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DUNGENESS CRAB RESEARCH PROGRAM

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by

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ABSTRACT

In 1974, the California State Legislature, recognizing the problem of low yields from the Dungeness crab resource of central California, directed the Department of Fish and Game to conduct an investigation into the causes of the decline. The Operations Research Branch of the Department has conducted preliminary studies and field operations necessary to formulate the Dungeness Crab Research Program. The objectives, research design, and work plans are presented for a 4-year program from July 1, 1975 through August 31, 1979.

1/ Marine Resources Administrative Report No. 75-8.
October 1975

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INTRODUCTION

The Problem

The central California Dungeness crab, *Cancer magister*, resource has yielded harvestable crabs at drastically low levels for 15 seasons in comparison to the long-term average of previous seasons, while the resource off northern California has fluctuated at relatively higher levels.

The Objective

The objective of the Crab Research Program is to determine factors causing the decline and continued low levels of California's Dungeness crab resource and to make management recommendations to protect and increase the resource.

This objective is in keeping with the research policy of the Department which defines research as "an activity which has the objective of resolving identified problems which affect the preservation and enhancement of fish and wildlife resources and their use." A criterion for a Departmental research program is to "Determine the reasons why resource production is below expected levels."

Background

The decline of the crab resource in central California is of serious concern because it indicates a long-term trend rather than a short-term fluctuation. The San Francisco area crab landings reached an all-time

peak of 8.9 million pounds during the 1956-57 season and then declined at the rate of approximately 2 million pounds each season until the 1961-62 season when only 710,350 pounds were landed (Figure 1). A slight increase was seen in landings during the 1962-63 and 1963-64 seasons when 1.3 and 1.2 million pounds were landed respectively and again in 1969-70 with a high of 1.5 million pounds. However, the long-term average for San Francisco crab season landings had been 4.8 million pounds from 1945-1960. The harvest of succeeding seasons has been at low levels. The 1972-73 season's take was 291,551 pounds. The 1973-74 season harvest was only 401,000 pounds, and the total of 215,000 pounds for 1974-75 was the poorest in the history of the fishery. Research cruise data do not indicate young crabs on the fishing grounds in sufficient abundance to give hope for a much better outlook for the 1975-76 season.

Landings of crabs in northern California, which had averaged 9.2 million pounds per season from 1955-56 through 1969-70, plummeted in recent seasons from an all-time high of over 14 million pounds in 1969-70, to 7.8 million in 1970-71, 2.5 million in 1971-72, 1.2 million in 1972-73 and to a record low of 360,000 pounds in 1973-74. During the 1974-75 season about 1.5 million pounds will be landed indicating a tendency for improvement. In addition, research cruises have revealed a relatively strong reserve of recruits in the population which should support continuation of the increase in landings in the 1975-76 season. This indicates a critical difference in crab survival between the relatively healthy population of northern California and the low yielding resource of the San Francisco region.

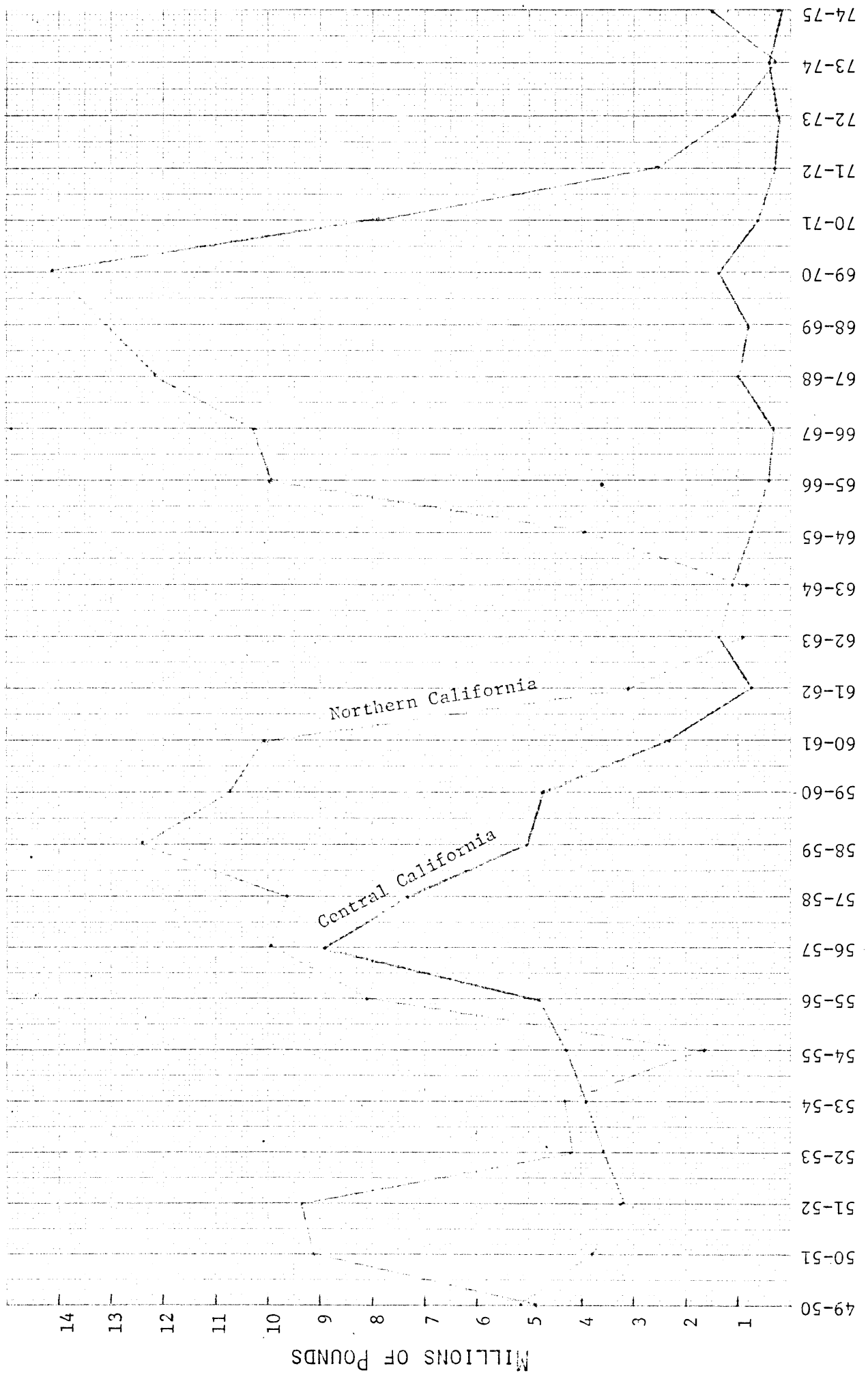


FIGURE 1. Dungeness crab landings from northern and central California, 1949-50 through 1974-75 season.

