PART II

SYMPOSIUM ON

"THE CHANGING PACIFIC OCEAN IN 1957 AND 1958"

Edited by OSCAR E. SETTE, JOHN D. ISAACS

Rancho Santa Fe, California

June 2-4, 1958

DEDICATION

This Symposium is dedicated to

TOWNSEND CROMWELL
and
BELL M. SHIMADA

associates in research of many of the participants in this Symposium, who lost their lives, June 2, 1958, in an airplane crash near Guadalajara, Mexico, while en route to join the research vessel *Horizon* to make further observations on the changing conditions in 1958.

PREFACE

In presenting these discussions of the surprising events of the years of change, the editors have attempted to retain the informality of the Symposium, altering the speakers' words only for the purposes of clarity.

In so doing, the editors have, of necessity, preserved not only informality, but a conspicuous irregularity of style. A few of the papers were read, some given from extensive notes, and some essentially extemporaneous. All unprepared papers were recorded as given, and all papers and discussions were submitted to the authors for review and revision. Some authors saw fit to delete vernacular expressions, others permitted them to remain. The editors have striven to see only that the thought was expressed clearly, and have made no attempts to alter the authors' decisions in regard to the choice of degrees of formality.

Impossible to retain in full was the spirit of a group of outstanding investigators from a wide range of disciplines attempting to understand the message from the incoherent mutterings of nature stirring with obscure excitations.

Following the Symposium the changes in the sea and atmosphere have continued to manifest themselves in various ways—the authors and the editors have resisted the temptation to liberally sprinkle the presentations with pertinent footnotes of these subsequent changes.

OSCAR E. SETTE
JOHN D. ISAACS

ACKNOWLEDGMENTS

On behalf of the participants of the Symposium, the editors wish to extend their sincere thanks to those who made the Symposium possible:—to Dr. Roger Revelle, Director, and to the Scripps Institution of Oceanography at La Jolla, California, for their sponsorship and for the many arrangements for travel and accommodations; to Mr. Julian Burnette, Chairman, and to the Marine Research Committee of the State of California, for their sponsorship and their broad recognition of the importance of the subject of the Symposium; to Mr. Reginald Clotfelter, Manager, and the staff of the Inn at Rancho Santa Fe for their fine arrangements and for their hospitality to the group; to our secretaries and recorders, Mrs. Lorrayne Buck, Mrs. Patricia Bridger, Mrs. John Wyllie, and Miss Barbara Edwards and to Mr. Richard Schwartzlose for his valuable assistance in the arrangements for the Symposium and for his devoted help to the editors during the preparation of these proceedings.

THE EDITORS

PARTICIPANTS

Ahlstrom, Elbert H.
U.S. Bureau of Commercial Fisheries
Biological Laboratory
La Jolla, California

Arthur, Robert S.
Scripps Institution of Oceanography
La Jolla, California

Athay, R. G.
High Altitude Observatory
University of Colorado
Boulder, Colorado

Berner, Leo D.
Scripps Institution of Oceanography
La Jolla, California

Brinton, Edward
Scripps Institution of Oceanography
La Jolla, California

Charney, Jule G.
Massachusetts Institute of Technology
Cambridge, Mass.

Davies, David H.
Scripps Institution of Oceanography
La Jolla, California
(Present address:
South African Association of Marine Biological Research
Durban, Union of South Africa)

Eckart, Carl H.
Scripps Institution of Oceanography
La Jolla, California

Ewing, Gifford C.
Scripps Institution of Oceanography
La Jolla, California

Favorite, Felix
U.S. Fish and Wildlife Service
Seattle, Washington

Fleming, Richard H.
University of Washington
Seattle, Washington

Fofonoff, Nicholas P.
Pacific Oceanographic Group
Nanaimo, British Columbia, Canada

Fuglister, Fritz C.
Woods Hole Oceanographic Institution
Woods Hole, Mass.

