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CALIFORNIA FISH AND GAME

"CONSERVATION OF WILD LIFE THROUGH EDUCATION"

Volume 31 San Francisco, July, 1945 Number 3

45142

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DEPARTMENT OF NATURAL RESOURCES

DIVISION OF FISH AND GAME

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VOLUME 31 SAN FRANCISCO, JULY, 1945 No. 3

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CALIFORNIA FISH AND GAME is a publication devoted to the conservation of wildlife. It is published quarterly by the California Division of Fish and Game. All material for publication should be sent to Brian Curtis, Editor, Division of Fish and Game, Ferry Building, San Francisco 11, California.

Subscribers are requested to notify the Division of Fish and Game, Ferry Building, San Francisco 11, California, of changes of address, giving old address as well as the new.

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PROGRAM OF THE BUREAU OF MARINE FISHERIES [1]

By Richard Van Cleve
Chief, Bureau of Marine Fisheries
California Division of Fish and Game

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[1] Submitted for publication, April, 1945.
The program outlined here comprises the ideas of the entire staff of the Bureau. Special credit is due Dr. Frances N. Clark in charge of the sardine investigations, Mr. J. B. Phillips who is now working on the age analyses of sardines, Mr. D. H. Fry, Jr. who has carried on the mackerel investigations and for the past year has supervised the Central Valleys salmon work, Mr Paul Bonnot who has for some years carried on the shellfish investigations, Mr. W. E. Ripley in charge of the soupfin shark investigations, and Mr. W. L. Scofield in charge of the statistical system's field work.

INTRODUCTION

The program of the Bureau of Marine Fisheries is outlined for three reasons. First, the need for stating the general objectives of the research program of this Bureau has long been felt. While parts of the discussion of these objectives are necessarily technical, it is hoped that it will give to the fishing industry and sportsmen of this State some idea of the ultimate purposes of this research. The principal lines of investigation are described in some detail with brief summaries of accomplishments to date to illustrate methods used to attain desired results. Second, the future course of these programs is charted in order to make known our plans, the fulfillment of which is felt will result in a sound basis for the conservation of California's marine and commercial fisheries resources. These plans are in no way intended to be inflexible since a fundamental quality of a sound research program is that it must be responsive to changes that may be demanded as it develops. Third, the principal problems that must be tackled are outlined, with some indication of the many species that will have to be included in the investigations to lay a foundation for intelligent exploitation.

At present the research program of the Bureau is drastically curtailed. Major shifts can therefore be accomplished after the war without dislocation or upset. A general statement of the program is therefore particularly necessary now.

Commercial marine fisheries research may be developed along two lines. Technological investigations may be used to improve methods of catching or preserving fish, and to furnish information on distribution to enable fishermen to find them more easily or to extend the range of their operations. Other investigations may be called biological research and are designed to provide for the conservation of the species.

The two objectives overlap in some respects, but are different enough to require separate treatment. The function of technological investigations is principally improvement of the industry through improved methods of utilization, and the objectives are obvious. The principal objective of the biological investigations, however, is not always so obvious. It has been defined as "conservation of our marine resources", "wise use", or "maximum use providing for continuous yield". Such definitions are meaningless unless the significance of these catch phrases is appreciated.

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The validity of the fundamental concept of obtaining through properly conceived and efficiently executed regulation a larger yield from a marine fishery than can be expected under a condition of unrestricted and over-expanded exploitation has been demonstrated for the north Pacific halibut (Thompson & Bell, 1934). This fishery is the first, and so far the only marine fishery that is entirely under regulation. For this reason the results are of great importance to all marine fisheries.

In 1930 intensive fishing by the entire fleet was required to land a catch of forty-nine million pounds of halibut in nine months of operations. The catch per unit of gear from the population of fish inhabiting the coast of southeastern Alaska, British Columbia, and Washington had fallen from 280 pounds in 1907 to 35 pounds in 1930. The catch from the less depleted stocks along the rest of the coast of Alaska to Unimak Pass in the Aleutian Islands had fallen from 288 pounds per unit in 1915 to 64.7 in 1930. The intense fishery on the more depleted stock had practically eliminated the spawning sizes of fish. The evidence of depletion was inescapable and by 1931 the fishing fleet was in distress, operating at a loss.

By this time a sound biological basis for regulation had been developed. With these combined stimuli, a new treaty was adopted in 1932 which provided for a total catch limit on each of these independent stocks of fish. The benefits were immediate; and by 1944 the catch per unit of gear had increased to 2.4 times its 1930 level off the coast of British Columbia and southeastern Alaska. More fish are now taken with a fraction of the effort required in 1930; and the released energies of the fishermen are available to use profitably in the increased production of other species.

Not all fisheries will lend themselves so admirably to regulation as does the halibut. However, the principles involved hold in all fish populations. That is, within broad limits, each species and each separate population of that species is able to produce fish at a certain rate, dependent upon its biological characteristics of growth, mortality, and rate of reproduction. To take more than this amount of fish will result in economic waste through the eventual decrease of total take, as well as the increased effort and cost of obtaining it. On the other hand, to take less than this amount is also a waste, since the full potentialities of the resource are then not being realized.

CONSERVATION OF CALIFORNIA FISHERIES

The increasing importance of California's fisheries resources with the increased population of this State not only demands that we make full use of the fisheries, but also that we do not over-use them. We must adjust the rate of exploitation of each species to the ability of that species to produce. This adjustment is the objective of the second branch of marine fisheries research. Without that research, the adjustment is impossible and our fisheries resources will eventually become depleted. Under such mismanagement, productive fisheries will be lost. The industry will be faced with increased costs and eventual dependence on less desirable species or imported products. In either case, the fishermen lose their means of livelihood.

The principal product of this branch of marine fisheries research is some form of regulation. Artificial propagation of marine species has been proven impracticable; and it is conceded that artificial propagation of anadromous species has not been proven more efficient than natural propagation, nor has it been found economically justifiable. There is no possibility of controlling the natural marine environment so as to produce a better yield. The only factor that can be affected is the rate of predation by man. This can be adjusted by regulation.

The stream environment of anadromous fishes can be controlled, and in fact along the western seaboard is being controlled in an adverse manner by the construction of dams and diversions that are rapidly closing large sections of our streams to such species, or are drying them up. This problem is particularly important to the salmon fisheries, and will be considered under the salmon program.

Because of the importance of well-founded conservation programs to the welfare of commercial, as well as sport fisheries, a discussion of the principles involved is necessary.

Reactions of Marine Populations to Their Fisheries

In the normal growth of a fishery there are certain developments which may be expected, provided the stock of fish exploited is in balance with its environment, and natural fluctuations are not great enough to mask the effects of the fishery. As noted above, in the halibut the amount of fish taken per unit of gear run, or, in other words, per unit of effort, has been found useful as a measure of the abundance. Using this measure, or any other appropriate one, the catch per unit of effort in any fishery will fall with an increasing intensity of fishing; and if this intensity finally becomes constant over a long period, the catch per unit will level off. The average size of fish taken in any fishery will decrease as the larger and older fish decrease in abundance; but this too should level off at some point if the fishery does not continue to increase in intensity. Normally, too, the fishery may be gradually extended either throughout the range of the species, or, as in the sardine fishery, to the limit of economical operation of the fishing fleet. Each further extension of the grounds is usually associated with increased efficiency of boats or gear, and signifies an increased intensity. Over a period of time, the extension of fishing range usually reaches a maximum for each change in gear and boats.

With the decrease in abundance of larger sizes of fish, the average length of life of a fish before it is caught will be less. The length of time over which dominant age groups can be traced in the fishery will decrease, and the fishery will come to depend more and more on fewer age groups.

Changes in number of older fish may also result in changes in numbers of eggs and young produced. These changes may be unimportant, compared with those resulting from variations in other factors, such as temperature of the water or abundance of the microscopic food at some early critical stage of development. The existence of dominant age groups of sardines, even under the early small fishery of 1920 to 1933 indicates that natural conditions played a large part in determining the size of any one year class. What factors cause these fluctuations are not known. Until better methods are perfected of determining abundance of the sardine eggs and larvae, or the absolute abundance of separate age groups in the population, and until these improved methods are extended over enough of the range of distribution to give dependable results, it is impossible to state whether or not changes in abundance of adults resulting from increased fishing intensities can or can not influence the abundance of the larger age classes through decreased production of eggs. In slow-growing species which are exploited for several years before reaching maturity, it is almost inevitable that the amount of spawn produced will be diminished by an intensive fishery. In species which mature earlier and at or before the time they enter the fishery, it is possible that the effects may not be so marked. However, too much faith must not be placed upon the ability of any stock to produce sufficient eggs and young under a heavy fishery until this capacity has been proven to exist.

A decrease in average size of fish with a shorter life expectancy, as well as a lower catch per unit of effort, associated with an increased range of fishing activity, may be merely evidence of the normal growth of a fishery. They indicate a decrease in abundance of fish, but this decrease occurs from the moment fishing of any intensity starts.

Depletion

What, then, is meant by overfishing, or depletion?

Both of these terms may be purely relative in their significance. They denote a reduction in numbers of fish, as a result of fishing, below the point at which the boats can operate economically. A specialized fishery, depending upon one species and not adaptable to taking other species, could die under these conditions, or an inefficient fishing method may suffer from overfishing where a more efficient operation could prosper. As far as we now know, there is little possibility of the biological extinction of most species by a fishery. Exception must be made in the case of the most efficient types of gear, the most valuable or accessible species, or those species with slow growth or a low rate of reproduction. In general, a fishery will kill itself long before it kills the species it depends upon.

In one sense, then, overfishing and its copartner depletion may be thought of as economic in nature, and might be defined as that state of a fishery where the abundance of the species upon which it depends has decreased as a result of fishing beyond the point at which the catch per unit of effort is sufficient to permit the boats to operate at a profit. Many complications arise, and the point at which the balance is tipped one way or the other will vary with the price of fish and the cost of operations.

There is another meaning that may be given to over-fishing, which is purely biological. Within the limits of natural fluctuations, every species, or each fishery, will have a certain level at which the efficiency of production in terms of pounds of fish is greatest. This level is determined by the rate of reproduction, the rate of growth, and the rate of natural death, which have characteristic values for each species but may vary within limits for separate races or populations. For any species and any combination of these values there is theoretically a certain range of fishing intensity which may be extended to give the highest return of which that species is capable (Baranov, 1918, Thompson & Bell, 1934). Under these conditions the excess of growth and recruitment over natural losses is entirely utilized in producing the largest annual catch possible without diminishing the brood stock. Overfishing may be thought of as that condition where the fishing intensity has become so great that this excess is thereby diminished.

Various features of the relationships between rate of natural death, fishing mortality, growth and catch have been discussed by many authors and developed primarily by Baranov, 1918, and applied by Thompson & Bell, 1934, and Thompson, 1937. From these discussions, it is clear that overfishing may exist in a stabilized fishery, and may vary in degree. It is apparent that the effects of over-fishing usually become of concern to the industry only when its biological effects result in a stock that cannot be economically exploited. This may or may not be at a level of abundance that is dangerous to the continued stability of the stock.[2]

Fisheries administrators must be concerned with the adjustment of the fishery to obtain the maximum yield.

The Function and Methods of Biological Fisheries Research

The above factors are fundamental to an understanding of the function of biological fisheries research in the conservation of a fishery. It is assumed that it is desirable to stabilize a fishery at its highest potential yield, and that it is undesirable to permit overfishing with its resultant decrease in rate of returns and the economic hardships thus imposed on the industry. The seemingly abstruse fisheries investigations of conservation agencies can be justified under these assumptions if they can be proven to lead to a solution of the problem of conservation.