Relevancy of the Research to Management

The need to understand the causes of the catastrophic condition of the central California crab fishery is real in terms of the economics crucial to the livelihoods of the fishermen, the economic values to the State, and the well-being of a renewable biological resource. Biologists, fishermen, dealers, retailers, and consumers are concerned. The Legislature became convinced of the need for investigation into the causes for the decline and in 1974 by Senate Bill 1606 directed the Department to conduct such an investigation and report its findings, together with recommendations for legislative and administrative actions necessary to protect and increase the abundance of crabs in state waters, to the Governor and Legislature by September 1, 1979.

The course of action for the research of the investigation is to determine the occurrence and distribution of critical stages of crabs in bays and nearshore waters, and to measure the effects of prevailing environmental factors on crab survival, particularly in populations of central California. This includes two major research efforts: one in crab biology, the other in the marine environment. The system to be studied consists of the sets of interacting biological and environmental factors, i.e., the ecology. The findings of the program will be measurement of the factors and the observable and calculable results of the interactions. Data of use in explaining reasons for the low levels of crab production will be used in arriving at conclusions and in developing management recommendations which become the end product.

The natural and man-caused conditions in the environment of crabs present an array of factors affecting the survival of the crab resource in all stages of the life history of the species. Management procedures based on the findings of research can, in some instances, be applied to improve environmental conditions, and to provide utilization of the crab resource at optimum levels to protect the resource and establish economically sound industry practices.

PROGRAM DEVELOPMENT

Research Design

Hypotheses relative to causes of the problem were formulated and examined to determine which were most plausible and subject to research by the manpower and funding anticipated through August 1979. The hypotheses generated were:

1. San Francisco Bay is an important nursery area for young crabs; its recruits are necessary for a sustained central California fishery, but natural or man-caused conditions prevent survival of adequate numbers of the young crabs.
2. Nearshore ocean water quality has deteriorated due to man's activities to a level below that necessary to support crabs through the critical larval and juvenile stages.
3. Satisfactory recruitment levels have been prohibited by effects of natural oceanographic conditions such as temperature, salinity, currents, etc., on larvae and juvenile crabs.
4. Intensive fishing pressure or pollution has lowered the population below a threshold level where natural reproduction is not sufficient to rebuild the resource.
5. Predation and cannibalism keep the crab population at low levels.

6. Crab production is kept low by a lowered food supply.
7. Intensive sport fishing on undersize crabs in San Francisco Bay is a factor affecting recruitment to the commercial fishery.
8. The crab population has been decreased by parasites or disease.

The hypotheses considered to be most applicable to the problem are Nos. 1, 2, and 3. These hypotheses suggest that the critical crab stages are the larval and juvenile forms occurring in bays and nearshore ocean waters, and that the most plausible causes of low survival should be sought in the effects of natural and man-caused environmental conditions. Though the major effort of the research program will be directed toward resolving problems suggested by the first three hypotheses, there will be some work scheduled to identify the possible effects of predation, lowered food supply, and effects of sport fishing for crabs in San Francisco Bay (hypotheses Nos. 5, 6, and 7).

It is not uncommon for crustacean species to hatch from eggs born by females in nearshore ocean waters. Some larvae become distributed in bays and estuaries having warmer waters of lower salinity. The larvae metamorphose into adult form and migrate back to the cooler, higher salinity coastal waters. In late spring juvenile crabs are found in both bay and nearshore ocean waters of central California. It is the determination of the interdependence of the two environments and the factors favoring survival of the larvae and juvenile crabs which requires the effort of this research program.

The study of crabs by the Department in previous years has revealed much information on the hatching and early growth of crabs in ocean and bay waters. The crabs of the study area hatch from masses of eggs on the

abdomen of females on sandy bottoms in the Gulf of the Farallones at depths of 55 m (30 fm) to the shallows in the breakers on the beach. The hatching occurs during winter months and is believed to reach its peak in January. The larvae are subject to dispersal by water currents during their development and metamorphosis into juvenile crabs. The larval period takes about 4 months. Juvenile crabs found in both ocean and bay waters are crabs which have not attained sexual maturity; this occurs when the crabs are about 100 mm (4 inches) in width. Researchers report larval and juvenile forms are critical stages in the life of crustacea and that these stages often demonstrate selective distribution in bays and estuaries. Others report short-term effects of synthetic organics, petroleum wastes, and heavy metals on various forms of crustacea, although long-term effects are not well documented.

Organization

The organizational structure for the research program was designed from the nucleus provided in the reorganization (May 1, 1974) by the Department to place research of marine resources in Operations Research Branch and management of marine fisheries in Marine Resources Region. The Dungeness Crab Research Program was assigned to Research Team No. 1 within Operations Research Branch. The activities of the research team were initiated in 1974 with two projects: (1) Crab Critical Stage Studies, and (2) Crab Environment Studies (Figure 2). The flow of the dynamics of communication, collection of information, and control of the units of the total structure for the program are anticipated to be continuous.