Haxo, Francis T.
Scripps Institution of Oceanography
La Jolla, California

Hubbs, Carl L.
Scripps Institution of Oceanography
La Jolla, California

Isaacs, John D.
Scripps Institution of Oceanography
La Jolla, California

Johnson, Martin W.
Scripps Institution of Oceanography
La Jolla, California

Klein, Hans T.
Scripps Institution of Oceanography
La Jolla, California

Marr, John C.
U.S. Bureau of Commercial Fisheries
Biological Laboratory
La Jolla, California
(Present address:
U.S. Bureau of Commercial Fisheries
Honolulu, Hawaii)

Munk, Walter H.
Scripps Institution of Oceanography
La Jolla, California

Murphy, Garth I.
U.S. Fish and Wildlife Service
Honolulu, Hawaii
(Present address:
California Cooperative Fisheries Investigations
Scripps Instituton of Oceanography
La Jolla, California)

Namias, Jerome
U.S. Weather Bureau
Washington, D.C.

Pattullo, June
Scripps Institution of Oceanography
La Jolla, California

Radovich, John
California Department of Fish & Game
Terminal Island, California

Reid, Joseph L., Jr.
Scripps Institution of Oceanography
La Jolla, California

Revelle, Roger R.
Scripps Institution of Oceanography
La Jolla, California

Robinson, Margaret
Scripps Institution of Oceanography
La Jolla, California

Roden, Gunnar I.
Scripps Institution of Oceanography
La Jolla, California

Saur, J. F. T.
U.S. Bureau of Commercial Fisheries
Biological Laboratory
Stanford, California

Sette, Oscar E.
U.S. Bureau of Commercial Fisheries
Biological Laboratory
Stanford, California

Schaefer, Milner B.
Inter-American Tropical Tuna Commission
Scripps Institution of Oceanography
La Jolla, California

Stewart, H. B., Jr.
U.S. Coast and Geodetic Survey
Washington, D.C.

Stommel, Henry M.
Woods Hole Oceanographic Institution
Woods Hole, Mass.

Takenouti, Yositada
Japanese Meteorological Agency
Tokyo, Japan

von Arx, William S.
Woods Hole Oceanographic Institution
Woods Hole, Mass.

Wooster, Warren S.
Scripps Institution of Oceanography
La Jolla, California

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INTRODUCTION

By the fall of 1957, the coral ring of Canton Island, in the memory of man ever bleak and dry, was lush with the seedlings of countless tropical trees and vines.

Two remarkable and unprecedented events gave rise to this transformation, for during 1957 great rafts of sea-borne seeds and heavy rains had visited her barren shores.

One is inclined to select the events of this isolated atoll as epitomizing the year, for even here, on the remote edges of the Pacific, vast concerted shifts in the oceans and atmosphere had wrought dramatic change.

Elsewhere about the Pacific it also was common knowledge that the year had been one of extraordinary climatic events. Hawaii had its first recorded typhoon; the seabird-killing *El Niño* visited the Peruvian Coast; the ice went out of Point Barrow at the earliest time in history; and on the Pacific's Western rim, the tropical rainy season lingered six weeks beyond its appointed term.

The meteorology of the North Pacific was most unusual, with intensification of the North Pacific low and slackening of the winds along the California Coast. In regions of the Pacific where intensive oceanographic measurements were being carried out, investigators were sharply aware of changes. Over much of the eastern North Pacific water temperatures were as much as three degrees centigrade higher than normal, and in the California current, more than four times the solar heat actually received, would have been necessary to account for the warming.

This widespread variation in the weather manifested itself dramatically on a local scale. At La Jolla, for example, the temperature of the sea surface reached the highest averages during July, August, and September of 1957 in 21 years. Southern California had one of its rainiest autumns in several years. Throughout the summer reports came in of the appearance in quantity of fishes that in recent years had been caught only as stragglers: by the end of September 1957 the party boats off Southern California had landed 2,805 dolphinfish against a previous high of 15 in 1947. Some of these events, related as anecdotal, might forever remain so, were it not that recent years have seen an upsurge in man's interest in the atmospheric and oceanic environment. This interest has been expressed by growth in research organizations motivated to record, study and understand the environment and its perturbations.

Beginning with organizations nearest the site of this Symposium, the University of California, Scripps Institution of Oceanography (SIO), in addition to its studies of the sea in all its aspects, has its Marine Life Research Program (MLR) devoted particularly to understanding the sea as the environment for important marine food resources. This division participates in the California Cooperative Oceanic Fishery Investigations (CCOFI)—a group effort under the aegis of the Marine Research Committee of California, in which also participate the South Pacific Fishery Investigations of the U.S. Fish and Wildlife Service (USFWS), the Pelagic Fish Investigations of the California Department of Fish and Game (CF&G), the California Academy of Sciences and Stanford University's Hopkins Marine Station. Of particular significance to the Symposium are the CCOFI observations of physical oceanography, plankton populations and fish spawning in the waters along the eastern margin of the Pacific Ocean abreast of California and Baja California by monthly visits to the grid of stations charted in figure 1.

