		"	17	39	47	310	710	870
"		"	21	50	61	120	280	340
"		"	16	37	44	160	370	440

Type of same	Scientific name	Collection site	ug Mn / g			ug Fe / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Ophiuroids		Pta. Higuero	21	44	54	110	250	300
"		"	12	27	32	110	250	300
"		"	14	30	37	240	530	650
"		"	13	29	35	180	240	490
"		"	13	27	33	160	350	440
"		"	11	29	34	100	280	330
"		"	19	36	44	100	190	230
"		"	11	28	33	70	180	210
"		"	9.6	22	26	110	240	300
"		"	14	29	34	160	350	420
"		"	11	30	37	80	220	270
"		"	11	24	29	360	830	990
Alga	Padina	Bonus	14	83	210			
"	"	"	17	120	220			
Marine angiosperm	Thalassia testudinum	Parguera	5.5	43	130	62	490	1500
"	"	"	8.3	54	140	100	670	1700
"	"	"	7.7	56	170	52	380	1100
"	"	"	15	83	230	24	130	360
"	"	"	3.3	26	99			
"	"	"	14	75	200			
"	"	"	8.8	53	150			

Type of sample	Scientific name	Collection site	ug Mn/gm			mg Fe/gm		
			Wet	Dry	Ash	Wet	Dry	Ash
Alga	Sargassum lendigerum	Pta. Higuero	9.3	48	130			
"	Sargassum sp.	"	6.6	28	88	.77		1.0
"	Gracilaria domingensis	Rincon	24	94	770	1.0	4.1	7.3
"	Bryothamnion triquetrum	"	20	92	170	.74	3.4	6.4
"	Padina	"	13	74	170	.59	3.4	7.9
"	Penicillus	"	12	54	76	.39	1.7	2.4
"	Padina	Rincon	12	72	140	.39	2.6	5.2
"	Dictyopteris	"	2.9	26	49	.85	7.5	.14
"	Penicillus	"	15	83	140			
"	Galaxaura	"	12	37	48	.41	1.3	1.7
"	Amphiroa fragilissima	"	29	73	91	.80	2.0	2.5
"	Bryothamnion triquetrum	"	5.5	140	160	.15	1.7	4.4
"	Padina	"	7.8	76	290	.18	1.7	6.7
"	Dictyota	"	5.8	80	410	.18	2.5	.13
Marine angiosperm	Thalassia testudinum	"	12	55	120	.71	3.2	7.0
Alga	Padina	Bonus	17	110	210	.78	5.0	9.7
"	"	"	9.0	65	120	.62	4.5	8.5
"	"	"	22	160	280			
"	"	"	21	99	170			
"	"	"	21	130	300			

Type of sample	Scientific name	Collection site	ug Mn/gm			mg Fe/gm		
			Wet	Dry	Ash	Wet	Dry	Ash
Alga	Amphiroa	Pta. Higuero	85	150	170	6.0	10	11
"	Padina	"	35	110	180	1.8	6.0	9.0
"	Padina gymnospora	"	3.5	20	54	.13	.70	2.0
"	Penicillus	"	19	97	140	1.0	5.0	4.2
"	Dictyosphaeria favulosa	"	17	120	160	.75	5.2	7.0
"	Cymopolia	"	99	150	200	.61	2.2	2.9
"	Dictyopteris Justii	"	27	100	170	1.3	4.9	7.9
"	Amphiroa	"	55	76	90			
"	Dictyosphaeria	"	60	230	260	1.6	6.1	6.8
"	Cymopolia	"	8.1	32	43	.66	2.6	3.4
"	Amphiroa	"	110	130	150	6.2	7.3	8.4
"	Penicillus	"	88	190	240			
"	Cymopolia	"	19	56	72	.90	2.7	3.4
"	Caulerpa	"	74	120	180			
"	Dictyota dentata	"	25	80	150			
"	Bryothamnion	"	130	200	260			
Miscelaneous sediments & algae		"	120	160	180			
Alga	Codium	"	49	170	230			
"	Penicillus	"	73	130	170			
Marine angiosperm	Thalassia testudinum	"	12	64	85	.13	.69	.91
Alga	Dictyopteris justii	"	14	75	140	.91	4.9	8.9
Marine angiosperm	Thalassia testudinum	"	11	53	120	.10		1.0
"	"	"	13	58	130	.19		1.8

Type of sample	Scientific name	Collection site	mg Na / g	
			Wet	Dry
Terrestrial	Piston core sed. T-16 B	343 meters deep-off Añasco R.	9.3	17
"	" T-16 C	"	10	18
"	" T-16 D	"	9.9	17
"	" T-16 E	"	10	18
"	" T-16 H	"	10	17
"	" T-16 J	"	11	17
"	" T-16 K	"	11	18
"	" T-16 L	"	10	16
"	" T-16 M	"	11	17
"	Piston core sed. T-17 A	Off Añasco River	8.6	14
"	" T-17 F	"	10	17
"	" T-17 G	"	8.9	15
"	" T-17 H	"	12	19
"	Piston core sed. T-18 A	64 m. deep off Añasco R.	9.5	15
"	" T-18 E	"	11	17
"	Piston core sed. T-19 B	31 m deep-off Añasco R.	9.6	18
"	" T-19 C	"	9.9	18
"	" T-19 E	"	8.2	15
"	" T-19 G	"	9.0	16
"	" T-19 H	"	9.7	17
"	" T-19 I	"	9.8	18
"	" T-19 J	"	10	16
"	" T-19 M	"	8.3	13
"	" T-20 B	351 meters deep of Añasco	11	18