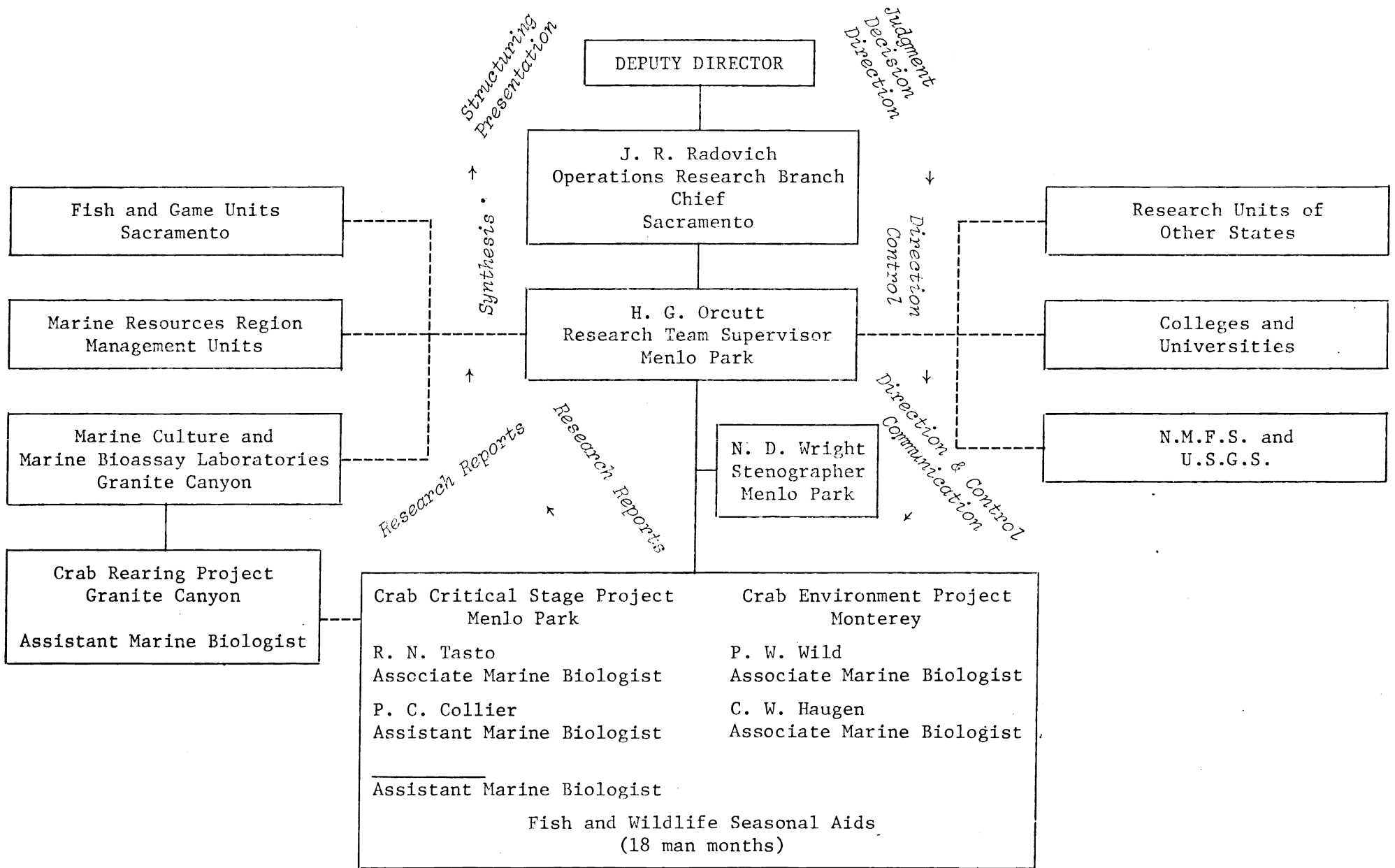


FIGURE 2. Dungeness crab research team organizational chart.

Research Team Activities - May 1974 Through June 1975

A comprehensive study of crab larvae and juvenile crabs in San Francisco Bay and the Gulf of the Farallones, including the measurement and analyses of innumerable environmental factors is necessarily complex. As a consequence, the research team's efforts were initiated with several activities designed to lead to selection of research tasks that would be within the scope of Research Team No. 1 in the 4-year research program to begin July 1975.

A review of scientific literature on crustacean biology, marine ecology, environmental science, and oceanography was initiated to assure that project personnel were well informed and up to date on the subject matter pertinent to the study of effects of environmental factors on critical stages of crustacea. A bibliography has been compiled and a collection of most recent and germane papers has been made. This work gives strong indications that larval stages are critical in crustacean populations particularly at times of metamorphosis.

We conducted a review of literature with emphasis on decapod larvae papers. A compilation of available information was made to form an illustrated key for use in sorting and identification of zooplankton collected on our research cruises and made available by other research groups.

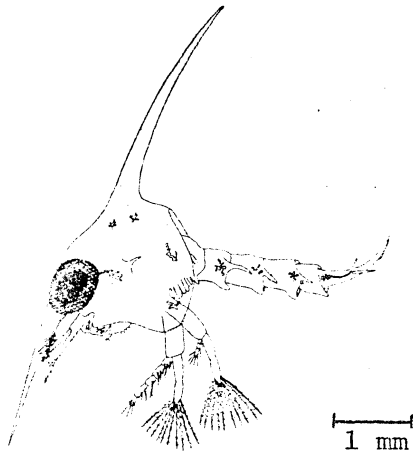
Analyses of existing biological data with special emphasis on the comparative growth rates of crabs in bays and ocean waters off central California indicate that the succession of molts is more rapid in bay waters. The identification of size groups as year-classes is essential to determine recruitment to the harvestable component of the resource.

However, the mixing of juveniles from bay and ocean in the ocean presents a wide size range for crabs of approximately the same age, making aging difficult. Attempts are to be made to resolve the differences in growth rates in bay and ocean waters.

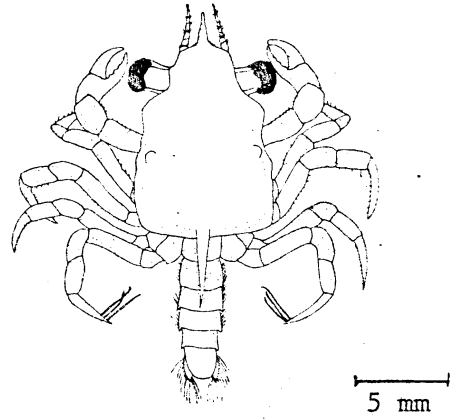
A major activity of the research projects in 1975 was the series of research cruises in April, May, and June. In each month, approximately 2 weeks of cruise time of the KELP BASS were directed to collection of crab zoeae, megalopae, and early crab instars (Figure 3). Special plankton nets, trawls, and dredges were used at stations in the Gulf of the Farallones and in San Francisco Bay. We have direct evidence from tagged crabs that crabs from the Bay enter the commercial fishery in the ocean. However, we do not have records of zoeae or megalopae in bay waters in quantities to give rise to the relatively large numbers of juvenile crabs in the Bay. In the search for the very critical stages when crab zoeae metamorphose to megalopae and the megalopae to the first crab form, we hope to find some answers. Searches for small crabs during their early stages, when the succession of molts is most rapid, will be made to determine when and where they first occur in large numbers on the bottom of the Bay or Gulf. Research cruises will be scheduled each year to collect much needed biological and environmental data in San Francisco Bay and the Gulf of the Farallones.

Temperatures and salinities were recorded during cruises to determine conditions when the larvae and juveniles are present.

The results of the cruises in April, May, and June 1975 will have much influence on future field studies, particularly on the decision to put emphasis on Bay or ocean surveys.