With interest to the south, in the eastern tropical Pacific, is the Inter-American Tropical Tuna Commission (IATTC) with headquarters on the SIO Campus and coastal field stations in Costa Rica and Panama. Further south is the Consejo de Investigaciones Hidrobiológica of Peru.

To the north is the Department of Oceanography of the University of Washington and the Pacific Oceanographic Group (POG) of Canada, carrying on extensive observations in the subarctic waters of the Pacific, supplemented by further observations made in connection with the North Pacific Fishery Convention by the U.S. Fish and Wildlife Service from its Pacific Salmon Investigations at Seattle and by the Fishery Research Board of Canada from its Biological station at Nanaimo.

In the central North Pacific, the Pacific Oceanic Fishery Investigations (POFI) has been studying physical and biological oceanography from the tropics to the subarctic; while from the western margin of the Pacific, the Japanese Meteorological Agency, together with the central and prefectural fishery agencies have been recording and studying events in the Northwest Pacific ocean. Less directly oriented to the Pacific but adding to the store of Pacific information are the survey and observation programs of the U.S. Coast and Geodetic Survey. Of special pertinence to this Symposium have been the records of the U.S. Weather Bureau and the studies by its Extended-Forecast Section.

Where programs of these organizations required cognizance of and coordination with each other's activities, the scientific leaders of projects concerned have met annually as the Eastern Pacific Oceanic Conference (EPOC). These meetings gave rise to joint oceanographic surveys in 1955 of the Pacific Ocean north of the 20th parallel of north latitude (NORPAC) and of the eastern tropical Pacific (Eastropic) and in 1956 of the central and western equatorial Pacific (Equapac).