The general objectives of biological marine fisheries research are: First, to define the stock of fish supporting a particular fishery; and second, to determine the factors affecting the abundance within the stock and to measure their effect.

The stock is first defined as to species. Then within each species the distribution and existence of separate races, or more or less independent groups, is determined, and the movement of individuals within the range of distribution is studied. In other words, we must find out whether the fishery is supported by one population, or by a number of independent groups—each requiring separate treatment.

Each independent group must be considered by itself, and the various factors controlling its productivity determined. The rate of reproduction in terms of numbers of eggs or young produced by the average individual and by the entire stock, and the variations in these numbers from season to season, must be related to the intensity of fishing and to associated natural factors. The rate of growth, determining the weight of the individual at any age, must be correlated with the size and age at maturity, and the size and age at which they are taken by the fishery. An estimate of natural mortality is necessary to aid in determining the level of fishing intensity which should be maintained to obtain the greatest yield.

All of these factors must be considered in the management of a fishery. While some are more important than others, intelligent regulation is impossible without some knowledge of all of them. Without this information, control cannot be planned; and if exercised, it usually expresses the desires of the strongest pressure groups. As such, it has

[2] For the sake of simplicity, the question of competition between species is omitted, as well as the problem of supplanting a depleted desirable species with a less desirable species through intense fishing. These problems are nevertheless real ones and must be considered.

no foundation in fact, and certainly cannot benefit the fisheries, while in some cases it may be harmful.

Fisheries research is, therefore, entirely practical in its objective. Contrary to frequently expressed opinions, its purpose is not to provide work either for indigent biologists or for those misguided people solely interested in delving into abstruse problems that are of concern only to similarly interested individuals. Its justification for support as a public enterprise is to furnish material on which administrators can base an intelligent and progressive conservation program. It is true that results obtained have in the past sometimes not been usable but these have arisen from programs that were not properly designed to relate the work to the industries exploiting the fisheries. In the course of the investigations many fundamental biological problems of only indirect application to administration are encountered and must be tackled. These supplement the main program but should never dominate it.

The application of the principles outlined above will become more apparent with the consideration of the problems of the different fisheries.

DISTRIBUTION OF RESEARCH EFFORT

One of the difficult problems encountered in planning a research program concerned with such a wide variety of species as is the Bureau of Marine Fisheries is the proper distribution of effort. The catch of fish and shellfish in California is recorded under seventy different categories. Many of these, such as "flounder", "sole", "shark", "rock bass", "salmon", etc., comprise several different species. There are approximately 120 different species of fish and shellfish which enter the California commercial catch in some form or other. The problem is to decide what species should be worked on first, and what type of information is needed.

This decision rests upon two factors: The commercial importance of the species (its productivity), and the need for information as shown by the course of its landings. Aside from the value of the various species compared with the value of other species in the State's total catch, there are certain problems that have arisen and will arise in the future which require solution. The cost of their investigation may be all out of proportion to the annual value of the fishes concerned. However, if, by a few years' concerted effort, those fishes can be saved for future generations, the money will be well invested.

The most noteworthy such case is found in the Central Valleys Irrigation and Power Development. As originally designed, the many dams proposed throughout the Central Valleys area, combined with the diversion ditches, would set up conditions under which even the much-persecuted Sacramento salmon could not long survive. Whereas a tax income is derived from salmon, amounting to from $15,000 to $30,000 per year, the cost of the investigation required to attempt to allay the adverse features of the project in favor of the salmon will amount to several times the income derived by the State from this fishery.

Another basic operation will be a complete survey of our clam beaches, and kelp and agar beds. Individually, none of these species—mollusk or alga—appear of importance, yet collectively they are definitely a factor in our fishing industry. In both these groups the beds are easily subject to heavy exploitation, and need control.

TABLE 1

California Landings and Value of Commercial Fish Landings by California Boats—1943

Species	*Pounds*	*Value*
Sardine	972,249,015	$10,781,440
Mackerel, Pacific	75,262,739	1,492,918
Tuna, Yellowfin	49,261,328	4,880,540
Tuna, Skipjack	28,893,784	2,582,850
Tuna, Albacore	21,384,864	3,477,417
Mackerel, Horse	12,698,974	235,878
Tuna, Bluefin	10,178,768	967,562
Squid	9,164,361	265,028
Salmon	6,581,076	1,227,624
Yellowtail	4,934,879	368,724
Sole	4,782,379	265,203
Barracuda	3,775,278	656,372
Shark	3,729,246	1,933,173
Sablefish	3,206,074	267,671
Rockfish	2,762,192	185,541
Shad	2,348,143	114,648
Crab	2,315,338	353,287
Tuna, Bonito	2,282,299	181,354
Anchovy	1,570,803	29,195
Smelt	1,562,241	198,787
Halibut, California	1,121,673	238,670
Lobster, Spiny	985,525	256,153
Oyster, Japanese	741,105	29,656
Cultus, Pacific	719,318	65,010
Sea-bass, Black	700,855	157,298
Abalone	680,444	54,786
Herring, Pacific	630,358	17,239
Clam, Pismo	611,634	57,911
All others	4,646,255	608,834
Totals	1,229,780,948	$31,950,769

The relative volume of landings of various species with their value to the fishermen are shown in Table I. In order of importance of research projects of this Bureau, the sardine investigations must retain first place, both because of the great importance of the fishery, and because of the extent of its development which has maintained the total yield at an average of 548,000 tons since the 1934-35 season. In spite of a considerably lower yield and value than other species, the salmon and Central Valleys investigations must come next in line of emphasis because of the impending loss of this species, resulting from the apparent desire to promote the use of water for every possible purpose except that of the fish. The five species of tuna are ranked next in importance, but their investigation will be delayed no longer than the time when an adequate staff can be set up. The wide fluctuations that have taken place in the mackerel catch indicate a definite instability of supply. We must try to determine what this instability arises from, principally with the idea that if by some chance it should be associated with controllable factors such as fishing seasons or amount of catch, then by proper allowance for these factors, the fluctuations could be diminished; or failing this, some method may be found whereby cyclical changes may be predicted. Other work concerned with the crab, shrimp, other shellfish, rockfishes and flatfish will be prosecuted as soon as adequately trained biologists can be obtained to carry on.

STATISTICAL RECORDS

The basis of fisheries research is a record of the amount of fish taken. A system of collecting detailed information as to catch by species, taken from defined areas, landed in particular ports, by different boats, using various types of gear, with records of the purchaser and price, has been developed by the Bureau of Marine Fisheries over the past twenty-five years. It has compiled the most complete and accurate record available anywhere for a comparable complexity of species.

Records of total landings and computed annual values of the products are not alone sufficient to justify the expense and effort required to maintain acceptable records. Their principal value is found in the record of fluctuations in abundance of the various species upon which the commercial fisheries depend. Whether one is dealing with kelp, mollusks, or fish, the fluctuations in yield, compared with the effort required to obtain that yield, are in most cases the best measures of the condition of the fishery.

To serve this purpose, statistical records must be complete and accurate, as well as current. They must be continually checked against changes in methods of fishing and marketing that might affect them or their accuracy.

Such a system cannot operate automatically, nor does it grow spontaneously. The excellence of the present system of the Bureau of Marine Fisheries is a direct result of the enthusiastic and untiring efforts of the many people who have worked with it. Its future depends upon an equal effort by those presently charged with that responsibility. The statistical system must keep pace with changes in the fisheries. Otherwise, it will suffer the fate of so many similar projects which have slipped gradually into an innocuous routine serving no one but those who profit from the salaries paid to administer it.

The statistical system has been described in detail in Fish Bulletin No. 44 of the Division of Fish and Game Fish (Bureau of Commercial Fisheries, 1935). It has depended upon close contact with fishermen, processing plants, and buyers, maintained principally by wardens of the marine patrol.

An effective system of maintaining and improving the statistical records of our fisheries must be based upon the cooperation of the industry. While the submission of statistical returns on landings is required by law, there is no way of enforcing accuracy except through the help of fishermen and buyers, unless the patrol effort could be greatly increased on both sea and land. This would be both impractical and undesirable. The cooperation of the industry can be neither developed nor retained without continuous contact by trained men. An efficient contact system is fundamental to a sound statistical system, and must be developed and maintained either through the marine patrol force or through statistical field men.

Type of Records Needed

The basic statistical record, of course, is the amount of fish landed. Various problems arise in this regard. While most of the species caught and sold are well recognized, a continual check is required to be sure that inaccuracies do not enter through the notation of fish under wrong specific names.

An even greater problem is found in the relative amounts of fish landed round, cleaned, or dressed. Since all figures are eventually recorded in terms of round weight, corrections must be applied to various species landed after cleaning. Changes have taken place in recent years in the methods of handling salmon, for example; and considerable quantities are landed cleaned. While some of these errors can be corrected through noting price differences, this is not a good check, partly because of different prices paid for the two species of salmon taken in the catch.

Another example of present difficulties is found in the shark fishery where practically all carcasses have in recent years been landed both cleaned and dressed. The livers have often been landed alone, and carcasses discarded. It is frequently impossible to separate these weights; and as a result our records of shark landings are inaccurate. In fact, the error has been estimated to be at least thirty per cent.

Since the matter of principal interest to conservation is the amount of fish removed from the fishery, some estimate must be obtained of the amount of fish caught but not recorded as sold because it is discarded as "unfit for human consumption".

It is impossible to say how large is the present error in our records due to all such factors. While the error is probably not large in most cases, a thorough survey of this problem throughout the State must be undertaken as soon as practicable to lay a foundation for corrections.

Location of Catch

Another basic record is the exact location of the catch. Statements made by individuals indicate that these localities are often purposely inaccurate, usually because fishermen are reluctant to reveal their choice fishing spots to other fishermen through dealers. Only interviews by the Division's employees can correct this, and will require continuous contact with fishermen.

Gear and Boat Records

License records of boats should give information on type and size of boat, and type of gear run. The gear varies throughout the season and must be continually checked. Observation of the gear used upon a particular boat once or twice a year is not enough, since more frequent changes are often made. Accurate records of the changes are required for the basic analysis of catch, according to gear. Some study will be required to determine how effective our records are in this regard. This can be carried on for certain species in the course of their work by the research staff. Others must be checked in the course of the survey of weight records.

When boats are first licensed, they are given a "Fish and Game number". This provides a means of identification for a boat that is free of the frequent changes and duplication of names and changes in Customs House numbers. Even these numbers must be checked frequently and new boats lacking numbers must be noted, as well as lost numbers replaced.

The statistical system requires first, a survey of its efficiency, as suggested. In some localities, notably northern California ports, field men working directly with the statistical staff will have to be stationed to maintain liaison with the industry. For the present the collection of records and checking of boats along the coast south of San Francisco must remain in the hands of the marine patrol, with occasional checks by scientific personnel.

Handling of Records

The original ticket forms filled out by the fish buyers, containing basic information, are collected and brought into or mailed by dealers to four central offices—San Francisco, Monterey, Terminal Island, and San Diego. In the San Diego offices these are checked for dealers' names, boat numbers and names, area of capture, etc.; and then sent to the central office at Terminal Island. San Francisco and Monterey offices are provided with facilities for punching the cards used in machine analysis. The punched cards, as well as checked original records, are sent to Terminal Island. These records of the catches of individual boats and of the purchases of dealers are by law confidential. They cannot be made available to the public except in the form of summaries "* * * * so as not to disclose the individual record or business of any person * * *" (Section 1096.5 of the Fish and Game Code).