Type of sample	Scientific name	Collection site	mg Na / g	
			Wet	Dry
Terrestrial	Piston core sed. T-20 C	351 m. deep off Añasco R.	9.3	15
"	" T-20 E	"	11	18
"	* " T-20 F	"	13	17
"	" T-20 G	"	10	16
"	Piston core sed. T-21 A	200 m. deep- off Añasco R.	9.2	19
"	" T-21 B	"	12	21
"	" T-21 D	"	9.9	16

Type of sample	Scientific name	Collection site	ug Ni / g		
			Wet	Dry	Ash
Algae	Not Known A-0019	Cayo Enriquez	5.5	29	64
"	Ulva lactuca A-22	Guanica	1.9	16	31
"	Hypnea musciformis A-26	"	1.9	22	30
"	Penicillus capitatus A-25	"	5.6	22	30
"	Gracilaria A-27	"	1.0	11	19
"	Codium Taylorii	"	1.5	19	29
"	Spatoglossum schroede: A-23	"	1.8	15	33
"	Bryothamnion triquetrum A-20	"	3.7	23	42
"	Laurencia papillosa A-28	"	1.6	13	22
"	Galaxaura cylindrica A-24	"	5.5	23	28
"	Mixture of Acantophora spicifera & Spyridia filamentosa	Cayo Enriquez	4.7	45	95
"	Halimeda Opuntia A-4	"	23	53	57
"	Lyngbia mayuscula A-2	Cayo Turremote	2.3	33	68
"	Gracilaria mammilaris A-14	Guanica	5.8	53	120

Type of sample	Scientific name	Collection site	ug Ni / g Wet	Dry	Ash
Algae	Hypnea musciformis A-15	Guanica	8.5	21	200
"	Gracilaria caudata A-10	"	2.1	19	41
"	Valonia ventricosa A-3	Cayo Enriquez	3.5	66	95
"	Laurencia obtusa A-5	"	5.6	65	123
"	Acantophora spicifera	"	0.94	21	56
"	Enteromorpha	"	0.30	7.3	17
Fishes	Chloroscombrus crysurus F-15	South of La Boquilla	12	59	24
"	" F-10	"	21	10	41
"	" F-27	"	0.54	2.5	11
"	" F-24	"	1.0	4.6	19
"	" F-8	"	0.43	2.4	6
"	Harengula F-7	"	1.1	4.1	20
"	Chloroscombrus crysurus F-25	"	1.2	5.4	22
"	" F-9	"	0.89	4.3	16
"	" F-19	"	1.3	5.3	23
"	" F-11	"	2.7	16	51
"	" F-17	"	2.1	9.8	38
"	" F-26	"	1.3	11	21
"	" F-12	"	2.1	4.4	17
"	" F-4	"	0.79	3.7	14
"	" F-20	"	2.2	10	42
"	" F-22	"	4.0	22	74

Type of sample	Scientific name	Collection site	ug Ni / g		
			Wet	Dry	Ash
Fishes	Chloroscombrus crysurus F-14	South of La Boquilla	0.43	4.0	16
"	" F-17	"	1.9	9.0	35
"	" F-21	"	1.1	5.5	18
"	" F-13	"	0.82	3.1	15
"	" F-16	"	0.45	1.3	9
"	" F-5	"	1.6	6.6	29
"	Harengula F-11	"	2.1	8.3	30
"	" F-8	"	3.1	11	33
"	" F-29	"	5.1	17	61
"	" F-48	"	2.3	9.0	25
"	" F-34	"	2.2	8.5	26
"	" F-15	"	4.1	14	38
"	" F-32	"	2.2	8.5	24
"	" F-14	"	3.2	12	33
"	" F-7	"	3.4	13	62
"	" F-4	"	4.4	16	42
"	" F-18	"	2.2	9.0	26
"	" F-36	"	2.5	8.7	31
"	" F-27	"	2.8	11	36
"	" F-52	"	3.5	7.9	25
"	" F-41	"	2.8	11	31
"	" F-23	"	2.6	9.3	34
"	" F-12	"	2.1	8.5	25
"	" F- 51	"	4.0	8.8	34
"	" F-22	"	2.6	8.6	36

Type of sample	Scientific name	Collection site	ug Ni / g		
			Wet	Dry	Ash
Fishes	Harengula F-31	South of La Boquilla	2.6	10	31
"	" F-22	"	2.6	8.6	36
"	" F-31	"	2.6	10	31
"	" F-30	"	2.5	9.5	31
"	" F-40	"	3.2	8.6	28
"	" F-24	"	3.6	15	40
"	" F-44	"	7.2	25	80
"	" F-6	"	2.0	7.1	27
"	" F-1	"	1.3	5.0	22
"	" F-38	"	1.5	5.7	20
"	" F-50	"	2.7	8.5	25
"	" F-21	"	2.8	11	27
"	" F-39	"	1.6	6.4	17
"	" F-2	"	4.4	17	48
"	" F-46	"	1.8	6.5	22
"	" F-28	"	1.6	6.3	19
"	" F-20	"	2.3	8.9	27
"	" F-45	"	2.8	10	38
"	" F-33	"	1.9	7.9	25
"	" F-26	"	2.3	8.1	26
"	" F-10	"	3.0	11	38
"	" F-49	"	1.8	6.0	22
"	" F-9	"	2.6	6.3	21
"	" F-14	"	5.1	18	52
"	" F-19	"	1.8	6.5	23
"	" F-35	"	2.0	7.3	25