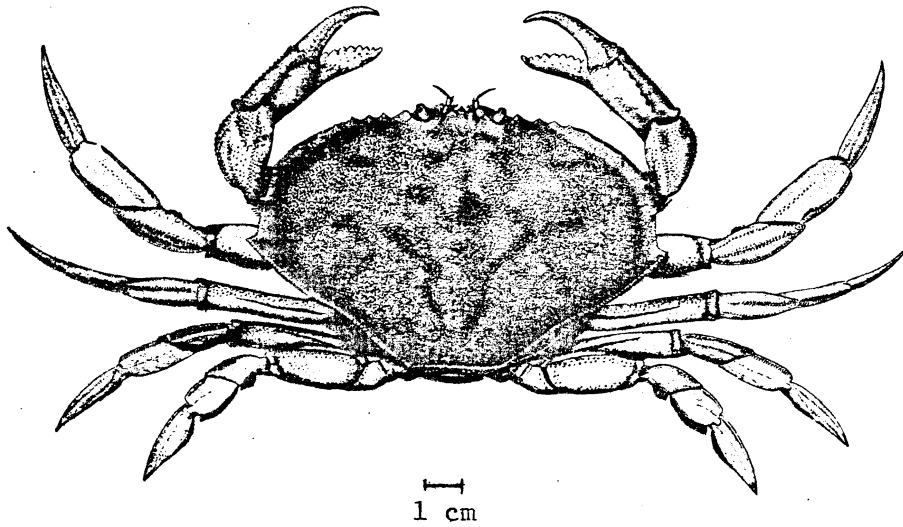


Zoea



Megalopa

LARVAE



ADULT

FIGURE 3. Representative stages of Dungeness crab, *Cancer magister*.

Special samples of crabs from several areas were submitted to the Department's Pollution and Water Quality Laboratories for analyses. The amounts of contamination by heavy metals and pesticides will yield information for use in determining future sampling programs. The need for special tests in the laboratory to show possible effects of these substances on survival and distribution of crabs will also be revealed.

Ovigerous crabs supplied to the Marine Culture Laboratory were used for hatching experiments and development of successful techniques of larvae rearing through all stages and metamorphosis into the crab form. Crabs, metamorphosed from megalopae caught in the ocean, have been reared through 10 molts in the laboratory.

The electrophoretic studies at U.C. San Diego designed to determine the subpopulations of crabs along our coast were started.

An examination of the sport fishery in San Francisco Bay in 1974-75 revealed that many small crabs are caught. This fishery may be of sufficient magnitude to have an effect on recruitment to the ocean fishery. This sport fishery and its impact on the nursery ground population will receive more attention during the 1975-76 season.

During the first part of 1975 the examination of data on hand contributed to our laboratory studies and pilot research cruises, knowledge of crab biology, oceanographic conditions which could affect crab larval survival, ranges of contaminants in crab tissue, local subpopulations of crabs, and seasonal and geographic distribution of larvae. All of these were of value in establishing the base from which to design the 4-year study.

Research Activities - July 1, 1975 Through September 1, 1979

The available data on growth of crabs and data of special collections of small crabs are to be studied to determine the differences in growth rates of the first stages of crabs in San Francisco Bay and nearshore ocean waters. This work will aid in the determination of times and places of occurrence of the various juvenile crab stages and the patterns of recruitment from bay and ocean environments to the fishery.

The major field activity of the program will involve sampling for the occurrence of larval, juvenile, and adult crabs in San Pablo Bay, San Francisco Bay, and in the Gulf of the Farallones (Figure 4).

Historical records of water currents, temperature, and salinity will be collected and examined to determine the characteristics of the marine environment when various stages of crabs are present. Differences in water conditions between years of good and poor recruitment to the crab population will be sought out.

The Marine Culture Laboratory is to be supplied with ovigerous crabs for continuing studies in hatching of larvae and development of mass culture techniques. The rearing procedures developed will have direct application in laboratory verification of effects of environmental factors on survival and growth of larvae in both the Marine Culture Laboratory (for natural factors) and the Marine Bioassay Laboratory (for contaminants).

Samples of crabs from different areas are to be taken for studies to measure differences in heavy metals, pesticides, and polychlorinated biphenyls (PCB's) in crab tissue. Arrangements have been made with the Department's Water Pollution Control Laboratory and Moss Landing Marine

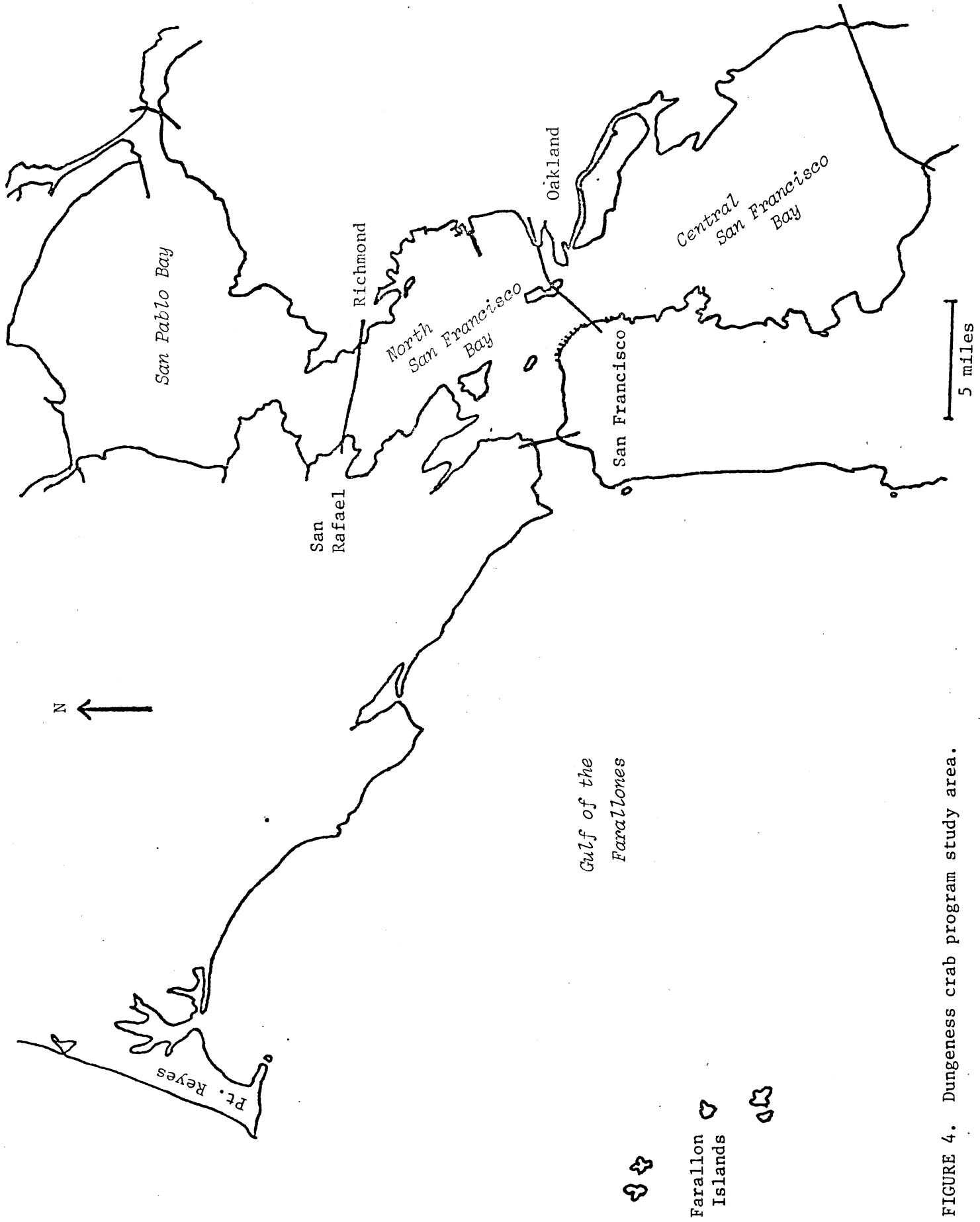


FIGURE 4. Dungeness crab program study area.