The analysis of these records which cover an average of over a billion pounds of fish each year requires an efficient and stable clerical staff. It is planned to move the main statistical office from Terminal Island to central California. This will relieve difficulties experienced in the past in maintaining a clerical staff in a relatively inaccessible locality, and will leave enough room in the present Terminal Island laboratory to accommodate the research staffs needed for the investigation of the tuna, mackerel, and other predominantly southern forms.

On the other hand, the locality to which the statistical center is moved must be suitable for the location of some of the research staff; and in view of this, the places open are very limited. Consideration of the many factors involved points to a choice between Palo Alto and Berkeley. The latter location appears to be most advantageous from the point of view of both the research and statistical staffs, and would have many advantages from the point of view of administration.

SARDINES

The sardine investigations have been carried on since the establishment in 1917 of a scientific staff in this Bureau. Much data have been collected; but some controversy has developed in the past as to the interpretation of the results. It seems to be worthwhile, therefore, to consider evidence that has been interpreted as proving depletion, and to examine it in the light of the present condition of the fishery.

Catch Per Unit of Effort

Investigations of the sardine fishery have shown that a decrease in catch per unit of effort has occurred since the 1935-1936 season. This decrease, as measured by the average catch per boat month has been calculated by Dr. F. N. Clark to be 34 per cent in the last 10 years.

The average return per unit of effort, expressed as adjusted weekly catch per boat (Silliman and Clark ms), is shown in figure 21-A as per cent of the 1932-33 average. Another measure of the same thing was calculated by taking the total monthly catch in California in the different years and dividing it by the number of boats fishing. It is interesting to note that this rough figure (shown in figure 21-B) is not very different on the percentage scale from the highly refined and corrected one calculated on a weekly basis. This is hardly surprising since the corrections imposed on the latter measure are based upon correlations which are true only on the average, and in which many complicating and unmeasured factors creep in. Corrections for these factors are only valid within the limits of the accuracy of agreement between the variables concerned, and when the trend line is used for this correction all the other possible degrees of relationship expressed in the variation of the individual observed values about the average or trend line are lost. Many other factors not measured by these corrections probably influence the magnitude of this measure of abundance.

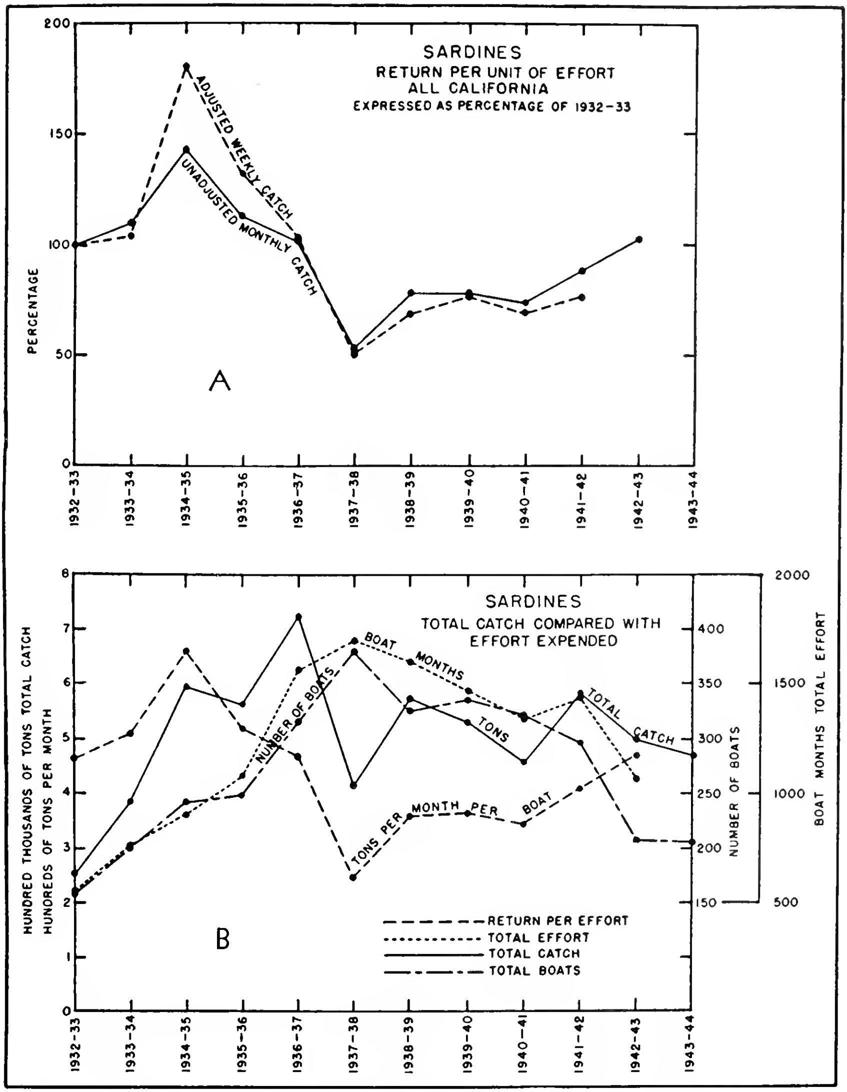

FIG. 21. California sardines. Return per unit of effort, and total catch compared with effort expended.

Of greatest interest is the fact that both measures show a definite tendency to level off at an average of about 70 per cent of the 1932-33 figure up to the 1940-41 season. In the past two seasons the trend is upward; and in the 1942-43 season it reached a level above that of 1932-33.

In figure 21-B, the catch in tons per boat per month in California is compared with the total number of boats fishing, total catch, and total effort, as measured by the total number of boat months, for each year. Theoretically, these various factors should be related in such a manner that a significant increase in number of boats or total effort from a lower to a higher level should be followed by an immediate increase in total catch. At the same time the catch per unit of effort should begin falling. After the initial increase in total catch, it too should change to some new level (as long as the effort remains constant), either higher or lower than before, depending upon whether the fishing has or has not reached its highest productive level.

The sardine picture is complicated by many factors. Previous reports (Clark, 1931) have shown that in some years for unknown reasons there is a greater survival of eggs and young and this results in the production of a large year class. Entrance of such a year class into the fishery when it has been preceded and is followed by several small year classes will result in a sudden increase in abundance of sardines with a subsequent decline until another large year class appears in the catch. A variation in abundance could be expected, therefore, from the appearance and gradual attrition of these large year classes, regardless of the reactions to variations of intensity of fishing.

Superimposed upon the effects of variations in size of the population of sardines is that of its availability to the fishermen. This may be determined by the size of schools that are formed, by the courses they follow in their migrations that bring them within the fishing areas or keep them offshore, and by the depths at which they occur or the speed with which they move through the fishing area. All of these may be the result of variations in the ocean currents off the coast, as well as of the location and abundance of food. In addition, prolonged periods of stormy weather or stormy negotiations over fish prices and sales practices have often held the fleets in port for weeks at a time.

In spite of all of these complicating factors and the rough, uncorrected measure of average catch per boat used, some agreement between the actual and theoretical picture is seen in figure 1-B. The effort (boat-months) and number of boats increased continuously from 1932-33 to 1937-38. The total catch kept pace with this increase until the season of 1936-37 when it reached the peak of 725,000 tons. The catch per unit (or catch per boat-month) increased up to a maximum in the 1934-35 season, thereafter falling steadily to 1937-38. Since the 1937-38 season, the number of boats has fallen off from over 379 to about 206 in 1943-44; and the number of boat-months has decreased from 1,700 to 1,059 in the same period. Much of this decrease has resulted from the loss of boats to the armed forces which began early in 1941. As a result, the sardine fishery has suffered an artificial reduction in total fishing effort in the last three seasons.

FIG. 22. The San Pedro fishing fleet. The larger boats are sardine purse seiners. The smaller boats fish with long line, with gill net for shore and bottom fishes, or with trolling gear for albacore.

The total catch has tended to vary around an average of slightly over 500,000 tons since the 1937-38 season. The catch per boat-month which hit a low point in 1937-38 remained fairly constant over the next three seasons, then showed a slight rise in 1941-42 and 1942-43. It is too early as yet to state whether or not this rise in catch per unit of effort has resulted from the decrease in total effort and therefore indicates an immediate positive reaction to such changes in the fishery. However, it would not be unreasonable to suppose that this might be true if the reactions of the sardine fishery are the same as those found in the halibut fishery (Thompson & Bell, 1934). On the other hand, this effect may have resulted from the enforced removal of catch limits or from the addition of the month of October to the southern California fishing season in 1941.

While the number of boats and boat-months have fallen steadily since 1937, the efficiency of the fleet has increased with the greater skill of fishermen in handling the gear, the use of radios in concentrating greater numbers of boats in areas of heavier abundance of fish, and with improvements in gear and boats. The true amount of effort may have remained at least at the same level as in 1937 until the great loss of boats occurred in the 1941-42 season.

With a multitude of complicating factors, more accurate measures of abundance of sardines and of the total effort expended by the fleet are both needed. However, if the present figures can be accepted as sufficiently accurate to indicate trends, some conclusions can be tentatively drawn. All such conclusions must be qualified, however, by the lack of definite knowledge upon many points of the biology of the sardine population such as: the variations in distribution and total success of spawning and the relation between such variations and the size of the resulting year class; the quantitative relationships between different sections of the population that extend from Mexico to Canada; the varying movements of this population that determine its availability to fishermen regardless of its actual size; as well as the effects upon catch per unit of effort of a large year class.

With these and other reservations in mind, the relationships indicated in figure 21-B may be interpreted literally as indicating that the abundance of sardines and resultant total production is affected by the

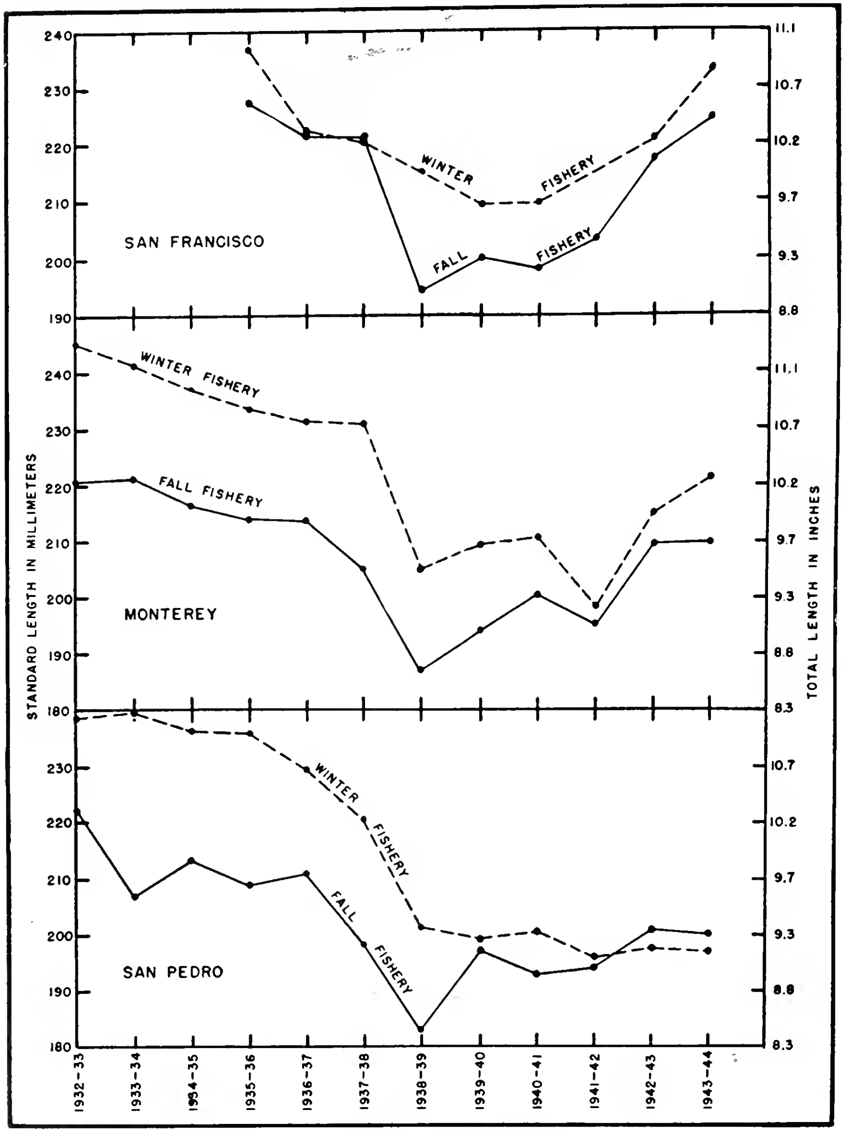

FIG. 23. Average length of sardines

amount of fishing effort expended. They may also indicate that a further increase in total fishing effort, much beyond that which held on the average during the period following 1937-38, will not result in a great permanent increase in total catch. Moreover, the average return per boat may be expected to fall as the number of boats increases. A further decrease in total catch may occur if the total fishing effort is increased markedly beyond the 1937-38 level. Confirmation of these relationships will require at least a partial solution of the problems outlined above. Public and industrial inertia will probably permit a further series of changes in the fishery to occur before action is demanded or becomes possible whether the result is favorable or unfavorable to the fishery.