Type of sample	Scientific name	Collection site	ug Ni / g		
			Wet	Dry	Ash
Fishes	Harengula F-17	South of La Boquilla	3.2	12	36
"	" F-47	"	2.5	9.0	26
"	" F-1	"	1.6	6.2	27
"	" F-49	"	2.6	8.8	32
"	" F- 10	"	3.6	13	45
"	Ophisthonema oglinum F-6	"	1.2	4.7	22
"	" F-8	"	1.7	6.7	25
"	" F-7	"	1.3	5.0	19
"	" F-2	"	1.4	5.6	25
"	" F-1	"	1.9	7.8	32
"	" F-10	"	1.6	8.3	32
"	" F-9	"	1.8	7.5	36
"	" F-4	"	2.6	11	44
"	" F-5	"	0.85	3.7	17
"	" F-3	"	1.5	5.6	18
Fish	Cetengraulis edentulus F-7	"	3.1	11.2	40
"	" F-4	"	2.3	16	29
"	" F-5	"	2.8	8.4	36
"	" F-1	"	1.0	4.5	20
"	" F-2	"	1.7	7.2	23
"	" F-3	"	3.6	16	48
"	" F-6	"	2.3	7.8	32
"	" F-8	"	1.3	5.1	17
Fish	Caranx latus F-16	"	4.0	16	50

Type of sample	Scientific name	Collection site	ug Ni / g		
			Wet	Dry	Ash
Fish	Caranx latus F-5	South of La"Boquilla	0.77	3.8	14
"	" F-13	"	1.0	4.5	20
"	" F-15	"	1.0	4.3	20
"	Harengula F-16	"	2.7	7.2	22
"	" F-37	"	1.2	4.1	17
"	" F-25	"	2.0	8.0	26
"	" F-5	"	4.0	16	50
"	Caranx latus F-14	"	1.5	4.9	25
"	" F-2	"	1.3	5.4	27
"	" F-7	"	2.1	9.8	45
"	" F-11	"	1.8	8.3	32
"	" F-1	"	1.6	7.2	23
"	" F-12	"	1.5	5.9	25
"	" F-3	"	0.38	1.8	8
"	" F-9	"	2.2	10	45
"	" F-8	"	2.6	11	40
Fish	Chloroscombrus crysurus F-1	"	1.4	6.6	18
"	" F-2	"	4.0	18	74
Plankton	P-21	South of Vieques	8.6	67	160
"	P-20	Spönge bank	4.8	74	130
"	P-18	Three miles s. of Desecheo Island	3.6	32	79
"	P-24	2 1/2 m. from point Brea Parguera	0.45	18	120

Type of sample	Scientific name	Collection site	ug Ni / g		
			Wet	Dry	Ash
Plankton	P-13	78 m. depth Añasco R. mouth	5.0	37	86
Sugar cane stems	TP-00008	Coconut area Rincon	0.72	1.8	74
Roots (mangle) subterraneas	TP-000013	La Parguera	5.8	5.9	82
Pajuil rojo	TP-00009	PRNC	3.0	4.4	42
Raices area de Mangles	TP-000014	La Parguera	0.35	1.5	69
Mango Leaves	TP-000020	PRNC	1.2	2.4	27
Tamarindo leaves	TP-000016	PRNC	1.2	4.3	57
Cascara y cachipa de coco	TP-000018	Coconut area Rincon	1.1	2.8	66
Mangrove leaves	TP-000017	La Parguera	1.6	3.8	29
Goma de Brazil	TP-00005	PRNC	5.8	7.7	107
Chucho	TP-000012	Coconut area Rincon	0.51	5.6	32
Sugar cane leaves	TP-00002	Coconut area Rincon	4.8	7.2	71
Jaboncillo	TP-00007	PRNC	3.3	6.7	58
Almonds	TP-00004	Coconut area Rincon	0.39	0.60	42
Algae	Mixture of Acantophora spicifera & Spyridia filamentosa A-0018	Cayo Enriquez La Parguera	4.7	46	95
Invertebrate	Nudibranchs I-4	Cayo Turremote	23	220	72
"	Brown sea urchin I-13	"	11	22	25