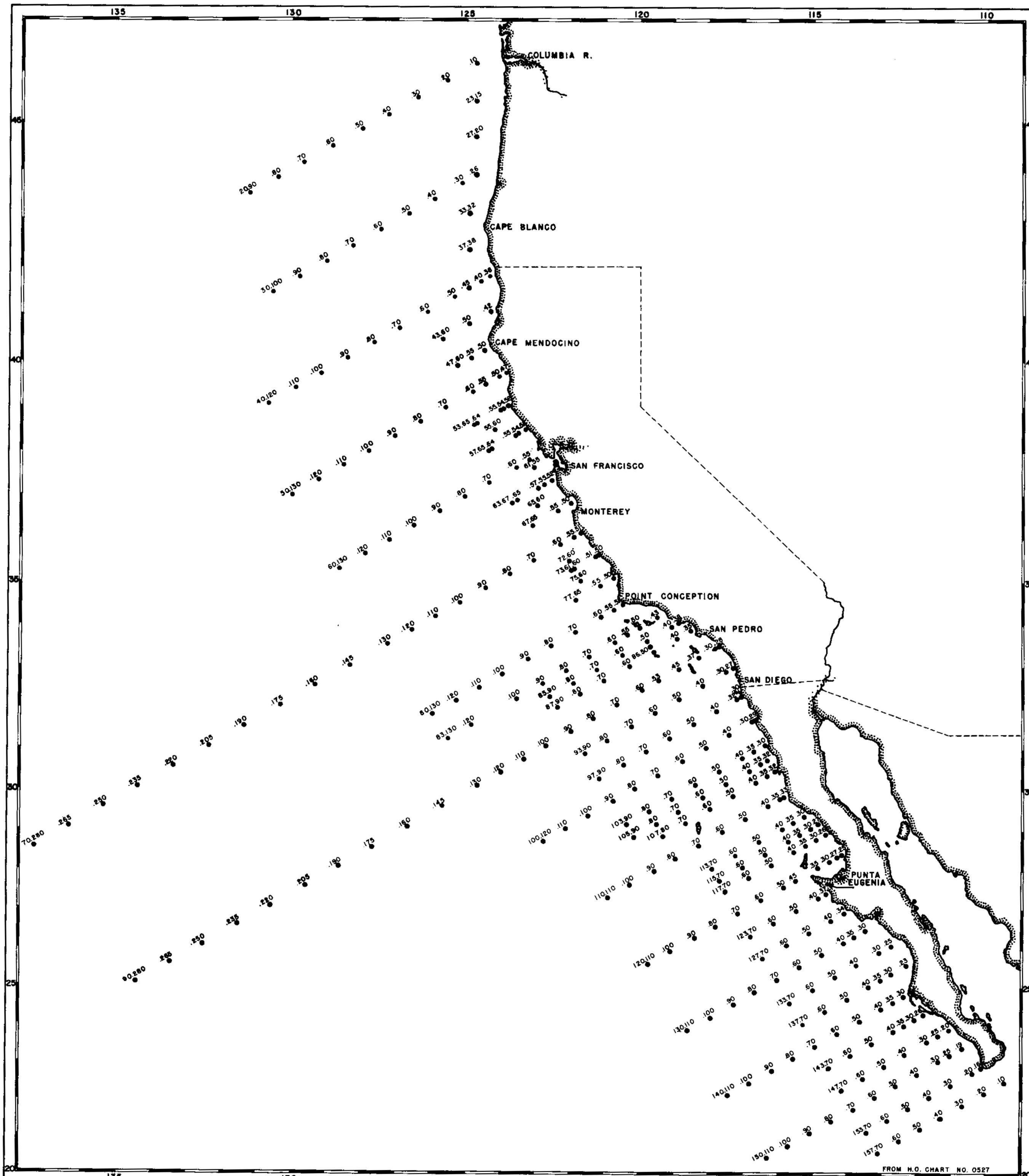

FIGURE 1. Station Plan, California Cooperative Oceanic Fisheries Investigations.

With the information gained from the widespread activities of these organizations by probing the ocean properties and sampling the ocean biota over vast areas, it was thought that, for the first time perhaps, there may exist a background adequately comprehensive and having depth and resolution sufficient to discern the grand pattern underlying the remarkable events of 1957. This Symposium was conceived to bring together the evidence for joint examination by scientists from disciplines of biology, zoogeography, oceanography, meteorology and even astrophysics.

Much of the evidence consists of observations recorded just prior to the Symposium, many of which had not been fully processed and none of which had been comprehensively studied. Therefore, the findings must of necessity be regarded as preliminary. These proceedings, documenting the evidence and the ideas brought together in this Symposium, and bringing about interdisciplinary awareness of interrelationships between atmosphere and hydrosphere and between living organisms and their environments, should increase the effectiveness of further research as to what happened in 1957. This in turn should prepare the way for more discerning observations of future changes and a more penetrating study of their causes and implications.

PROCEEDINGS

INTRODUCTORY STATEMENT

JOHN D. ISAACS

It is very good to see all of you here. You have received some summaries of the changes that the oceans and atmosphere have undergone in the last year. I have been looking forward to seeing the day when this group discusses these important events.

Everyone invited has been able to come with the exception of Dr. von Arx, who is on an expedition. He originally planned to row ashore, fly back here and attend, but it was a bit too complicated for him, I take it. I have a message from him and a short paper, which Fritz Fuglister will read.

Dr. Revelle is not able to be here today, as he had to fly back to Washington on a congressional hearing on IGY. We expect him back tomorrow.

We hope you will have a pleasant, stimulating, and prosperous session, and that an informal spirit will prevail.

I will begin immediately with introductions, using the somewhat alphabetical list on the agenda, which I think each of you have.

First is Dr. Elbert Ahlstrom, Assistant Chief of South Pacific Investigations of the Fish and Wildlife Service on the Scripps Campus. He is associated with much of the work at Scripps, and particularly in the last ten years with the distribution of fish spawning, eggs and larvae in the Eastern North Pacific with the Cooperative California Fisheries Investigations.

Dr. Robert Arthur is next on the list, Associate Professor of Oceanography at Scripps, and Chairman of the Department of Marine Geophysics, teaching and doing other very important work in meteorology and oceanography.

Felix Favorite is from the Seattle Laboratories of the U.S. Fish and Wildlife Service, and has been studying the variations in the locations of the northern fishes, mainly the salmon, and the related oceanographic and meteorological conditions. There is a sort of international problem, I understand, as to the Asiatic and North American salmon population, which the salmon do not quite understand.