Average Size

Clark, 1939, noted a steady decrease in the average sizes of fish taken at the three ports in the fall and winter fisheries. Extended to the 1943-44 season, the average size shows practically the same trend as the catch per unit of effort, although the decrease started in 1932, at the same time the intensity of fishing began to increase.

Average sizes of fish, obtained from samples of the catch at the three ports, are shown in figure 23 for the fall and winter fisheries. These fisheries were divided on the basis used by F. N. Clark (1939). San Pedro shows a leveling off of the average sizes since 1938-39, indicating that the total fishing intensity, the growth, recruitment, and natural mortality are very nearly in balance. The increase in average size for both fall

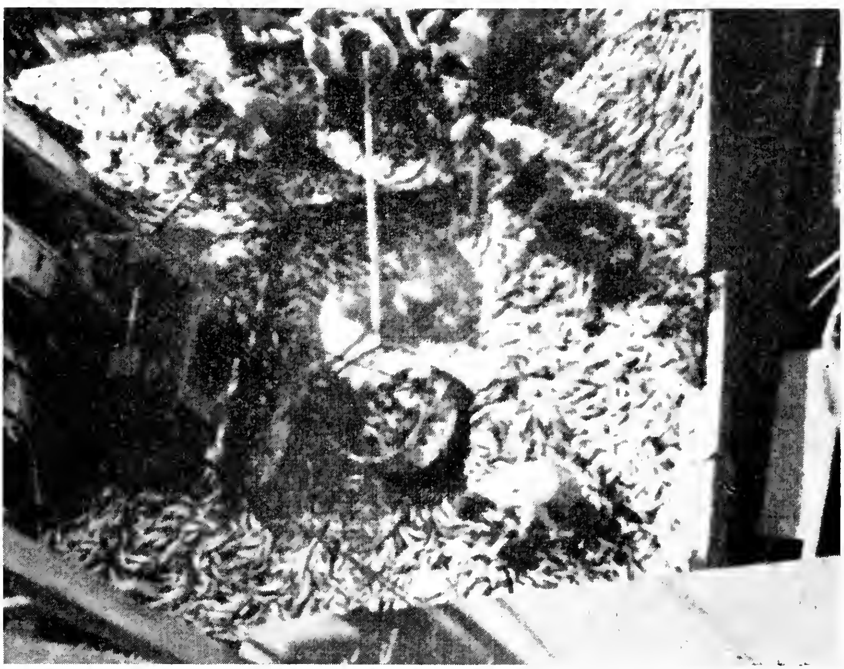

FIG. 24. Unloading a "deckload" load of sardines (1933).

and winter fish off San Francisco and Monterey is difficult to explain at present, but may be due to variations in relative abundance of small fish due to changes in size of dominant year classes. The San Francisco fishery shows several differences in results of tagging experiments that point toward the validity of this explanation. (Clark & Janssen ms.)

Clark also demonstrated that the dominant age classes which formerly could be followed and noted in the fishery for eight to ten years now retain their dominant positions for from two to four years only.

All of these measures of population condition indicate a decrease in abundance over that which existed prior to the great growth of the fishery, beginning in the 1934-35 season. At least they indicate a decrease in abundance of the sizes of fish that support the fishery. However, it appears that some sort of stability was reached by 1938-39, and is being maintained under present levels of fishing intensity.

Recruitment

Silliman (1943) published a theoretical treatment of the rates of disappearance of the various age groups at present intensities, compared with those noted for the period of 1919-20 to 1932-33. Combining these with total catch and relative amounts of effort, he found an increase of two-and-one-third times in the rate of recruitment under the more intense fishery than under the former less intense one. The possibility that this increase in rate of recruitment resulted from a natural cycle in environmental conditions which resulted in a heavier spawning and greater survival of young in the latter period, as well as the nature of the date and method of analysis used, make it necessary to accept this conclusion with some reservations. Results of last year's sampling give further indication that this increased recruitment was not a result of the decreased abundance, and was due to one or two dominant year classes that were produced in this period. It cannot be interpreted at present as proving a direct relationship between intensity of fishing and rate of recruitment.

The important features of the reactions of the sardine to its fishery will be found in the continued course of the above-noted measures of abundance. The average catch per unit of effort, as measured above, the average size of fish, and associated length of life of the dominant year classes apparently have reached a level under present fishing intensity and have shown a tendency to rise with a decreased intensity of fishing. It now remains to be seen if natural fluctuations in abundance will be great enough to upset periodically this balance, and either bring about a major decrease or increase in abundance with its associated repercussions on the industry. Even though such a level may have been reached, a further increase of intensity of fishing should cause another fall in abundance.

Where should the abundance be adjusted, presuming such a course of action should be found necessary? There is a possibility that the economics of the fishery may cause it to adjust itself finally to reach its own level of intensity; but if this does not occur, and the average size of fish, and average rate of return should again begin their downward trend with increased fishing, how far should they be permitted to go?

Present knowledge of the sardine and its fishery is not sufficient to permit setting such a figure. Much will depend upon the results obtained by fishermen in the next few years. If the total catch falls markedly with an increased fishing intensity, regulations should be adopted to curtail the catch. However, it cannot yet be predicted whether or not this will happen. Until the expected increase of intensity has occurred and the reaction is noted, no further recommendation can be made.

Present Program

The present sardine program of the Bureau of Marine Fisheries is greatly restricted because of lack of personnel. It has been carried out in cooperation with fisheries departments of Washington, Oregon, the Fisheries Research Board of Canada, and the U. S. Fish and Wildlife Service. Current work consists of maintaining and working up the samples of fish collected from fishing boats; and of determining the ages of the fish in these samples and therefrom obtaining information as to the relative strength of various year classes and the rate at which they disappear from the fishery. As shown by Sette (1943), Walford and Mosher (1943), and others, the use of these samples requires a complex series of manipulations to correct for various factors, all of which tend to produce errors in the results. These errors distort the picture that would be presented were the stocks completely available to the fishery, and no factors other than natural mortality and fishing mortality, growth and recruitment, measured. The availability of the fish, and the unmeasured but hypothesized effects of weather and other influences upon the efficiency of the fleet in producing fish make it very difficult to determine the accuracy of the results obtained.

It is obvious that the more simple and direct the approach to this problem can be made, the more quickly will usable and understandable results be obtained.

The primary objective is to determine the nature of the stock that supports the sardine fishery. This has been attacked by tagging—the simplest and most direct approach possible. The number of fish tagged by the participating organizations is shown in Table 2, with the number of tags returned from the fishery up to the end of 1943.

TABLE 2

Numbers of Sardines Tagged by Different Agencies to Date and Numbers of Tags Returned

Fisheries department tagging	*No. of fish tagged*	*No. of fish recaptured*
California	108,333	7,591
Fisheries Research Board of Canada	20,391	485
Oregon	7,788	70

Tagging methods, and methods of obtaining recaptured tags are described by Clark & Janssen ms. and by Hart (1943). The distributions of the returns indicate that fish migrate throughout the range of the fishery from southern California to British Columbia. When corrected for the different numbers of fish taken by the fishery at different parts of the coast, the rate of decline in abundance calculated for the entire coast is about 61 per cent. When the returns obtained in the California fishery from California tagging experiments are used for calculating rates of decline, higher rates are obtained than when returns from the northwest fishery are included. The differences are probably a measure of the loss of fish from California waters due to migration of the fish to the northward. The many complexities introduced by the combination of many experiments carried out in different years and therefore subject to as many different sections of the varying trend in fishing intensity, as well as to different sections of the ecological trend, render it difficult to interpret these results. Complexities occur in the distribution of the fish. However, these are of minor importance to the main thesis that the sardine fisheries of British Columbia, Washington, Oregon, and California seem to be based upon the same stock.

Future Program

The results of the investigations to date define the program for the future. It is not desirable to set up exact rules or methods under which this program should be carried out, but merely to point out various objectives which at present appear to be most important and to require the most effort. While the work outlined here is essentially that contemplated for the staff of the Bureau of Marine Fisheries, it will have to be carried out with the assistance of other cooperating agencies.

Objectives

Changes that have taken place in sardine abundance, as indicated by the various measures of catch per unit of effort, and the changes that have occurred in the intensity of fishing, and total catch, shown by the previous investigation of the biology of the species, require that the program must be pursued along several lines.

The California Division of Fish and Game, having as its duty the conservation of the species, as well as the "economical utilization" of the fish resources of the State (Sections 31 and 1068 of the Fish and Game Code), must continue to follow the relation of catch per unit of effort to total effort, total catch and the related reactions of the species itself to variations in those factors.

Future changes in fishing intensity must be closely watched, along with the reaction of the sardine population to these changes. The variations in average size of fish, average catch per unit of effort, total catch, life expectancy of dominant age groups, as well as frequency of occurrence of these dominant age groups and the consistency of their occurrence will all determine whether or not regulation is required. They will also indicate the type of regulation that may have to be imposed.

Fluctuations in total catch must be studied to determine their causes, if possible; and eventually some basis for predicting the course of future abundance (or production) must be established.

Measure of Fishing Effort

At present the measures of fishing effort are unsatisfactory, if not non-existent. The use of the catch per boat per week, or catch per boat per month as the catch per unit of effort appears to leave too many factors of unknown importance unmeasured. Even with the application of corrections for various independent variables such as weather, stage of the moon, etc., as was seen above for the catch per boat-week, the corrections still do not change the trend shown by the rough catch per boat per month. Obviously, this gap must be filled. This may be accomplished, either by interviewing a significant number of boats each day as to the previous night's activities, or by the establishment of a system of boat logs. The latter will require a system of daily interviews anyway until it can be well established and can never be expected to work well without frequent interviews and copying of these logs at each port. The feasibility of such logs must be investigated, and tried out at the earliest possible moment.

Another source of information will be found in sending out trained observers with the boats to gather notes as to fishing practices. This work should precede the establishment of logs in order that the information to be requested may be of the right kind. It will also make it possible to set up a system of logs that will be most effective, and will be the least possible burden to the boat captain.