Type of sample	Scientific name	Collection site	ug Ni / g Wet	Dry	Ash
Invertebrate	Panulirus argus I-18	Joyuda beach	9.3	39	41
"	Chiton Squamosus 18 H	Bonus Nuclear Plant	18	23	25
"	Panulirus argus I-22		2.8	22	22
" Jellyfish	I-10	3 m. from Bta. Arenas	8.8	200	25
Invertebrate sponge	Species 745 I-24	1/2 mile from Pta. Higuero	12	62	180
"	Squamosus linne 16 H	Bonus Nuclear Plant	21	27	30
"	Panulirus argus I-17	Joyuda beach	1.4	6.0	45
" sponge	I-35 Species 765	1/2 mile from Pta. Higuero	3.1	12	76
Invertebrate	Acanthopleura granulata 7H	Bonus Nuclear Plant	13	17	20
" sponge	I-7	Cayo Turremote	2.2	20	39
Invertebrate	White sea urchin	"	19	19	23
"	Black sponge I-49 a	Desecheo	25	150	310
"	Orange sponge I-50 a	"	6.5	25	110
Terrestrial	Pueraria hirsuta	PRNC	3.1	9.5	140
"	Brazil rubber	"	5.6	7.5	100
Algae	Not Known	Cayo Enriquez	6.6	35	76
"	Spyridia filamentosa	"	1.7	17	38
Terrestrial	Piston core sed. T-22 A	358m. off Añasco R.	36	58	

Type of sample	Scientific name	Collection site	ug Ni / g Wet	ug Ni / g Dry	ug Ni / g Ash
Terrestrial	Piston Core sed. T-22 B	358m. off Añasco R.	37	60	
"	" T-22 C	"	36	61	
"	" T-22 D	"	34	57	
"	" T-22 E	"	40	68	
"	" T-22 F	"	36	63	
"	" T-22 G	"	40	73	
"	" T-22 H	"	34	62	
"	" T-22 I	"	34	60	
"	" T-22 J	"	34	65	
Invertebrate sponge	Species 732 I-41	1/2 mi. off Pta. Higuero	49	79	100
"	Species 792 I-37	"	14	37	83
"	Species 774 I-42	"	14	66	260
"	Species 731 I-38	"	25	49	99
"	Species 738 I-48	"	30	57	93
"	Species 769 I-43	"	18	67	230
"	Species 766 I-45	"	16	72	200
"	Species 747 I-26	"	14	56	84
"	Acanthopleura granula 4H	Bonus Nuclear Plant	45	60	69
Invertebrate	Acanthopleura granulata 3H	"	69	93	107
" sponge	Species 773 I-47	1/2 mile off Pta. Higuero	12	69	160

Type of sample	Scientific name	Collection site	ug Ni / g Wet	Dry	Ash
Invertebrate sponge	Species 767	1/2 mile off Pta. Higuero	6.3	29	84
Invertebrate	Panulirus argus 24 H	Joyuda beach	27	50	99
"	" 24 S	"	5.0	22	110
Sponge	Species 745 I-24	1/2 mile off Pta. Higuero	16	88	260
"	Species 728 I-23	"	14	3.0	260
Invertebrate	Brittle star I-1	Cayo Turremote	35	67	80
" sponge		La Parguera	6.3	37	96
"	Species 727 I-32	1/2 mile from Pta. Higuero	9.2	57	110
"	Species 748 I-31	"	15	71	190
"	Species 772 I-33	"	11	39	110
"	Species 750 I-30	"	20	70	140
"	Species 768 I-34	"	5.2	23	140
"	Species 744 I-29	"	13	78	160
"	Species 754 I-27	"	13	53	75
"	Species 736 I-39	"	46	75	88

Type of sample	Scientific name	Collection Site	ug Ni / g		
			Wet	Dry	Ash
Detritus		Añasco Bay	29	59	70
"		"	9	32	60
"		"	13	38	58
Mollusc	Anadara sp.	"	35	45	49
"	Pitar sp.	"	38	39	39
"	"	"	17	41	44
"	"	"	45	46	47
Echinodermata	Luidia senegalensis	"	19	41	54
"	"	"	91	26	34
Crustacea	Shrimp	"	3.5	14	65
Fish	Symphurus plaguisa	"	2.6	10	50
"	" 111 cm.	"	1.5	6	37
"	" 125 cm.	"	2.9	12	58
"	" 126 cm.	"	2.7	1	51
"	" 126 cm.	"	1.8	7.6	41
"	" 130 cm.	"	3.7	14	59
"	" 118 cm.	"	1.7	7.1	40
"	" 131 cm.	"	1.9	8	41
"	" 132 cm.	"	1.8	7.4	35
"	Larimus breviceps 149 cm.	"	6	23	90
"	" 166 cm.	"	2.3	8.4	39
"	"	"	3	13	52

Type of sample	Scientific name	Collection site	ug Ni / g			ug Mn / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Echinometra lucunter	Rincon	43	63	69	16	23	25
"	"	"	45	62	69	19	26	28
"	"	"	49	50	57	20	21	24
"	"	"	74	81	90	19	21	24
"	"	"	27	46	52	12	20	23
"	"	"	47	49	55	19	20	23
"	"	"	34	46	54	15	19	22
"	"	"	49	50	57	20	21	24
"	"	"	37	60	67	15	24	27
"	"	"	52	53	60	19	21	22
"	"	"	45	46	51	17	18	20
"	"	"	25	42	47	9.6	16	18
"	"	"	41	44	49	18	19	22
"	"	"	37	43	48	14	16	18
"	"	"	50	51	57	21	22	25
"	"	Parguera	32	51	56	14	22	24
"	"	"	30	46	52	14	21	24
"	"	"	37	48	52	14	18	20
"	"	"	35	52	57	15	22	24
"	"	"	38	53	59	14	20	22
"	"	"	28	45	49	12	19	21
"	"	"	28	43	47	14	21	23
"	"	"	36	54	59	18	27	30
"	"	"	25	42	46	12	19	21
"	"	"	31	49	55	10	16	18
"	"	"	39	52	58	13	18	19