Dr. Leo Berner is a member of Scripps staff in Dr. Martin Johnson's Division. Leo is a zoogeographer studying the distribution of the salps, and tomorrow he will discuss the distributions of the salps in the Eastern North Pacific and their variations.

Dr. Edward Brinton, a zoogeographer also, is studying the distribution of the euphausiids as related to the physical conditions of the oceans. He will tell us tomorrow of some biological evidence from the distribution of the euphausiids.

I am sure that Dr. Jule G. Charney is known to many of you as Professor of Meteorology at Massachusetts Institute of Technology and recently of the Institute of Advanced Studies at Princeton. Dr. Charney is a native son of California—one of the few who has wandered to the East Coast. He is the chairman of our session today.

Dr. David Davies came from South Africa a little over a year ago to join the Scripps staff, and has a long history of important work in fisheries as related to oceanography. He has carried out a comprehensive study of the South African pilchard, a fish closely related to our sardine.

Dr. Grant Athay is a guest from the High Altitude Observatory of the University of Colorado. Some time ago I inquired of Dr. Roberts, Director of the Laboratory, hoping that he or one of his staff could address an evening session on solar events as interrelated to meteorology. In this letter, I suggested that quite possibly the stretch from biology to astrophysics was a little wide, and that they might not want to participate in the whole Symposium. However, I found that they felt no barrier, and thought it would be a valuable Symposium from all standpoints.

Dr. Carl Eckart is known to most of you I am sure. He is Professor of Geophysics at Scripps. To enumerate his honors would sound as if I were bragging that I knew him.

Dr. Nicholas Fofonoff is a guest from the Pacific Oceanic Group at Naniamo, British Columbia. He is concerned with dynamic oceanography and he will tell us of the north Eastern Pacific oceanographic conditions in today's session.

Dr. Richard Fleming is certainly known to all of you. He is Professor of Oceanography and head of the Department of Oceanography at the University of Washington. He won his medals as co-author of *The Oceans* and other important contributions.

Fritz Fuglister, from Woods Hole, has long been interested in dynamic oceanography. I am glad that the Atlantic is not acting up to such an extent that the Woods Hole Oceanographic Institution staff is unable to spend its time worrying about the Pacific.

Dr. Harris Stewart is with the U.S. Coast and Geodetic Survey in Washington. He has been studying Pacific sea levels and tide records and will report on this. He is a former student of Scripps, and was a shipmate of mine on Capricorn Expedition.

Dr. Francis Haxo, member of the Scripps staff, Associate Professor of Marine Botany and head of the Division of Marine Botany. Tomorrow Francis is going to tell us about Dr. Balech's findings as to what the phytoplankton has been doing off the California Coast.

Dr. Carl Hubbs, head of the Division of Marine Vertebrates at Scripps, has been keeping tab on the Pacific for many years; fishes, birds, whales, temperatures, and prehistoric man. Some years ago he initiated a temperature survey and carried out extensive studies of coastal temperatures along the Baja California Coast. Today he is going to discuss the Quaternary history of Pacific climates.

Next is John Isaacs, Associate Professor of Oceanography and Program Director of Marine Life Research. A naive, enthusiastic sort of person.

Dr. Martin Johnson, well known to many of you, also is co-author of *The Oceans*, and Professor of Marine Biology in the Division of Marine Invertebrates. He has stimulated the work on zoogeography that Dr. Berner and Dr. Brinton will discuss tomorrow. His own work on the phyllosoma larvae of the spiny lobster, is important evidence for us to consider.

John Marr, Chief of South Pacific Investigations of the U.S. Fish and Wildlife Service, has a long history of thoughtful research in oceanography as related to fisheries. With John Radovich and myself, he sits on an advisory committee of the California Cooperative Oceanic Fisheries Investigations.

Dr. Walter Munk is Professor of Geophysics at Scripps, and at this moment is writing a book on his subject. He does not like to be called the "world's greatest living oceanographer," which reminds me of the Pacific Proving Grounds where they have a regulation that you cannot send a congratulatory message home, so we commonly send a message saying "Regulations forbid me to send a message congratulating you on your birthday."

Garth Murphy from Honolulu, is Director of the Fish and Wildlife Service's Pacific Oceanic Fisheries Investigations. Garth is responsible for some of the charts that I enclosed with the prospectus. He is going to discuss Central Pacific conditions.