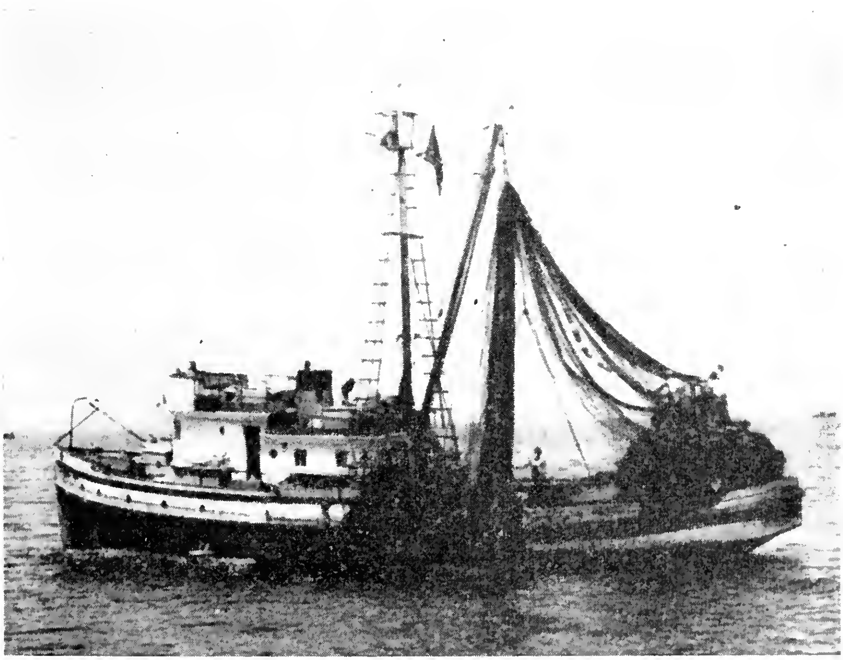

FIG. 25. Sardine purse seiner hauling its net. The net is hauled by taking a bite with the line from the end of the boom. The crew merely stacks the heavy net.

Samples of the Catch

The cooperative study of catch samples may be continued with age analyses to determine the strength of various age groups in the fishery. Measurements of changes in average size of fish, also obtained from these samples, constitute a measure of the reactions of the stock to the changes in the fishery. However, the amount of benefit derived from these observations over the past 24 years has not been in proportion to the effort involved. This activity may have to be curtailed until basic information on important phases of the biology of the species has been gathered and analyzed.

Tagging

Results of work now in progress give a measure of the rates of mortality now operating on the sardine stock. They indicate a need for further tagging to check these values, and to provide a basis for studying the effects of migrations on the rates of decline. Returns from the last tagging experiments are still coming in.

Further tagging is required to clear up some features both of mortality rates and of various features of distribution and migration. It must be undertaken on an intensive scale by the Bureau of Marine Fisheries in cooperation with those agencies that have shown their interest in this investigation. The program of actual tagging might be completed in two, or three years, but may require more time and should result in two things: a uniform distribution of large numbers of tags along the entire coast from Mexico to British Columbia; and at least one intensive concentration of a large number of tags (about 100,000) in one selected area to be released throughout one fishing season. Repetition of this type of experiment may be necessary. Three to four boats operating simultaneously along the coast throughout the year either on fish purchased from fishermen or caught by the tagging boats should fill the requirements.

Egg and Larval Work

Quantitative sampling of the eggs and larvae, as now carried out by the U. S. Fish and Wildlife Service, is confined to the area south of Point Conception. A survey should be conducted along the entire coast from Lower California north to British Columbia, which would cover enough of the year to be sure that previous surveys which indicated a lack of spawning in the northern region were not made at the wrong time of year or in the wrong season. A cooperative program of such sampling should be instituted to extend the region of observation to determine definitely whether significant results can be obtained by sampling the southern area only. The results of such work, combined with hydrographic and plankton studies, will apply to the determination of causes of fluctuations in the size of dominant year classes, and eventually assist in predictions of abundance.

Young Fish—Bait Fishery

The live bait fishery supplying both sport and commercial fishermen in southern California takes an unknown quantity of young sardines each year. A system of obtaining usable records from this fishery was being established when work was stopped by the loss of the man in charge to the Navy. This work must be taken up again as soon as possible, and extended to determine the relation of this fishery to the abundance of young sardines.

In general, the work must be aimed at quickly developing the simplest yet most accurate method of observing the sardine fishery that will indicate the changes that occur in the abundance of the species with changes in the fishery. Regulations should not be imposed until required. It is probable that the most practical method that can be devised will be the limitation of total catch. Such a limit will have to be pro-rated among the various sections of the coast on some basis to be agreed upon between the various states and the Province of British Columbia.

SALMON

In the early development of California, few people must have considered the effects of placer mining and dredging for gold upon the fish which used the streams for spawning. The resultant destruction of salmon must have been great. Later the development of power and irrigation projects as well as of debris dams continued a heedless destruction of this species through elimination of spawning areas and killing of both adults and young in dry streams and in irrigation and power ditches. Estimates made of the amount of salmon spawning area lost in the central Valleys vary from 50 per cent to 75 per cent of the original total. However, these have been based at best upon imperfect knowledge of what the salmon consider usable stream bed. There is little doubt, however, that 75 per cent would probably be the closest estimate.

The attrition of spawning areas has been so gradual that no one thought of its eventual effects in spite of the fact that a prosperous salmon fishery was built up during the latter part of the nineteenth century and the first 20 years of this one. Ignorance of many basic phases of the salmon life history, as well as a blythe disregard for conservation until recent times, contributed to this negligence.

With some appreciation of the fundamentals of conservation as well as of the biology of the salmon has suddenly come the realization that in the Central Valleys area this species has reached the limit of its endurance in loss of spawning areas and loss of fish through inadequate protection of both adult and immature migrants. This realization has been crystallized by the grandiose scheme now in progress of formulation and execution by various federal agencies for complete utilization of all water in this area.

The salmon investigations in California are determined for the immediate future largely by these water development programs for electric power generation, irrigation, and flood control. With large dams, impassable to salmon, planned for practically every major stream in the area in which salmon occur, and with smaller diversion dams below them, the future of salmon in California will depend upon whether or not these artificial hazards can be adapted to the requirements of the fish. Gravelly stream beds must be accessible to adult salmon that move in from the sea to spawn. These areas must be covered with flowing water of suitable temperature, and free from silt, for the development of the young during three or four months following spawning in the fall of the year. Thereafter, the young salmon must be able to move downstream again to the sea in order to complete their life cycle.

Two species of salmon occur in California in significant numbers—the Silver salmon (*Oncorhynchus kisutch*) and the King, Chinook, or Tyee salmon *(Oncorhynchus tschawytscha)*. The former is found principally in the small coastal streams where major water development has not yet been extended. The latter inhabit the larger streams, and form the major portion of the sportsmen's salmon catch, as well as the commercial fishermen's. This species is the one principally affected by the extensive hydro-electric, irrigation, and flood control projects now built or planned for postwar construction. This species is of principal concern for this reason, but the Silvers must also be included in the program inasmuch as they furnish a significant portion of the commercial and sport catch, and will be affected eventually by the water "conservation development" of coastal streams.

TABLE 3

Total Landings in Pounds of King and Silver Salmon in California 1939-1943

Year	*Unclassified*	*King*	*Silver*	*Total*
1939	2,142,579	634,282	9,532	2,786,393
1940	3,413,971	2,448,483	809,934	6,672,388
1941	16,523	3,157,070	614,163	3,787,756
1942	9,601	6,215,157	301,935	6,526,693
1943	1,674,180	4,562,322	331,263	6,567,765

The salmon life history, combined with its relationship to the water development programs, divides the investigation into two phases. One aspect involves the protection of salmon and other anadromous species from the results of damming the streams in which they spawn or through which they pass on the way to or from the spawning grounds. It includes provision of fish ladders where necessary and desirable for the adults, and screens in water diversions to protect the young during their downstream migration. Also involved is the planning storage capacity and flow schedules of the various dams to provide adequate water for the fish below them, and where possible the location of dams where adequate water conservation can be combined with the preservation of sufficient spawning area to preserve at least part of the runs.

The other phase of the investigation is concerned with the conservation of the species in the sense that it involves the study of the biology and distribution of the species, and the relation of the various races of fish to the commercial and sport fisheries. The object of this phase of investigation is the adaptation of its regulation to the requirements of maintaining the species. The existence and definition of separate races, and the methods of distributing the burden of fishing over the different groups, must be determined so as to obtain an adequate spawning escapement of each one, protecting those that need building up.

A study of methods of fitting the dam construction programs to the salmon requirements is being carried out with the cooperation of the U. S. Fish and Wildlife Service. This organization is already operating the salmon salvage work at Shasta Dam on the Sacramento River; and is laying a foundation for the formulation of protective measures for anadromous fishes on the upper Trinity River where several dams are planned near Fairview, and on the Sacramento River below Shasta to the Table Mountain damsite. The California Division of Fish and Game is carrying on the work in the lower Sacramento Valley and in the San Joaquin Valley where it is hoped that the various structures planned will be able to provide water and spawning gravel for the runs so that salvage will not be required.

The Central Valleys Project

The principal agencies now planning major water projects in California are the U. S. Army Engineers and the U. S. Bureau of Reclamation. Locations of the dams planned for future construction by these agencies are shown in Figure 13 of "A preliminary report on the fishery resources of California in relation to the Central Valley Project (Van Cleve,

1945) with the locations of those dams already completed which block salmon runs. The spawning areas remaining below the proposed and completed dams are also indicated.

In the Central Valleys area every salmon spawning stream has been or will be affected by these structures. With the exception of the dam planned for the Table Mountain site on the Sacramento River, however, none of them will eliminate all of the spawning grounds in the streams on which they are located. Moreover, in all cases except the above, and the Tuolumne River where the present run uses the available beds to fullest capacity, the spawning areas left will have a capacity for more than the present runs using them, provided adequate flows are maintained; and also provided that the water released below the dams is cool enough for survival of spring and early fall-run fish. Therefore, if these dams are planned to furnish enough water to maintain flows over the right periods of the year, there should be no need for such a salvage program as has been provided at Shasta Dam. Detailed study of each project will be required, however, to determine what will be necessary. All provisions of flows will be ineffective unless the Cross Delta Channel planned by the U. S. Bureau of Reclamation is constructed so as to provide free and natural access of all fish to their native streams (see Van Cleve, 1945).

Spawning Ground Surveys

In planning for the salmon in the Central Valleys area, it is necessary to presume that all major dams now planned will be constructed. From this starting point, the factors affecting the areas below them must be studied to determine their availability to salmon, as well as their capacity in terms of spawning fish. Surveys of most of the streams have been made in the past, but with information that has been obtained more recently on the type of gravel and stream conditions considered by the salmon to be suitable for spawning, a re-inspection of practically all of them has been necessary. If possible, the capacity of the different streams at different flow levels must be determined to ascertain what volume of water is needed, and the total quantity that must be provided for the fish.

Both spring and fall salmon are found in many of the streams.

The spring runs enter the Central Valleys area, on the average, in May. They reach their height in June, then taper off through July into the fall run which appears in August. These late runs reach their greatest volume in October or November, tapering off into December. Some streams lack a spring run, while the fall run is practically non-existent in others. Apparently their varying strengths have been determined by the way the water in these streams has been utilized by irrigation and power dams that have been in existence for many years, rather than by the varying intensity of the fishery. For example, a spring run of approximately ten thousand fish migrates up the San Joaquin River each year, and has held over the summer months below Friant Dam since it blocked the river in 1942. Few fall fish reach this area since the river is usually dried up by irrigation diversions at the so-called "sack dam" near Dos Palos. A few late fall fish still come upstream but these cannot pass this dry area until after the fall freshets which wash the "sack dam" out. It is not surprising therefore to find indications of the preservation of a late fall, or what might better be termed a winter run in this stream.