Type of sample	Scientific name	Collection site	ug Ni / g			ug Mn / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Echinometra lucunter	Parguera	31	51	55	12	18	19
"	"	"	27	43	47	11	17	18
"	"	"	24	42	47	9.3	17	18
"	"	"	35	56	60	13	20	21
"	"	"	35	51	56	13	19	21
"	"	"	53	55	61	13	14	16
"	"	"	35	41	45	12	14	16
"	"	"	43	44	50	16	17	19
"	"	"	27	31	35	11	13	15
"	"	"	29	30	33	13	14	16
"	"	"	24	31	35	11	14	16
"	"	"	17	20	22	12	14	16
"	"	"	32	36	41	11	13	15
"	"	"	28	29	32	12	13	15
"	"	"	24	31	35	9.8	13	14
"	"	"	32	34	38	11	12	14
"	"	"	30	43	49	8.6	13	14
"	"	"	18	27	31	8.1	13	14
"	"	"	22	31	34	11	15	16
"	"	"	24	44	48	8.1	15	16
"	"	"	18	35	38	6.5	13	14
"	"	"	21	37	41	6.8	12	14
"	"	"	18	35	39	7.4	14	16
"	"	"	19	37	41	7.4	14	16
"	"	"	16	31	34	6.8	14	15
"	"	"	19	37	41	6.4	13	14

Type of sample	Scientific name	Collection site	ug Ni / g			ug Mn / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Echinometra lucunter	Parguera	17	31	34	8.0	15	16
"	"	"	20	37	41	7.6	14	16
"	"	"	23	41	45	7.8	14	16
"	"	"	17	31	34	7.7	14	16
"	"	"	21	35	39	7.1	12	14
"	"	"	21	40	44	6.7	13	14
"	"	"	15	31	34	6.2	12	14
"	"	"	9.1	18	20	6.5	13	14

Type of sample	Scientific name	Collection site	ug Ni/g			ug Mn/g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Tripneustes esculentus	Bonus Site	17	42	47	11	26	29
"	"	"	15	42	51	7.7	21	25
"	"	"	17	40	45	9.1	21	24
"	"	"	18	42	47	8.8	20	23
"	"	"	16	38	42	8.9	22	24
"	"	"	14	35	40	8.8	22	24
"	"	"	18	41	47	10	23	26
"	"	"	17	40	45	11	27	30
"	"	"	20	48	53	19	47	52
"	"	"	19	45	50	7.7	19	21
"	"	"	17	41	46	9.7	24	27
"	"	"	18	41	46	7.5	19	21
"	"	"	15	39	45	8.5	22	25
"	"	"	15	44	51	8.7	25	29
"	"	"	13	33	53			
"	"	"	14	40	45	8.6	24	27
"	"	"	16	42	47	9.3	23	27
"	"	"	15	42	48	7.2	20	23
"	"	"	18	50	58	8.9	25	29
"	"	"	16	40	47	8.0	21	24
"	"	Parguera	23	59	69	9.2	23	27
"	"	"	27	66	75	10	24	27
"	"	"	24	59	69	10	26	30
"	"	"	17	45	51	10	26	30
"	"	"	19	52	67	8.3	22	28
"	"	"	21	55	62	8.3	22	25

Type of sample	Scientific name	Collection site	ug Ni / g			ug Mn / g		
			Wet	Dry	Ash	Wet	Dry	Ash
Echinoderm	Tripneustes esculentus	Parguera	21	60	69	8.8	25	28
"	"	"	28	79	97	7.0	20	24
"	"	"	28	66	75	9.0	21	24
"	Echinometra lucunter	Pta. Higuero	29	32	37	191	212	191
"	Eucidaris tribuloides	"	24	30	32	11	13	14

Type of sample	Scientific name	Collection site	ug Pb / g Wet	Dry	Ash
Invertebrate sponge	Species 765 I-35	1/2 mile off Pta. Higuero	0.64	2.5	16
"	Species 738 I-40	"	16	30	49
"	Species 769 I-43	"	3.8	14	48
"	Species 749 I-28	"	4.4	21	29
"	Species 736 I-39	"	32	51	60
	Species 745 I-24	1/2 mile from Pta. Higuero	2.3	12	36
" mollusk	Acanthopleura granulata 7 H	Bonus Nuclear Plant	33	45	52
Invertebrate	Panulirus argus 24 S	Joyuda beach	1.0	5.0	24
" sponge	Species 747 - I-26	1/2 mile off Pta. Higuero	6.3	26	39
Invertebrate	Chiton squamosus	Bonus Nuclear Plant	43	54	59
" sponge	Species 744 I-29	1/2 mile off Pta. Higuero	3.8	23	46
"	I-7	Cayo Túrremote	3.0	28	54
"	Species 792 I-37	1/2 mile off Pta. Higuero	4.3	12	26
"	Species 731 I-38	1/2 mile off Pta. Higuero	9.0	17	34
Invertebrate	Brittle star I-1	Cayo Turremote	26	48	58
"	Acanthopleura granulata 6 H	Bonus Nuclear Plant	32	45	54
"	Panulirus argus 24	Joyuda beach	18	34	67
" sponge	Species 727 I-32	1/2 mile off Pta. Higuero	1.1	7.0	13