Laboratories to conduct preliminary tests on heavy metals. Tests for pesticides and PCB's will be run by the Department's Pesticide Laboratory. The levels and types of toxicants discovered in preliminary tests will dictate the types of similar tests that need to be run during the 4-year study. Information from these tests will be valuable also in designing bioassay experiments with larval and juvenile crabs.

Electrophoretic studies of crab tissues were begun in 1975 through a contract with the University of California at San Diego. Tissue of crabs from several locations are being examined to determine the polymorphic isozyme systems that can be isolated to identify origins of crab subpopulations along the California coast. Such information is of value in providing a biological basis for delineation of study areas.

The National Marine Fisheries Service and the U.S. Geological Survey have been contacted regarding their work in San Francisco Bay. Both agencies are cooperating by providing San Francisco Bay plankton samples of previous years for examination to determine times crab larvae occur in the Bay. The U.S. Geological Survey has a large research unit studying water characteristics, currents, and plankton in the San Francisco Bay and estuary system. The expertise of the Survey's staff and capabilities of their excellently equipped survey ship POLARIS will provide a valuable source of information on physical and chemical factors and plankton in coastal and bay waters. It is anticipated that their reports and ours will lead to an unprecedented accumulation of data on environmental and biological factors in San Francisco Bay. It is from such data that useful information on the degree of interdependence of the ocean and bay crab populations can be determined. An indication of the importance of the bay

system in contributing to the strengths of the ocean fishery will give us a stronger basis for further studies in the long-term program.

Work Plans

The two projects of the Dungeness Crab Research Program are (1) Crab Critical Stage Project and (2) Crab Environment Project. The activity plans for the studies in each project identify the several tasks to be coordinated and accomplished in the 4-year program. The tasks are described and Gantt type work flow charts illustrate the timing and man-power requirements for each study. The Critical Stage Project includes studies of larval, juvenile, and adult crabs and associated species (Figures 5, 6, and 7). The Environment Project studies are of natural and man-caused factors and their effects on crab physiology and distribution (Figure 8). In addition, flow charts of Field Operations and the Administrative Plan are included (Figures 9 and 10). In addition, a task precedence diagram (Figure 11) presents an overview of how the various tasks relate to each other and lead to the successful completion of this program.

The proposal for Research Team No. 1 with a permanent staff of six scientists, a stenographer, and 18 man-months of temporary help per year would provide 426 man-months for the 50 months of the program July 1, 1975-September 1, 1979. Many additional man-months of assistance will be needed from other Department programs. The distribution of effort by man-months is summarized in Table 1.

TABLE 1. Distribution of Effort by Man-months.

<u>Work plan</u>	<u>Flow chart no.</u>	<u>Man-months</u>		
		<u>Research team #1</u>	<u>Others</u>	<u>Totals</u>
Crab critical stages project				
Larvae	1	66.1	50.5	116.6
Juveniles	2	52.1	35.7	87.8
Adults	3	16.8	7.7	24.5
Crab environment project	4	120.0	16.8	136.8
Research vessel crews	5		105.7	105.7
Administrative activities	6	<u>171.0</u>	<u>3.0</u>	<u>174.0</u>
	Totals	426.0	219.4	645.4

Kinds of Data

The data gathered by the projects of the Dungeness Crab Program will be varied and can be divided into two main categories: biological and nonbiological. The biological data on crabs will be the sizes and condition of crabs caught by all methods, data on growth, habits, and physiological reactions to controlled conditions in the laboratory. Data on predators will be recorded during examinations of stomachs taken from selected vertebrates on research cruises. Species associated with crabs will be recorded and relative abundance noted. Measurements of crabs will be to the nearest millimeter, fish and invertebrates when kept for further study will be measured by 2-mm (0.1-inch) intervals. Station locations will be recorded to tenths of minutes of latitude and longitude. Tows of plankton nets and drags of trawls and dredges will be timed to the minute.

The recording of temperature, depth, and salinity will be made at sea except for salinity below the depth capability of our conductivity probe. Water samples will be taken at deep stations and salinities will be

determined in the laboratory. Depths will be in meters. Temperatures will be to the nearest degree C and salinity in parts per thousand.

Our preliminary estimate is for occupying approximately 150 stations per year. The recording in the field of station data, oceanographic parameters, and counts and measurements of crabs and associated species is expected to generate some 4,000 data sheets during the program. The recording in the laboratory of species, their relative abundance, and life stages from plankton samples, fish stomachs, and special collections plus the many record sheets of culture, tolerance tests, bioassays, and contaminant studies will swell the data files of the program.

Anticipated Obstacles

Major anticipated obstacles will be administrative procedures, vessel scheduling, gear maintenance and loss, and vagaries of weather.

Administrative procedures of budgeting, procurement of equipment, and staffing are expected to be limiting factors with built-in delaying actions which hinder program operations. Fortunately during the months of preliminary preparations for the program some of these obstacles have been identified and steps taken to expedite procedures. The staffing to four biologists, a stenographer, and some seasonal help was provided with the 1974 reorganization of the Marine Resources Region and Operations Research Branch when Research Team No. 1 was designated for priority research in central and northern California. Preliminary field operations were established with assurances of additional manpower (two biologists and 18 months of temporary help) for the program. If not provided the proposed activities must be reduced accordingly. The procurement of supplies, gear, and

equipment has been on a scrape, borrow, and emergency purchase basis from other projects and sources of funds.

The availability of research vessels is subject to priority of various programs, staffing problems of crews, and vessel overhauls. These vessel problems are common to all programs in need of a reliable research platform at sea. The accomplishment of cruise plans is limited and at times precluded by the weather. It is not unusual in any season to lose a week of sea time due to adverse sea conditions off central California.

Similar Studies

A recent review of the literature, in addition to our many years of concern over the status of the resource and exchange of information with the other Pacific states, has not revealed similar studies to determine causative factors of a long term low production of a crustacean resource. Preliminary examination of fluctuations of Pacific coast crab landings in relation to upwelling indices of cool coastal waters has not revealed a significant correlation. The studies of blue crab in the Chesapeake Bay area have been on basic biology including development and distribution. These studies revealed hatching in the deeper more saline waters with subsequent growth to maturity in upstream less dense estuarine waters. Research there is now focused on periodic fluctuations in stocks.