The spring run fish have survived because they were able to move upstream before the river was dried up. They formerly spent the summer in the cool head waters of the San Joaquin where melting snow water maintained temperatures low enough for their survival. They have been held successfully below Friant Dam because the water flowing out of this reservoir also maintains low enough temperatures throughout the summer.

Surveys of these streams must not only show the area of "suitable" gravel they contain, but also the extent of gravel areas that are covered with water of suitable characteristics for spawning. Moreover, the most suitable gravel is useless unless the fish have access to it. Therefore, all existing dams and weirs below these spawning areas must be examined to determine whether fish ladders must be installed or replaced.

The principal hazards to upstream migrants which require immediate correction are listed in Table 4 with remedial measures that are recommended. Many other blocks exist. In fact, upon study of the salmon runs in the Central Valleys area and the difficulties that have been placed in the way of their survival, it seems remarkable that any of them have survived.

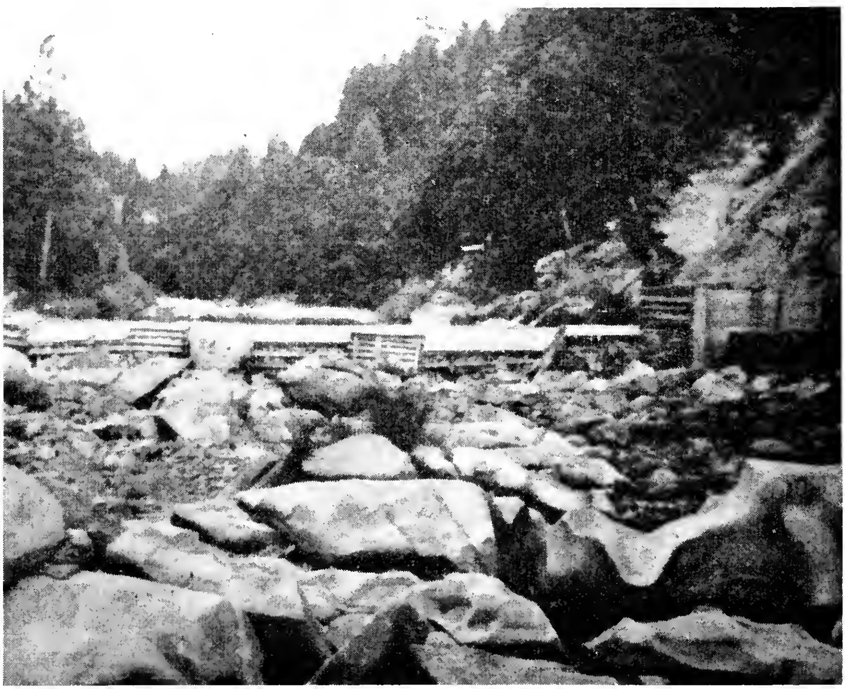

FIG. 26. Enterprise Dam, South Fork of the Feather River. One example of a complete obstruction to the upstream migration of salmon.

In some areas considerable numbers of adult salmon are lost in the irrigation ditches. Even though such fish may succeed in spawning in the canals, the young are lost in the fields if the eggs develop to hatching. The fish enter the canals in many ways. In some cases, canals that might not need a screen for the protection of downstream migrants will require a rack to prevent adults from dropping down into them. Drainage canals or overflow spills also provide easy access to many of these channels, and apparently are important factors in diverting many salmon from the regular migration routes. Regardless of whether the home-stream tendency of the salmon is not so invariably effective as is maintained by some enthusiasts, or the salmon in the Central Valleys area are adapted to the highly variable and sometimes unfavorable conditions of the southernmost range of the species, the fact remains that the Chinooks of this region seem to enter almost any stream that is available to them, even though they do tend to return apparently to the same general area from which they came. Of course, confusion may arise from the mixture of waters in the irrigation canals, and the spilling of it at random wherever it is convenient.

TABLE 4

Principal Hazards to Adult Salmon in Central Valleys Requiring Immediate Correction

Stream	*Hazard*	*Correction Required*
Sacramento	Anderson-Cottonwood Dam	Eliminate fish traps behind uprights. Install bar screen above tunnel.
	Glenn-Colusa Ditch	Screen entrance and drainages.
Mill Creek	Clough Dam	Install new ladder on N. end.
	Los Molinos Dam	Install new ladder on S. end.
Deer Creek	Stanford-Vina Dam	Install new ladder on S. end.
Butte Creek	15 dams and mouth of creek	Install ladders, regulate flow. Screen ditches and spills to upstream migrants.
Feather	Sutter-Butte Dam	Install new ladder on W. end. Repair or replace east ladder.
	Sutter-Butte and Great Western Canals	Screen upper ends against adults (see table 5).
Yuba	Daguerre Pt. Dam	Install new ladder in center.
Mokelumne	Woodbridge Dam	Repair apron to eliminate fish traps. Install new ladder.
Tuolumne	Modesto Dam	Install new ladder in center of stream.
	Pollution at Modesto	Eliminate.
Stanislaus	Pollution at Escalon	Eliminate.
	Goodwin Dam	Eliminate pool trap below dam. Reduce fluctuations in water flow.
Merced	Various gravel dams	Replace with collapsible dams or install ladders. Adjust flows, screen spills.
San Joaquin	Sack dam	Construct permanent apron with collapsible ladder and flow. Clear channel below dam.
	Mendota Dam	Install new ladder at E. end.
	Salt Slough and blind leads	Screen all spills and blind leads.

Protection of Downstream Migrants

Protection of downstream migrants covers a number of difficult problems that may take years to solve completely. The time at which the young move downstream must be weighed against the operating period of the various canals as an aid to determine the need for screens. The size of the migrating fish must also be determined. Salmon fry have been taken at Hood on the main Sacramento River below the town of Sacramento between mid-December and mid-June during 1939, 1940, and 1941. Their lengths averaged from 31.5mm. ($1\frac{1}{2}$ inches) in December to over

80 mm. ($3\frac{1}{2}$ inches) in June. Other samples obtained at Mossdale on the lower San Joaquin River during the months of January through June of the same years were similar in size. Moreover, samples taken at Martinez in Carquinez Straits in 1939 and 1940 averaged as small as 34.93 mm. ($1\frac{3}{8}$ inches) during February and March (Hatton and Clark, 1942).

It is evident from these figures that losses of young will hinge upon the period of operation of the ditch. Those ditches operated during the migrating period must be tested by fyke nets for actual losses; and where screens are required, they must be designed to protect the size of migrants involved.

Fyke nets, now being used almost exclusively to study these problems, are not entirely satisfactory. The fine-meshed nets do capture such migrating smaller sizes, but unless they are fished in turbulent, rapid-flowing water, the fish soon become large enough to escape the nets. Moreover, the one-quarter inch mesh used normally will allow the escape of unknown numbers of the smallest migrants through the meshes, especially when being hauled. This factor has probably caused a considerable error in determining the relative numbers of fish migrating at different sizes. Reports of large numbers of young salmon of 90 mm. length, and larger in some streams, indicate that possibly more than the previously accepted 10% of the young remain in the rivers until they reach this size, but suffer a disproportionate mortality because of inadequate protection.

It may be assumed that the routes of downstream migration will follow the main streams. However, the complexity of sloughs and ditches, especially in the San Joaquin Valley, will require study before a protection program can be based upon any particular series of channels.

Screen Program

Protection of downstream migrants is for the most part a matter of screening the ditches in which the young salmon are lost. A list of most important hazards to downstream migrants is given in Table 5. Projects listed are but a part of the whole program that must be undertaken eventually but they are the most important ones that require immediate attention. In those cases where actual losses have been proven, immediate remedial measures must be undertaken.

It is regrettable that as yet no screen has been devised that is completely satisfactory under all conditions. The size of mesh on all bar screen and wire barrel screens now installed in the Central Valleys area is too large to stop smaller salmon migrants, or for that matter, the young of any migratory species. On the other hand, substitution of a finer mesh will require expensive installations of much larger size to provide adequate flows in the ditches. The need for the finer mesh will depend upon the relation of the period of operations of each ditch to that of the downstream migration of young and to the actual losses of young salmon in each ditch. The latter can be determined by fyke netting. The possibility of using the electric fish screen or some modification of it is being investigated. It may also be possible to develop new and more efficient types of mechanical screens.

Of major importance in any fish screen installation is some provision for taking fish away from the front of the screen and back into the stream from which they are diverted. By-passes are lacking on most screens now installed, even though there is no possibility of the small fish swimming back up the ditch against a heavy flow of water, or in some cases back against a head of four to five feet of water where the screen is installed below the control gates. Even if small salmon possessed sufficient intelligence to return upstream to seek healthier channels, they could not do so under such circumstances.

TABLE 5

Principal Hazards to Downstream Salmon Migrants in Central Valleys Requiring Immediate Correction

Stream	*Hazard*	*Work required*
Sacramento	A.C.I.D. Ditch	Screen against 35 mm. fish below tunnel.
	Glenn-Colusa	Screen against 35 mm. fish above pumps. Bypass to main river.
Mill Creek	Los Molinos Ditch	Add correct bypass. Test for loss of migrants.
	Clough Ditch	Test for screen and install bypass.
Deer Creek	Deer Creek Irr. Co. Dam	Install bypass and fine mesh screen.
	Stanford-Vina Ditch	Install fine mesh screens, and correct bypasses in both N. and S. ditches.
Butte Creek	15 dams and various diversions	Study all diversions for loss of young and type of screens required.
Feather		Test Sutter, Butte and Western Canals for loss of young.
Yuba		Test Hallwood I. D. (Daguerre Point Dam) for loss of young
Mokelumne		Test Woodbridge I. D. Canal for loss of young.
Tuolumne		Possibly reduce fluctuation of water level.
Merced		Test ditches and screen those requiring it.
San Joaquin		Screen all canal take-offs where water diversions begin before end of migration.

The size of the job involved in screening all Central Valleys diversions may be appreciated from the list given by Hatton (1940, Appendix C) of number and size of pumps taking off from the Sacramento and San Joaquin Rivers and their tributaries. A total of 1,497 of these diversions, varying in size from 2″ to 48″ in diameter, are listed for the two river systems.

Salmon Conservation

The basic ideal in the second phase of salmon investigations would be to distribute both the sport and the commercial fisheries in such a manner that their burden would fall upon the various races or stocks of salmon in proportion to the ability of that stock to produce. This, of course, would require a determination of the existence, distribution and size of different races at various stages of the life history and would depend upon the maintenance of the identity of these races in the region of the fishery. This is very unlikely. It undoubtedly would be impossible to separate the salmon taken in the outside fishery into those that spawn in the different streams in the Central Valleys area, or in any similar stream area. However, if the stocks which reproduce in the various streams migrate through the inshore and river fishing areas during certain fairly well-defined periods, it might be possible to distribute the river fishery and possibly the inshore troll fisheries, especially off San Francisco Bay, accordingly.

The irregularity of the runs in the rivers in different years would make it impossible to set up an inflexible system to distribute properly the fishing strain over the different races. The closest approach so far to a good system of regulating such a fishery is the idea of weekly closed seasons. The effectiveness of such a system will depend, however, upon the length of time that it takes a group of fish to migrate through the fishing area, in the case of the commercial fishery. If the closed season is of such short duration that it merely affords an opportunity for more fish to get into the fishing area but not through it, it may be ineffective in permitting the escapement of adequate numbers of the various groups that happen to migrate through the fishery during the period of its greatest intensity.