Type of sample	Scientific name	Collection site	ug Pb / g		
			Wet	Dry	Ash
Invertebrate (sponge)	Species 766 I-45	1/2 mile Pta. Higuero	1.0	4.6	13
"	Species 748 I-31	"	3.3	15	41
"	Species 791 I-36	"	2.7	16	48
Invertebrate Lobster	Panulirus argus I-18	Joyuda beach	0.61	2.6	27
Invertebrate sponge	Orange sponge sp. #2 I-50a	Desecheo	1.7	6.4	29
"	Species 768 I-34	1/2 mile off Pta. Higuero	0.75	3.3	21
"	Species 728 I-23	"	1.5	6.6	27
Invertebrate mollusc	Chiton squamosus	Bonus Nuclear Plant	34	43	49
"					
Jellyfish	I-10	3 mi. from Pta. Arenas Mayaguez	1.5	34	42
Invertebrate sponge	Species 754 I-27	Pta. Higuero	5.7	23	32
"	Species 740 I-44	1/2 mile off Pta. Higuero	28	44	64
"	Species 773 I-47	"	0.37	1.7	5
Invertebrate mollusc	Acanthopleura granulata H-4	Bonus Nuclear Plant	24	32	36
"	Nudibranchs I-4	Cayo Turremote	0.41	4.0	13
Invertebrate sponge	Species 772 I-33	1/2 mile off Pta. Higuero	4.7	17	49
Invertebrate	Crab	Cayo Turremote	14	41	72
"	White sea urchin	Cayo Turremote	37	38	45

Type of sample	Scientific name	Collection site	ug Pb / g Wet	Dry	Ash
Invertebrate	Panulirus argus I-22	Joyuda beach	0.56	4.3	44
" sponge	Species 767 I-46	1/2 mile off Pta. Higuero	0.75	3.5	10
"	I-00001	Parguera	1.8	10	27
"	Species 750 I-30	1/2 mile off Pta. Higuero	7.0	25	48
"	Acanthopleura granulata H-3	Bonus Nuclear Plant	31	42	48
"	Species 732 I-41	1/2 mile off Pta. Higuero	27	43	56
Invertebrate	Panulirus argus I-17	Joyuda beach	1.7	7.1	55
"	Brown sea urchin I-13	Cayo Turremote	23	49	55
" sponge	Species 774 I-42	1/2 mile off Pta. Higuero	2.1	10	39
Algae	Galaxaura cylindrica	Guanica	11	46	56
"	Bryothamnion triquetrum	Guanica	4.4	28	50
"	Gracilaria	"	1.7	18	31
"	Codium taylorii	"	1.4	18	28
"	Penicillus capitatus	"	11	44	59
"	Ulva lactuca	"	2.1	18	34
"	Hypnea musciformis	"	2.3	27	36
"	Spatoglossum schroederi	"	3.1	26	56
"	Laurencia papillosa	"	3.0	21	36
"	Hypnea musciformis	"	2.0	5.0	44

Type of sample	Scientific name	Collection site	ug Pb / g		
			Wet	Dry	Ash
Algae	Not Known A-1	Cayo Turremote	2.1	25	68
"	Laurencia obtusa A-5	Cayo Enriquez	1.3	15	29
"	Lyngbia mayuscula A-2	Cayo Turremote	2.3	33	68
"	Valonia ventricosa A-3	Cayo Enriquez	2.5	48	68
"	Gracilaria caudata A-10	Guanica	0.79	7.0	15
"	Mixture Acantophora spicifera & Spyridia filamentosa	Cayo Enriquez	1.8	18	36
"	Enteromorpha	"	NOT DETECTED		
"	Codium Taylorii	Guanica	6.2	73	150
"	Halimeda opuntia	Cayo Enriquez	18	42	45
"	Laurencia papillosa	Guanica	1.3	9.0	44
"	Gracilaria mammilaris	"	2.6	24	54
"	Thalassia	Belvedere	0.62	5.6	21
"	Spyridia filamentosa	Cayo Enriquez	1.1	12	26
"	Acantophora spicifera	"	0.74	17	44
Terrestrial	Mangrove subt. roots	Parguera	2.2	2.2	31
"	Pueraria hirsuta	PRNC	1.8	5.4	79
"	Mangrove aereal roots	Parguera	0.071	0.29	14

Type of sample	Scientific name	Collection site	ug Pb / g		
			Wet	Dry	Ash
Terrestrial	Almonds	Coconut area Rincon	0.32	0.50	35
"	Brazil rubber	PRNC	4.3	6.0	80
"	Mangrove leaves	Parguera	0.93	2.2	17
"	Jaboncillo	PRNC	2.7	5.4	46
"	Sugar Cane stems	Coconut area Rincon	NOT DETECTED		
"	Tamarindo leaves	PRNC	2.6	9.1	120
"	Chucho	Coconut area Rincon	0.61	6.6	38
"	Coconut hard shell & meat	"	0.41	1.0	24
"	Pajuil rojo	PRNC	3.2	4.6	44
"	Mango leaves	"	1.1	2.2	25
"	Sugar cane leaves	Coconut area Rincon	3.0	4.5	44
Fishes	Chloroscombrus crysurus F-4	South of La Boquilla	1.9	9.0	34
"	" F-1	"	1.7	8.0	22
"	Harengula F-1	"	2.4	6.4	28
"	Opisthonema oglinum	"	1.2	4.7	20
"	Cetengraulis edentulus F-8	"	1.5	6.0	20
Plankton	Mixture P-24	2 1/2 mile off Point Brea Parguera	1.1	45	300
"	" P-13	78 meter depth Añasco R. mouth	4.7	35	81
"	" P-18	3 miles south of Desecheo Isl.	9.2	80	200