Resources Required

The Dungeness Crab Research Program is presented as a 4-year study from July 1, 1975 to September 1, 1979. The minimum in personnel for the research unit, Research Team No. 1, is six biologists, one stenographer,

and 18 months of temporary help each year. The civil service classifications for the program are presented in Table 2.

TABLE 2. Civil service classifications for Dungeness crab program.

<u>Assignment</u>	<u>Civil service class</u>	<u>Man-months per year</u>
Program Supervisor	Laboratory Supervisor	12
Critical Stages Project Leader	Associate Marine Biologist	12
Critical Stages Biologist	Assistant Marine Biologist	12
Critical Stages Biologist	Assistant Marine Biologist	12
Environment Project Leader	Associate Marine Biologist	12
Environment Biologist	Associate Marine Biologist	12
Stenographer	Stenographer Range B	12
Temporary Help	Fish and Wildlife Seasonal Aid	<u>18</u>
	Totals	102

The total minimum manpower requirement for Research Team No. 1 for the proposed 50 month program is 426 man-months.

Any reduction of biologist or temporary help time will require curtailment of program activities, primarily in field operations on research vessels which of course, reduces the amount of basic data collected.

The Marine Culture Laboratory facilities and approximately 80 man-months of biologist assistance from its staff are required for completion of the planned tasks requiring laboratory checks and evaluations.

A direct supportive need is the crew time of research vessel crews of Marine Resources Region and the Anadromous Fisheries Branch estimated to be 17-1/2 man-months per year. In addition vessel operations and maintenance should be prorated to the crab program.

Approximately \$8,000 for other than Research Team No. 1 salaries and \$12,000 for supplies and equipment were expended for program activities January-June 1975. Equipment costs are expected to be lower in succeeding years.

A baseline for budgeting costs of operations and equipment has not been established but an estimate is \$34,000 for operations and \$3,000 for equipment annually after basic equipment is obtained in 1975 and 1976.

The final report of the findings of the Dungeness Crab Research Program, together with recommendations for legislative and administrative action to protect the resource and increase the abundance of crabs in California waters, will be prepared during the period May-August, 1979.

The costs of printing the final report should be met by provision of \$7,000 in the 1979-80 fiscal year.

Task Descriptions and Work Flow Charts

Work Flow Chart No. 1

Task Descriptions:

1. It is planned that 300 to 400 plankton tows per year will be made from Department research vessels to sample for the occurrence of Dungeness crab larvae in the Gulf of the Farallones and in north San Francisco Bay and San Pablo Bay. The primary collecting device will be a 0.5-m (1.7-ft) opening-closing plankton net; a standard 0.5-m plankton net will be used in waters shallower than 20 m (66 ft). Collection of these samples could establish a vertical and horizontal profile of crab zoeae in the Gulf of the Farallones and the San Francisco Bay-estuary complex. Experimentation will be conducted into methods of

- collecting crab larvae, other than plankton nets. Additional time is required for the design and testing of gear used in plankton sampling.
2. The plankton samples will be returned to the laboratory for processing each year. Processing will consist of isolation and enumeration of Dungeness crab larvae and identification of closely associated species. At a minimum, the time of one fully-trained person must be applied to this task throughout the year.
 3. Culturing of crab larvae from eggs through all larval stages will be conducted by biologists on the staff of the Department's Marine Culture Laboratory (MCL). This activity will require an expenditure of nearly 12 man-months per year during the larval-rearing season. The major activities during this period will be feeding and care of larval crabs and rearing food organisms. The non-rearing period will require a few hours per day applied to systems design and maintenance, literature research, and miscellaneous activities.
 4. Analysis of data emanating from the above activities will take place continually. Field activities may be altered necessarily in light of results from previous operations. Time periods will be set aside to run statistical analysis on accumulated data, to develop appropriate sampling techniques and to discuss trends generated by field observations. Data analysis will be performed primarily by project personnel with assistance from the Biometrics Unit at Menlo Park.

Work Flow Chart No. 2

Task Descriptions:

1. An estimated 100 days per year will be spent aboard Department research vessels in an attempt to sample for the occurrence of juvenile Dungeness crab. Juvenile crabs will be used for distribution, age, growth, tolerance, and tissue studies. Primary collecting devices will be a 5-m (16-ft) otter trawl, a 13-m (43-ft) crab trawl and a 2.4-m (8-ft) beam trawl. Experimentation will be conducted into additional methods of juvenile crab collecting. Additional time is required for the design and testing of gear.
2. Concurrent with the sampling for juvenile crabs, project personnel will collect, identify and determine the relative abundance of species in the Dungeness crab's biological community. An additional hour per vessel-day is required for this activity.
3. Concurrent with the culturing of crab larvae, a biologist of the staff of the Department's Marine Culture Laboratory will culture crab instar stages from the megalops stage. The care of the juvenile crabs and providing food will require 6 man-months of time annually. This research will refine techniques for full production procedures necessary to provide young crabs for testing tolerances to varying environmental conditions.
4. Bottom trawls conducted during the research cruises will yield numerous associated vertebrate species. Each year about 500 stomachs will be collected from selected bottom feeding fish taken in the research trawls.

5. The stomachs of vertebrates sampled from bottom trawls will be preserved and taken to the Laboratory for processing. Processing will consist of isolation and enumeration of whole or partially digested juvenile Dungeness crab and identification of closely associated species. Results of this analysis may yield useful information on distribution and predation of juvenile crab.
6. Approximately 72 man-days will be required to assess the impact of the local sport fishery on nursery ground population numbers. The operation would consist of observations by trained personnel of the sport fishery for crabs in San Francisco Bay and San Pablo Bay.
7. Analysis of data emanating from the above activities will take place continually. Field activities may necessarily be altered in light of results from previous operations. Time periods will be set aside to run statistical analysis on accumulated data, to develop appropriate sampling techniques and to discuss trends generated by field observations. Data analysis will primarily be performed by project personnel with assistance from the Biometrics Unit at Menlo Park.

TASK	1975			1976			1977			1978			1979													
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Tasks	Man-months			Totals
	Research team #1	Others		
1. Collection of juvenile crabs from research vessel trawls; crabs will be used for distribution, abundance, age, growth, mortality, and tissue studies.	5.5	0.6 MRR	6.1	
2. Collection, identification, and determination of relative abundance of species in crabs biological community.	5.5	0.6 MRR	6.1	
3. Rearing of crab instar stages from megalopae and providing food.	-	25.9 MCL	25.9	
4. Collection of vertebrate stomachs taken primarily in trawls from research vessels.	5.5	0.6 MRR	6.1	
5. Laboratory processing and examination of vertebrate stomach contents for evidences of juvenile crab.	24.0	-	24.0	
6. Study on local piers and jetties to assess impact of sport fishery on nursery ground population numbers.	3.6	-	3.0	
7. Analysis of data.	8.0	8.0 BU	16.0	
	52.1	35.7	87.2	

MRR - Marine Resources Region; MCL - Marine Culture Lab.; BU - Biometrics Unit.