Jerome Namias of the Weather Bureau, Chief of the Extended Forecast Section, will lead off the session this morning with the meteorological picture of 1957-58. In a recent letter, he said that he has become more and more excited about what is going on in the Pacific.

John Radovich of the California Fish & Game is head of the Pelagic Fishes Investigations at Terminal Island. I am sure that John is going to try to show that fishes are better oceanographers than we are when he tells about the redistribution of fishes in the last year.

Joseph Reid, member of the Scripps staff, has for some years been oceanographer for the Marine Life Research group, carrying out important work in the eastern North Pacific. He will tell us about the conditions in this area over the last decade.

Dr. Roger Revelle cannot be here today, as I have said.

Gunnar Roden is associated with Joe Reid in the studies on the meteorology and oceanography of the eastern North Pacific. Joe and Gunnar have collaborated in a comprehensive paper on this subject.

Ted Saur is from Dr. Sette's laboratory in Palo Alto, and has a long history of important work in oceanography at Scripps, and in the Navy as Aerological Officer, and with the Naval Electronics Laboratory as a Research Oceanographer.

Dr. Elton Sette is with us as sort of a father confessor for all those who think they have found a relationship between meteorology, oceanography, and fisheries in general. He already has thought of all these relationships many years ago. Dr. Sette, the head of U.S. Fish and Wildlife Service's Ocean Research at Stanford, has spent his time exclusively with these relationships in the last few years. It is a compliment to the Symposium that he has come here.

Dr. Milner B. Schaefer is in charge of Inter-American Tropical Tuna Commission, a Pan American organization, located on the La Jolla Campus, and is studying oceanography in association with high seas fisheries—mainly tuna.

Henry Stommel is a staff member of the Woods Hole Oceanographic Institution, whom we can think of as an East Coast Walter Munk.

Dr. Yositada Takenouti is a guest from the Japanese Meteorological Agency. Dr. Takenouti will tell about what is happening on his side of the ocean.

Another visitor, Dr. Warren Wooster, Oceanographer at Scripps, has just retired to Estados Unidos after a couple of years with the Consejo in Peru.

I would also like to introduce Dick Schwartzlose, secretary of this Symposium, and an important member of the Marine Life Program; and our fair recorders, Barbara Edwards and Virginia Wyllie. Mrs. Buck, who is hostess, will take care of any letters you want typed, arrangements, telephone calls, etc.*

Shortly I will turn this session over to Dr. Charney, but I wish to say one or two words about this Symposium. You have listened to these introductions and, of course, realize that there is a very wide interdisciplinary representation of participants. This is really not a requirement that we imposed, but one that was dictated by the oceans. I hope we can, indeed, look across these interdisciplinary boundaries and find all existing shreds of evidence that might place restrictions upon the model that we erect.

I hope that we can have a free and easy session here. People can wander up and look at the charts and feel free to ask for explanations that will make things clearer, and I hope that discussion will be general.

I think to a great extent that this change we are looking at may be a matter of increased attention in the last 15 years. The amount of attention given to the oceans, to meteorology, indicates a world-wide interest in these matters. Reports of unusual happenings come from wide places. More people are in more strange places, writing letters about more strange

* The following staff members of Scripps Institution also attended the Symposium on the 2d and 3d days: Dr. June Pattullo, Assistant Research Oceanographer; Margaret Robinson, Chief, Bathythermograph Section; and Hans Klein, Head, Data Collection and Processing Group. Eds.

happenings. We easily could break this Symposium into a series of anecdotes about these changes. But much of this is the result of interest and attention. Despite the unusual appearances of many of these changes, I feel that this is not a thousand-year change nor a fifty-year change, but perhaps a ten-year change.

Before I turn this over to Dr. Charney, I wish to mention another bit. I have been looking at air temperatures along the coast with the idea that for selected marine stations they were a rough integration of the oceanographic temperatures, which were not so much determined by the conditions at one point, but rather reflected the conditions over a rather larger area.

This chart (Fig. 2) starts in 1926 and continues to the present. It gives the air temperature at San Diego as fall means, annual means, and spring means. We see that in the last ten years, spring means and annual means have been singularly unchanging. Before then we had wide fluctuations year after year up to 1948. The other marine stations, figure 2, display similar trends. Thus we are looking in this Symposium from the base line of a recent decade that was relatively changeless. That is, it so happens that the most intensively investigated decade was a monotonous one, year after year, compared with the previous two decades, and possibly compared with the last five.