Type of sample	Scientific name	Collection site	ug Pb / g		
			Wet	Dry	Ash
Plankton	Mixture P-20	Sponge bank	1.2	18	35
Invertebrate	Black sponge I-49 a	Desecheo	3.5	21	42

Type of sample	Scientific name	Collection site	ug Sr / g Wet	Dry	Ash
Invertebrates	Barnacles 21-S	Cayo Turremote	0.032	0.26	9.2
"	Tripneustes esculentus	"	0.53	0.55	6.5
" (sponge)	Species 744 I-29	1/2 mile of Pta. Higuero	0.051	0.30	6.1
"	Species 748 I-31	"	0.025	0.12	3.1
"	Black sponge I-49 A	Desecheo	0.011	0.065	1.3
Invertebrate	Acanthopleura granulata	Bonus Nuclear Plant	1.1	1.5	18
" sponge	I-8	Cayo Turremote	12	65	960
Invertebrate	Panulirus argus I-22 A	Joyuda beach	0.13	0.98	100
"	Acanthopleura granulata 6-H	Bonus Nuclear Plant	59	83	1,000
" (sponge)	Species 746 I-25	1/2 mile of Pta. Higuero	2.6	6.5	80
Invertebrate	Purpura patula 23-H	Cayo Turremote	140	150	1,500
" (sponge)	I-7	"	2.4	23	400
"	Species 740 I-44	1/2 mile of Pta. Higuero	51	80	1,200
Invertebrate	Acanthopleura granulata H-3	Bonus Nuclear Plant	310	420	4,800
"	Panulirus argus I-17	Joyuda beach	0.38	1.6	120
" (sponge)	Species 773 I-47	1/2 mile of Pta. Higuero	9.4	56	1,300
Invertebrate	Panulirus argus I-18	Joyuda beach	0.23	0.95	100
Alga	Enteromorpha	Cayo Enriquez	.006	0.11	3.3

Type of sample	Scientific name	Collection site	ug Sr/g Wet	Dry	Ash
Marine angiosperm	Thalassia	Cayo Enriquez	.012	0.077	5.2
Alga	Dictyota divaricata	Belvedere	0.015	0.11	10
"	Acanthophora spicifera	"	0.11	.097	3.2
"	Codium isthmocladum	Cayo Enriquez	0.82	13	250
"	Caulerpa racemosa	Belvedere	1.3	10	840
"	Sargassum polyceratum	"	7.2	62	2,100
"	Penicillus capitatus	"	44	230	3,400
"	Caulerpa racemosa	Parguera	1.5	26	800
Plankton	Mixture of shrimps & isopods	Mona Island	2.8	6.9	690
"	Mostly shrimps	"	2.0	4.3	520
"	Mostly isopods	"	6.9	13	1,600
"	Plankton & river sed.	3 mi. outside Pta. Arenas	3.2	50	620
Fishes	Cypsilurus cyanopterus PV. (skin & scales)	South of Vieques	18	51	280
"	Ablennes hians gills	Culebrinas Bay	32	130	440
"	AG, muscle	"			100
Terrestrial	Piston core sed. T-20 E	351 m. depth off Añasco R.	95	1,600	
"	" T-19 S	31 m. depth off Añasco R.	6.3	100	

Type of sample	Scientific name	Collection site	ug Sr/g Wet	Dry	Ash
Terrestrial	Piston core Sed. T-16 A	343 m. depth off Añasco R.	570	1,000	
"	" T-16 B	"	690	1,300	
"	" T-16 C	"	760	1,400	
"	" T-16 D	"	600	1,000	
"	" T-16 E	"	820	1,400	
"	" T-16 F	"	690	1,100	
"	" T-16 G	"	1,300	2,200	
"	" T-16 H	"	770	1,300	
"	" T-16 I	"	1,400	2,200	
"	" T-16 J	"	770	1,200	
"	" T-16 K	"	850	1,400	
"	" T-16 L	"	840	1,300	
"	" T-16 M	"	890	1,400	
"	" T-17 A	Off Añasco	2,000	3,400	
"	" T-17 B	"	1,300	2,200	
"	" T-17 C	"	1,500	2,500	
"	" T-17 D	"	1,600	2,700	
"	" T-17 E	"	1,700	2,800	
"	" T-17 F	"	1,200	2,100	
"	" T-17 G	"	1,000	1,600	
"	" T-17 H	"	1,100	1,700	
"	" T-17 I	"	1,100	1,900	
"	" T-17 J	"	1,200	1,900	
"	" T-17 K	"	1,200	1,900	
"	" T-17 L	"	1,500	2,300	
"	" T-20 A	351 m. depth off Añasco R	680	1,200	