Preliminary tagging experiments have been carried out in the troll fishery and indicate a fairly wide-spread and indiscriminate mixing of fish from different regions, although there appears to be a partial division at about Point Arena of fish arising from the central California and northern California rivers.

The number of tags released and recovered in the different years is shown in Table 6.

TABLE 6

Number of Tagged Salmon Released and Recovered in Various Years

Salmon Tagged

Year	North of Point Arena		South of Point Arena		Total
	King	Silver	King	Silver	
1939	550	0	144	211	905
1940	548	7	396	303	1,254
1941	1,027	8	321	111	1,467
1942	1,149	95	514	7	1,765
Totals	3,274	110	1,375	632	5,391

Salmon Recovered

Year	North of Point Arena		South of Point Arena		Oregon	Washington	Total
	Offshore	Rivers	Offshore	C. V. Rivers			
1939	1	2	4	8	1		16
1940	6	2	5	30	1		44
1941	5	10	4	51	3	1	74
1942	15	31	14	77	5	1	143
1943	2	1	13	13		2	31
Totals	29	46	40	179	10	4	308

These tagging experiments were not carried out in such a manner as to give quantitative results. While a fair number of tagged fish were released, the effort it was possible to expend upon watching for tags in the markets and fishery, as well as on the spawning beds, was not sufficient to give any idea of the actual number of tagged fish caught or returning to the rivers. The consistency of the results from the three years of tagging, however, does permit several conclusions on general distribution and origin of the fish which support the California outside troll fishery.

Few salmon taken in California waters apparently enter streams north of the California line (Clark and Hatton, 1942). As indicated by results obtained in the tagging experiments by Williamson (1927) in which the salmon were tagged off the coast of British Columbia and recovered in rivers south of there as far as the Sacramento, it is evident that the California streams not only provide the bulk of the fish taken off the coast of California, but also probably provide some of the salmon for the troll fisheries in the far north. We can presume, therefore, that the regulation of the California troll fishery will benefit the races of salmon that depend upon the California rivers for their spawning grounds.

An intensive tagging program will be required to define the distribution of fish in the ocean and their relation to the various rivers. It is possible that the marking of young fish may be resorted to if some assurance can be obtained through experimental work that the marks used or developed will give results that will be representative of the reactions of the unmarked fish. The tagging experiments will be required to determine the rate of movement of various runs through the fishing area.

In the tagging of adults, the size of the program will undoubtedly be somewhat limited by available personnel for some time. It will hardly be worthwhile to do such tagging on a small scale over a long period. Tagging should be intensive and may be planned either to cover the whole coast of California at the same time or may be concentrated in one area. Whatever plan is finally adopted, it must be remembered that the release of tagged fish is the smallest part of a salmon tagging program. Significant results will then depend upon an intensive search of the fishery for recaptured specimens as well as a thorough inspection of all spawning areas.

Experimental work has been carried on in the past season in an attempt to use tagging of adult salmon in the streams as a basis for estimating the total number of fish migrating into a particular stream. This, supplemented where possible by counts on the spawning beds, appears to be an economical way of making such estimates, and is much more practical than the installation of expensive weirs on every stream that it is desired to study. The almost annual loss of the count of some part of every run through the enforced removal of weirs during flood periods casts doubts upon the accuracy of the counts that depend upon them alone. It is quite obvious that we cannot concentrate our efforts upon one stream and expect to extrapolate the results freely to others.

Size Limits

There is a rather strange relationship, in the case of an anadromous fish such as the salmon, between the size limits as imposed on the inland fisheries, and those imposed on the outside fisheries. At present the California Fish and Game Code prescribes a minimum size of mesh for the nets to be used in the river fishery. The purpose of this is apparently to prevent capture of small salmon.

Such a regulation would be perfectly understandable in the case of a fish that was growing. However, in the case of a salmon which has reached maturity, and has ceased feeding when it enters the delta fishery, this regulation is directly opposed to the principles of selective breeding. The minimum size mesh of $7\frac{1}{2}''$ during the principal salmon fishing season permits the escapement of the precocious male salmon called "Jack salmon" and the smaller females. At the same time, it encourages the capture of the largest males and females. Thus, instead of following the accepted practice of livestock raisers who market their less desirable stock and reserve the largest and best stock for breeding purposes, the mesh regulations in the river salmon fishery must be such as to take a disproportionate toll of the larger, most desirable fish, and to preserve the smaller and less desirable ones for breeding purposes. Presence of heavy runs of the small-sized Jack salmon on many of the streams along the west coast of North America undoubtedly is associated with similar ill-conceived mesh regulations.

An intensive study of sizes of salmon and the effect of various sized meshes of gill nets must be undertaken in order to determine the policy that should be pursued in handling this situation. It is not desirable that we should continue a regulatory program that will have as its eventual result the development of a pigmy race of salmon. On the other hand, no changes should be made in these regulations until adequate study has indicated a safe course to follow. The relations between mesh size and fish survival are too complex to blindly discard old or adpot new regulations. Such unsubstantiated action might be far more harmful than present practices, however ill-advised they may be.

On the other hand, the effectiveness of present size limits imposed upon the ocean troll fisheries must be studied, from a different standpoint. It is highly probable that these size limits are beneficial, if proper care is taken to release small fish from the hooks without injury.

Scope of Program

The salmon program, in order to be effective, must be state-wide in its scope. Plans now being drawn up by the Army Engineers indicate the possibility of a series of dams being constructed in the Klamath and Trinity rivers. Definite plans are being made by the U. S. Bureau of Reclamation for a series of dams on the Upper Trinity River in the vicinity of Fairview. Whether or not these dams are constructed, any salmon program that has for its object the proper protection of the species must include the Klamath and Trinity rivers, as well as the other rivers in which salmon spawn. Phobably it will be necessary to concentrate the efforts of the staff in the Central Valleys for the present in order that proper provisions may be made for the fish in this area in the planning of the various reclamation and flood control projects. The salmon programs in the northern streams must be taken up, however, in conjunction with the offshore conservation program unless plans for water development force the institution of intensive investigations there before that time.

One important problem that must be faced is determination of the efficiency of the artificial propagation of salmon in terms of fish taken by the sport and commercial fishermen. This will involve first of all development of a method of marking young fish that will not decrease

FIG. 27. Indian Weir at Hoopah on the Trinity River. While in operation, until taken out by the first heavy rains, this weir is an effective block to the early fall salmon.

their chances of survival as do the rather drastic methods now used of removing two or more fins. We have already lost in the neighborhood of 75 per cent of the original salmon spawning area in the Central Valleys streams. With the construction of more dams there, and in the Klamath and Trinity Rivers, we will lose much more. We must know if it is economically and physically possible to substitute hatcheries for some of these natural spawning grounds.

Summary

The salmon program will undertake first the determination of the flow of water that must be provided in each stream below the lowest impassable dam planned by the Army Engineers or Bureau of Reclamation in order to maintain the most efficient size of salmon run for that particular stream. In order to protect the runs of fish which exist or will be built up below such dams, efficient fish ladders must be constructed over smaller diversion dams that lie below the spawning grounds. The young salmon must be protected during their downstream migration by the installation of adequate screens wherever required by the combined considerations of location and type of diversion, schedule of water use, and the schedule of downstream migration of the young salmon.

Experience with both fish ladders and screens now installed in the Central Valleys area indicates that a special crew will be needed by the

FIG. 28. Upper Trinity River. This section of stream will be inaccessible forever t salmon and steelhead upon completion of a dam at Fairview and diversion o the Trinity River from the Trinity Watershed into the Sacramento River.

Division to supervise the maintenance and proper operation of th screens and ladders. One of the biggest problems in this regard is th development of a fish screen that will prevent the loss of great number of small salmon migrants. An adequate flow of water below any of th dams planned in the Central Valleys area, with the exception of Tabl Mountains, will ensure the perpetuation of good-sized salmon runs i practically all of the streams, since good spawning beds of adequate siz will remain, even though a considerable portion of the spawning are in the State will have been blocked off by these dams. With the installa tion of efficient fish ladders and proper types of fish screens, there will be little danger of further depletion from this source.

The conservation of the fisheries, aside from the protection of the spawning adults and the young, will involve a tagging program of some magnitude, and probable a study of the racial characteristics of the salmon in an attempt to separate the fish into different streams by anatomical characters. It is important that the relationships of the runs from the different streams to the fisheries along the different parts of the coast of California be understood, that the time of these runs be defined, and their size be studied in order that we may arrive at sime measure of the size of the fishery that should be allowed. Practicability of such an extensive investigation as will be involved must be carefully scrutinized before a research program of any magnitude is undertaken.

TUNA

In the remaining fisheries of the State, the data collected and analyzed are not yet sufficient to permit a clear discussion of programs. The principal fisheries that must be tackled first are the tuna and mackerel.

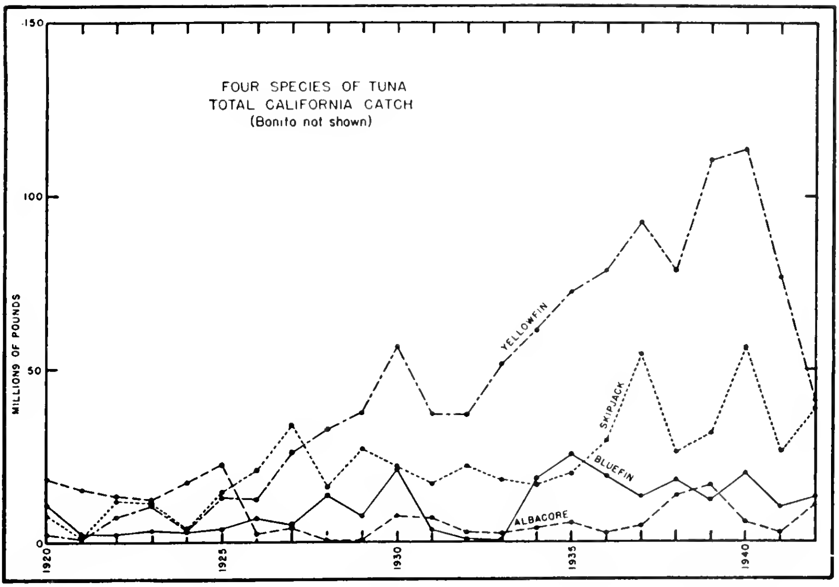

FIG. 29. Four species of tuna. Total California catch. (Bonito not shown).

The total annual catch of the five species of tuna since 1920 is shown in Table 7, and Figure 29. The growth of the fishery has depended upon the increased take of skipjack (*Katsuwonus pelamis*), and yellowfin (*Neothunnus macropterus*). The bluefin, albacore, and bonito catches have been normally smaller, and the two former species have fluctuated widely in their yields, reaching the catch levels of the skipjack and yellowfin in only a few years. These two species averaged 78 per cent of all tuna landings in California over the period 1930 through 1942.