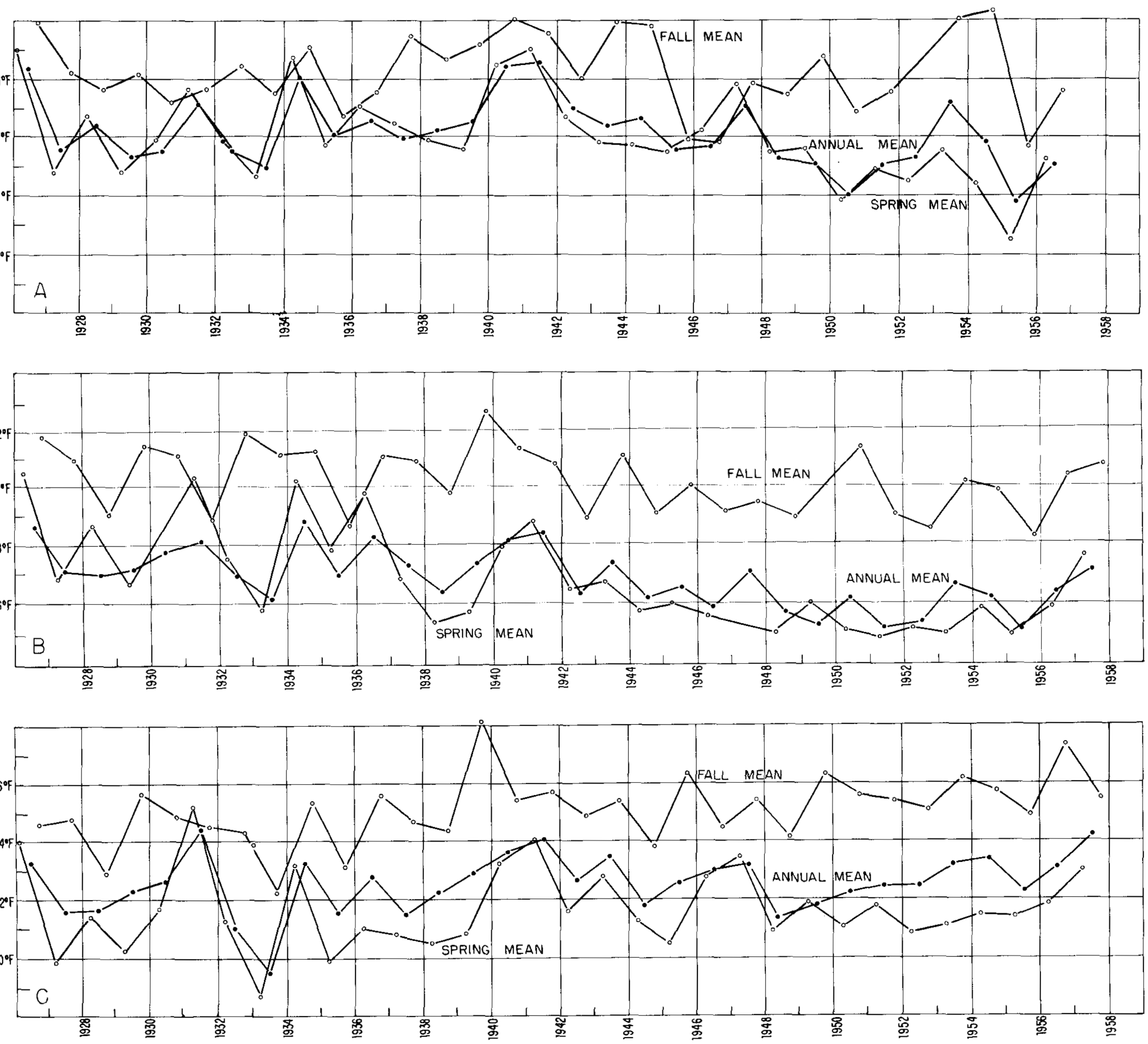

FIGURE 2. Mean Air Temperatures (Spring, Fall, Annual). A) Tatoosh Island, Washington. B) San Francisco, California. C) San Diego, California.