Type of sample	Scientific name	Collection site	ug Sr/g Wet	Dry	Ash
Terrestrial	Piston core sed. T-19 A	31 m. depth off Añasco R.	2.5	46	
"	" T-19 K	"	6.4	100	
"	" T-19 G	"	5.9	100	
"	" T-19 I	"	6.1	100	
"	" T-19 E	"	2.4	44	
"	" T-19 B	"	4.5	84	
"	" T-19 M	"	12	180	
"	" T-19 C	"	2.5	44	
"	" T-19 D	"	3.1	56	
"	" T-19 J	"	8.8	140	
"	" T-19 F	"	5.6	100	
"	" T-19 H	"	122	210	
"	" T-19 L	"	44	70	
"	" T-18 A	64 m. depth off Añasco R.	38	60	
"	" T-18 B	"	34	50	
"	" T-18 C	"	64	90	
"	" T-18 D	"	63	90	
"	" T-18 E	"	57	84	
"	" T-18 F	"	131	190	
"	" T-18 G	"	85	120	
"	" T-21 A	200 M. depth off Añasco R.	200	420	
"	" T-21 B	"	140	260	
"	" T-21 C	"	560	960	
"	" T-21 D	"	240	400	
"	" T-21 F	"	160	230	

Type of sample	Scientific name	Collection site	ug Sr / g		
			Wet	Dry	Ash
Terrestrial	Piston core sed. T-20 B	351 m[redacted] depth off Añasco R.	1,100	1,800	
"	" T-20 C	"	1,300	2,200	
"	" T-20 D	"	1,100	1,700	
"	" T-20 F	"	1,100	1,500	
"	" T-20 G	"	1,100	1,700	
"	" T-20 H	"	1,500	2,100	
"	" T-20 I	"	1,000	1,600	
"	" T-20 J	"	1,100	1,800	
"	" T-22 A	358 m. depth off Añasco R.	1,600	2,600	
"	" T-22 C	"	1,400	2,300	
"	" T-22 D	"	1,300	2,200	
"	" T-22 E	"	1,700	2,800	
"	" T-22 F	"	1,700	3,000	
"	" T-22 G	"	1,300	2,400	
"	" T-22 H	"	1,300	2,400	
"	" T-22 I	"	1,200	2,100	
"	" T-22 J	"	1,200	2,300	
"	Sea bottom sed. T-15	230 m. depth añasco R.	140	280	400
"	" T-14	190 m. depth añasco R.	170	310	330
"	" T-3	20 ft. depth inside Cat Is.	3,900	5,500	5,600
"	" T-7	20 m. depth Enriques P.	3,100	4,600	
"	" T-6	"	2,700	4,200	

Type of sample	Scientific name	Collection site	ug Sr / g		
			Wet	Dry	Ash
Terrestrial	Sea bottom sed. T-4	20 ft. depth Añasco R.	4,500	6,000	
"	" T-9	St. 2, 8 m. depth mouth Añasco R.	13	23	24
"	" T-12	65 m. depth off Añasco R.	72	100	100
"	" T-11	St. 4, 60 m. deep mouth Añasco R.	59	100	100
"	" T-13	28 m. depth Añasco R.	150	290	310

Type of sample	Scientific name	Collection site	ug Sc/g			ug Zn/g		
			Wet	Dry	Ash	Wet	Dry	Ash
Detritus		Añasco Bay	65	13	16	230	460	550
"		"	4.5	19	31	86	300	570
"		"	4.7	18	27	340	990	1500
Mollusc	Anadara sp.	"	0.03	0.04	0.04	150	200	220
"	Pitar Sp.	"	NO SCANDIUM			150	160	160
"	"	"	0.07	0.18	0.20	38	93	100
"	"	"	NO SCANDIUM			150	150	160
Echinodermata	Luidia senegalensis	"	2.1	4.5	6.0	71	150	200
"	"	"	0.08	0.23	0.31	81	230	300
"	"	"				96	270	390
"	"	"				84	240	350
"	"	"				100	270	390
"	Clathrata	"				110	460	470
"	Polychaeta	"	4.8	27	66			
Crustacea	Shrimp					27	110	500
"	60 cm.	"				21	84	370
"	70-80 cm.	"				26	110	500
"	80 cm.					21	81	350
"						36	140	670
"		"				27	110	520
"	"	"				27	99	580
Fish	Symphurus plaguisa	"				30	120	580
"	" 111 cm.	"				20	79	470
"	" 125 cm.	"				23	91	460
"	" 126 cm.	"				28	110	560
"	" 126 cm.	"				28	120	620

Type of sample	Scientific name	Collection site	ug Zn / g		
			Wet	Dry	Ash
Fish	Symphurus plaguisa 130 cm.	Añasco Bay	33	130	540
"	' 118 cm.	"	24	100	570
"	" 131 cm.	"	15	65	330
"	" 132 cm.	"	25	100	470
"	Larimus breviceps	"	21	84	310
"	" 80 cm.		23	93	380
"	" 110 cm.	"		79	320
"	" 121 cm.	"	21	110	320
"	" 126 cm.	"	16	64	260
"	" 144 cm.	"	22	93	380
"	" 149 cm.	"	38	150	570
"	" 166 cm.	"	34	120	580
"	"	"	20	87	350