FIGURE 6. Work flow chart no. 2, juvenile crab studies plan.

Work Flow Chart No. 3

Task Descriptions:

1. On cruises of Department research vessels sampling for the occurrence adult crabs will be concurrent with the plankton and juvenile crab sampling activities. In addition to trawl gear, commercial crab traps will be used. The primary objective of this sampling will be to gain information on distribution, growth increments, reproductive condition and sex ratios of adult crabs. Additional efforts may be expended in obtaining samples through commercial crab fishermen.
2. During the egg-bearing season, efforts of project personnel will be expended to collect ovigerous female crabs for egg culturing experiments and egg tissue analysis. Personnel may be required to accompany commercial crab fishermen when they are pulling their traps or to set and pull Department crab traps.
3. During the mating and egg-bearing seasons male and female crabs will be observed in the laboratory in studies of mating, reproduction, and biological infestations of egg masses.
4. An electrophoretic study on crab tissue to determine subpopulation structure of the Dungeness crab resource from Morro Bay to Kodiak, Alaska was contracted for in 1974-1975. Collection and transportation of crabs, reviewing of reports, analysis of reports and supplemental activities will require about 1 month of project action.
5. Analysis of data from the above activities will take place continually. Additional data is available from landing statistics of the Marine Resources Region. Data analysis will be performed by project personnel with assistance from the Biometrics Unit at Menlo Park.

TASK	1975			1976			1977			1978			1979		
	J	A	S	J	F	M	J	F	M	J	F	M	J	F	M
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Final Report
(Chart 6)

Tasks	Man-months		
	Research team #1	Others	Totals
1. Collection of adult crabs to gain information on growth increments, reproductive condition and sex ratio. Collections to be made from research cruises and commercial fishermen.	5.5	0.6 MRR	6.1
2. Collection of ovigerous female crabs and mature male crabs for reproduction studies, egg-culturing experiments, egg-tissue analyses, and egg infestation studies.	2.3	1.1 MRR	3.4
3. Conducting studies of reproduction and infestation of eggs.	-	4.0 MCL	4.0
4. Collection of crabs from various locations from Morro Bay to Kodiak, Alaska and electrophoretic study to determine if subpopulations can be identified.	1.0	-	1.0
5. Data analysis (Biological data of project and landing statistics of MRR).	8.0	2.0 MRR	10.0
	16.8	7.7	24.5

1. Collection of adult crabs to gain information on growth increments, reproductive condition and sex ratio. Collections to be made from research cruises and commercial fishermen.
2. Collection of ovigerous female crabs and mature male crabs for reproduction studies, egg-culturing experiments, egg-tissue analyses, and egg infestation studies.
3. Conducting studies of reproduction and infestation of eggs.
4. Collection of crabs from various locations from Morro Bay to Kodiak, Alaska and electrophoretic study to determine if subpopulations can be identified.
5. Data analysis (Biological data of project and landing statistics of MRR).

MRR - Marine Resources Region
MCL - Marine Culture Lab.

FIGURE 7. Work flow chart no. 3, adult crab study plan.

Work Flow Chart No. 4

Task Descriptions:

1. Historical data on sea surface temperature and salinity, upwelling and currents, etc., throughout the crab's range will be compiled and graphs prepared. The data will be keypunched for computer storage by the Menlo Park Biometrics Unit. Various sets of oceanographic data will be compared with landings statistics and various crab life history phenomena to look for possible correlations with high or low landings and the physiology, distribution, and abundance of crabs.

Ocean water temperature and salinity data will be collected on all research cruises. These will be compared with historical data to determine if conditions occurring now are typical.

2. Based on input from Task 1 above, and identification of critical stages in crab life history, laboratory experiments will be designed and conducted to study the effects of oceanic parameters on the crab's physiology, distribution, and abundance. This work will be done at the Marine Culture Laboratory by a project biologist with assistance from Marine Culture Laboratory personnel. It will depend upon a supply of larval and juvenile crabs reared by MCL personnel. Research animals may be supplemented by collections on research cruises.
3. Documentation will be made of levels and (or) effects in crabs of heavy metals, chlorinated hydrocarbons, PCB's, petroleum products, detergents, chlorination and biostimulation of domestic effluents, etc.

An ongoing literature survey will collate historical data and keep project biologists aware of current developments.

Crab eggs, larvae, and tissue samples from 400 crabs (100 adults and 100 juveniles each from San Francisco and Eureka areas) will be collected and processed for heavy metal testing. The samples will be divided between the Water Pollution Control and Moss Landing Marine Laboratories for testing of 10 heavy metals known to be potential environmental toxicants. Comparisons of the results between the San Francisco and Eureka areas will provide the basis for further laboratory experiments on environmental toxicants in crabs.

An additional 200 juvenile crabs and samples of eggs and larvae will be processed for testing for chlorinated hydrocarbons and PCB's. Testing will be done at the Department's Pesticide Laboratory.

Contacts will be made with agencies working on other parameters. Included are such agencies as: National Marine Fisheries Service, Tiburon (petroleum products and detergents); University of California, Sanitary Engineering Research Laboratory (chlorination and biostimulation of domestic effluents); Regional Water Quality Control Boards (monitoring and knowledge of waste outfalls), and others.

The feasibility of a special scientific contract to study effects of chlorination and domestic sewage on larval and juvenile crabs will be explored with Sanitary Engineering Research Laboratory, utilizing their bay model tanks.

4. Based on input from Task 3 above and identification of critical stages in the crab's life history, laboratory experiments will be designed and conducted to study effects of suspect parameters on appropriate crab stages. Bioassays will be done at the Marine Bioassay Laboratory

(MBL) by a project biologist with assistance from MCL and MBL personnel. Appropriate studies will be coordinated with other agencies wherever possible.

This research will depend upon a supply of larval and juvenile crabs to be reared at the Marine Culture Laboratory. The studies may be supplemented with collections from research cruises.

5. Data analysis will be ongoing during the project. Planning and implementation of Tasks 2 and 4 will depend upon preliminary analysis of data from Tasks 1 and 3. Analysis will be largely by project biologists, but considerable assistance from the Biometrics Unit will be necessary. Computer programs will be run to analyze large quantities of oceanographic and toxicant data. These will aid in determining the need for further sampling, and in designing laboratory experiments.

Annual data review, analysis and program planning will be done to keep the project on course.

TASK	1975			1976			1977			1978			1979		
	J	A	S	J	F	M	J	F	M	J	F	M	J	F	M
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Final Report
(Chart 6)

Tasks	Man-months		
	Research team #1	Others	Totals
1. Oceanographic data collection on cruises, literature, and various agencies. Including examination and comparison of historical environmental data with crab landings.	25	0.6 MER	25.6
2. Effects of natural environmental factors on crabs.	30	2.1 MCL	32.1
3. Environmental toxicant study.	25	..	25.0
4. Effects of man-caused environmental factors on crabs.	20	2.1 MCL	22.1
5. Data analysis.	20	12.0 BU	32.0
	120	16.8	136.8

MRR - Marine Resources Region
MCL - Marine Culture Lab.
BU - Biometrics Unit

FIGURE 8. Work flow chart no. 4, environmental studies plan.

TASK	1975			1976			1977			1978			1979												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
1	-						-	-	-	-	-							-	-	-	-	-			
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3							-											-							

	<u>Research vessel (crew time)</u>	<u>Man-months crew time</u>
		<u>(with SCOFIELD)</u> <u>(without SCOFIELD)</u>
1. KELP BASS	Crab research cruises April, May, and June each year (4-man crew).	56.0 MRR 64.0 MRR
2. STRIPED BASS	One week of San Francisco Bay studies each month, September through February each year (one boat operator).	5.7 AFB 5.7 AFB
3. N.B. SCOFIELD	Crab research cruises in March of each year (11-man crew).	44.0 MRR 69.7

MRR - Marine Resources Region
 AFB - Anadromous Fisheries Branch

FIGURE 9. Work flow chart no. 5, research vessel operations plan.

1975 1976 1977 1978 1979

TASK	J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D
1	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
2	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
3	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
4	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
5	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
6	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
7	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
8	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
9	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -
10	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -

Tasks

1. Preparation of personnel records, expense claims, montaly reports.
2. Program planning, budgeting, project evaluations.
3. Clerical services: shorthand, typing, filing, telephone, business services.
4. Procurement of supplies, equipment, gear maintenance.
5. Public information.
6. Meetings - State-Federal, P.M.F.C., CalCOFI, ORB Staff, Training, Universities, U.S. Agencies.
7. Cruise Reports, Annual Reports.
8. Marine Resources editing. (One Research Team member is also the Marine Resources Editor.)
9. Final Report. (This will be a concentrated team effort during the last several months of the program.)
10. Vacation, holidays, sick leave (Perm. staff of 6 biologists, clerical included in Task 3).

Research team #1 man-months

4	8	50	12	4	13	6	12	22	+3 BU	
Total									171	174

FIGURE 10. Work flow chart no. 6, administrative phase.

SYNTHESIS AND RECOMMENDATIONS

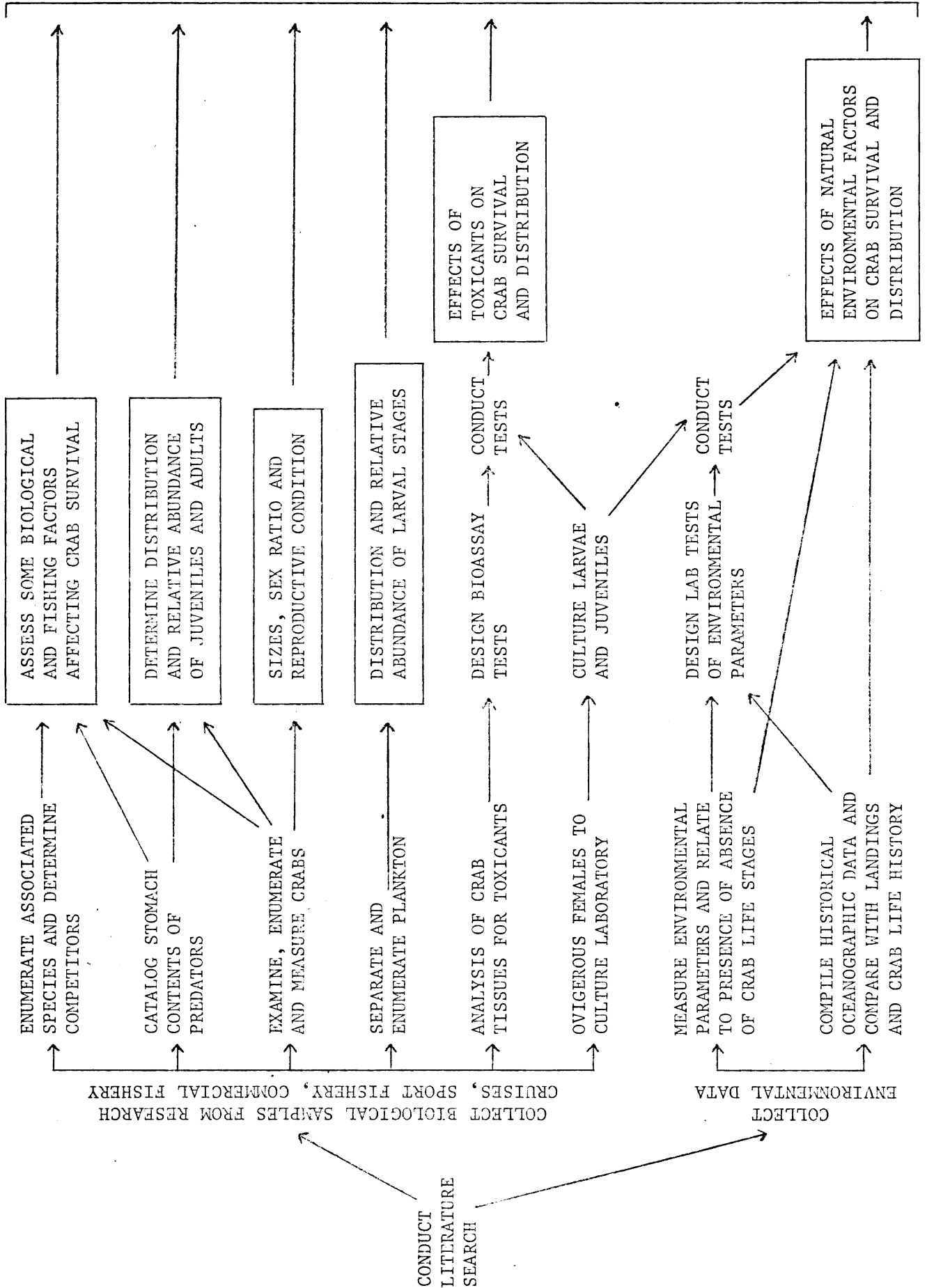


FIGURE 11. Dungeness crab research program task precedence diagram.