The value of the fish, as indicated by the price paid to the fishermen, is determined by the quality of the meat (whiteness) and percentage

TABLE 7

Annual Landings of Tuna

1920-1942, Inclusive

Year	Albacore	Bluefin	Bonito	Skipjack	Yellowfin	Miscelaneous	Total
1920	18,876,647	10,530,272	873,498	7,957,427	1,965,024	5,482,574	45,685,442
1921	15,276,727	2,031,648	320,737	1,138,993	1,237,616	1,552,845	21,558,566
1922	13,231,823	2,838,193	929,065	11,862,382	7,337,405	692,352	36,891,220
1923	12,514,833	3,218,090	1,115,247	11,462,522	10,836,925	662,370	39,809,987
1924	17,695,362	3,241,110	1,038,369	3,780,971	3,063,398	546,538	29,365,748
1925	22,206,923	3,803,677	866,530	14,235,089	13,237,898	426,853	54,776,970
1926	2,469,921	6,526,533	3,121,604	20,951,348	12,564,986	260,855	45,895,247
1927	4,579,367	4,898,386	1,718,008	33,805,960	25,934,045	----------	70,935,767
1928	340,774	13,700,870	2,105,903	15,948,104	32,253,206	----------	64,348,856
1929	312,155	7,526,857	2,918,544	27,066,588	37,444,924	----------	75,269,068
1930	7,288,685	21,921,282	5,164,260	20,485,587	56,657,768	----------	111,517,582
1931	6,976,401	3,534,030	3,079,673	16,506,761	36,581,376	----------	66,678,241
1932	3,087,215	1,071,206	2,862,286	21,636,577	36,923,410	----------	65,580,694
1933	2,794,452	560,492	2,252,199	17,093,041	51,075,630	----------	73,775,814
1934	4,236,020	18,357,828	3,202,694	16,409,439	61,137,102	----------	103,343,083
1935	5,678,793	25,173,083	7 896,484	19,803,954	72,294,133	----------	130,846,447
1936	2,456,004	18,924,883	7,215,916	29,271,030	78,361,272	----------	136,229,105
1937	4,743,709	12,693,922	7,808,070	54,698,995	92,406,606	----------	172,351,302
1938	13,574,635	17,728,031	7,839,993	26,152,974	78,363,005	----------	143,658,638
1939	16,423,234	11,835,715	9,918,875	31,186,950	110,417,801	----------	179,782,575
1940	5,588,670	19,970,268	5,290,964	56,650,155	113,898,209	----------	201,398,266
1941	2,746,974	9,519,012	10,176,699	25,585,468	76,701,760	----------	124,729,913
1942	10,621,193	12,844,564	1,650,689	38,715,182	41,167,441	----------	104,999,069
Averages	9 23%	11.07%	4.25%	24.88%	50 10%	.05%	99.58%

yield in terms of canned fish. In this respect albacore comes first, followed by yellowfin, bluefin, skipjack, and bonito, in that order. While the total tuna catch in 1940, which may be taken as typical, amounted to only 15.7 per cent of the total California landings, their total value to the fishermen made up 55.3 per cent of the total value of all fish brought into California ports. These fisheries, therefore, are the most valuable in the State.

Because of their wide range of distribution, the tunas present problems of investigation different from any other species taken in the California fisheries. The percentage of catch of each species taken in waters off the coast of California is shown for each year from 1930 to 1942 in Table 8. The albacore catch is almost entirely of local origin with an average of 97.6 per cent coming from California waters. The local catch of bluefin averages 77.6 per cent and bonito 66.2 per cent of total landings. In contrast with these species 86.8 per cent of the skipjack landings come from "outside" waters, while 99.6 per cent of the total yellowfin catch arose from foreign regions. These two fisheries have been extended beyond the Galapagos Islands on the south, and as far as Hawaii on the west. Improvement of fishing methods and use of freezing facilities, either on transport vessels, mother ships, or in island cold storage plants located near the centers of fishing, can extend the range of fishing far beyond present limits whenever such extension becomes economically feasible.

With such a fishery covering an area far beyond presently-accepted limits of even national control, it will be impractical and undesirable for our State organization to attempt to carry our investigations as far as the fishery may be expanded. The limit imposed upon our research must not be determined arbitrarily, however, since our responsibility to

TABLE 8

Per Cent of California Tuna Landings Taken in California Waters By Species

Year	Albacore		Bonito		Bluefin		Skipjack		Yellowfin	
	California	Outside	California	Outside	California	Outside	California	Outside	California	Outside
1942	75	25	52	48	80	20	0.6	99.4	0	100
1941	100	0	71	29	93	7	16	84	0	100
1940	100	0	67	33	94	6	5.6	94.4	0.2	99.8
1939	100	0	68	32	79	21	9	91	0.4	99.6
1938	99.6	0.4	60	40	93	7	0	100	0	100
1937	100	0	73	27	85	15	4	96	0.2	99.8
1936	100	0	31	69	73	27	33	67	1.0	99
1935	97	3	29	71	73	27	11	89	0.7	99.3
1934	100	0	94	6	99.7	0.3	0	100	0	100
1933	------	------	88	12	58	42	0	100	0	100
1932	100	0	56	44	43	57	2	98	0.4	99.6
1931	100	0	97	3	67	33	73	27	2	98
1930	100	0	75	25	71	29	15	85	0	100
Averages	97.6	2.4	66.2	33.8	77.6	22.4	13.2	86.8	0.4	99.6

the fisheries from which a large portion of our income is derived and upon which a large portion of the California fishing and canning industries depend is limited theoretically only by the boundaries of their activity. The only limit to our research efforts that can be considered tenable will be the outer boundaries of the range of research of other collaborating research organizations, or if these are lacking, the limits of the distribution of the tuna populations upon which our California fisheries are based. Even these limits will probably be extensive, and the resulting effort required on our part will be proportionately great.

Investigations of the California tuna fisheries have so far been fragmentary. Early interest centered on the albacore which was the first tuna fishery developed. Investigations of the relation of its catch to

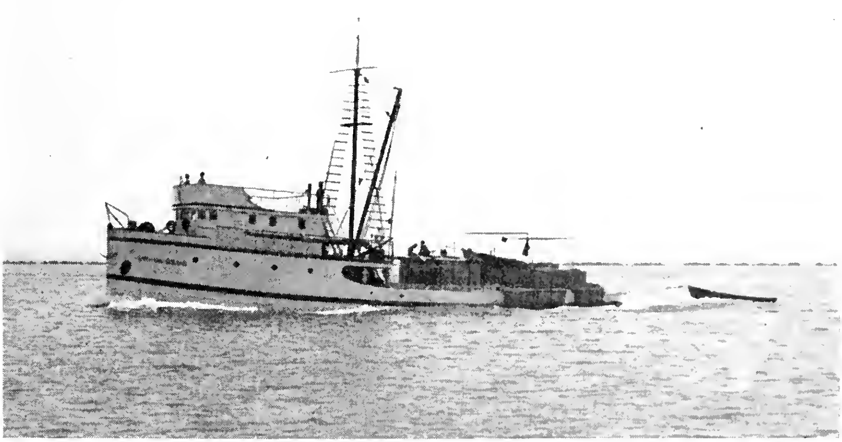

FIG. 30. An early example of the large "bait" boats that fish tuna with live bait and poles.

temperature of the water indicated that there was some correlation. Records also show that the albacore boat catch was studied and some samples of the market landings were taken. However, because of the great turnover in staff that took place in the early '20's, and probably also because of the failure of the albacore fishery in 1926 with the growth of importance of the other species, these data have been lost and no results were ever obtained.

The staff of the Bureau of Marine Fisheries later took up the investigation of all five species of tuna, and after a preliminary survey of the problem found that a better definition and description of the various species of fish taken by the fishermen was required.

A detailed study was made of five species of tuna, following the methods outlined by Kishinouyi (1923) who worked on the Japanese tuna. Godsil and Byers (1944), reporting on this work in Fish Bulletin No. 60, have found that but one species each of skipjack, yellowfin, and albacore is found over the full range of the Central and North American fisheries, as well as in Hawaiian and Japanese waters. Comparison of these species was made from specimens obtained from the localities concerned. No foreign specimens of bluefin were obtained; but comparison of published descriptions with findings for Eastern Pacific bluefin indicates the existence of a separate species in the Japanese waters. This work also established the identity of another species of tuna found here in small numbers as *Parathunnus mebachi* which is a common western Pacific species. The bonito has not been included in this preliminary work.

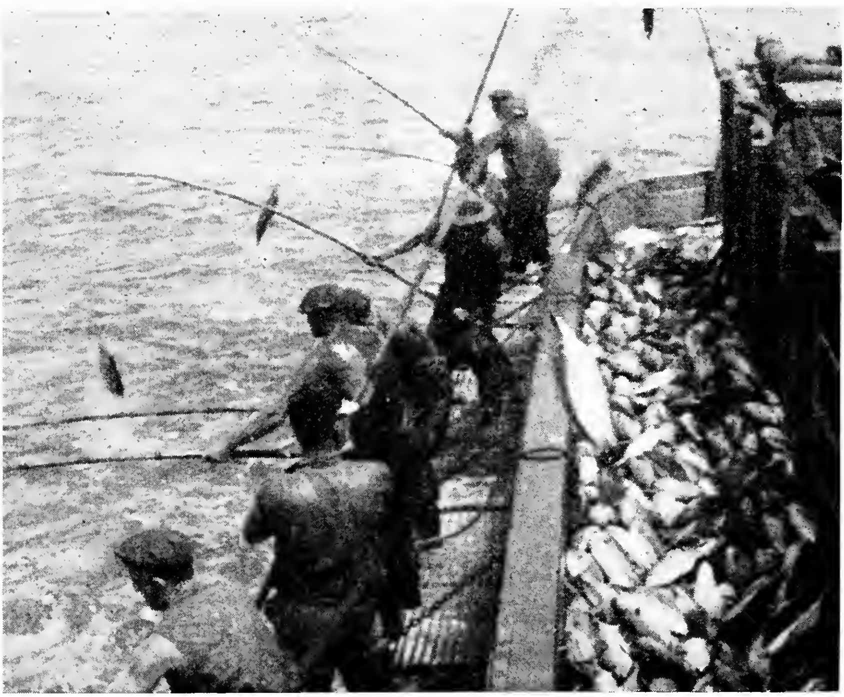

FIG. 31. Skipjack fishing off Central America.

The results of the work accomplished to date indicate clearly the futility of trying to interpret the statistical data without a sound biological background. It is impossible to depend upon the identification of species made by the industry, and such material cannot be used as a basis for the catch data until corrected by adequate biological work.

The definition of species begun with the albacore, yellowfin, skipjack, and bluefin tunas should be extended to the bonito. The distribution of the various species must then be studied and related to the distribution of fishing. At the same time, the statistical material now on file, including data as to landings and origins of catches by species, must be analyzed and correlated with the biological data. It is quite possible that examination of this material will show the need for changes in methods of recording and classifying species as well as localities in order to make it usable. As soon as practicable, a history of the development and extension of this fishery should be worked out from all available records to form a basis for interpretation of future events.

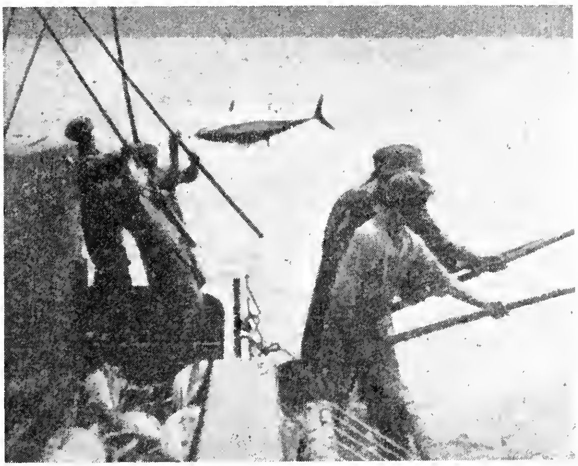

FIG. 32. Three-pole tuna, Revilla Gigedo Island.

It is not possible to say what new developments might be expected in the method of recording the catch. These must evolve from a study of the fisheries for the different species. The sooner the necessary investigations can be made, the sooner the collection of statistics will be brought into harmony with the methods of fishing and the biological units exploited. The major biological problem at present appears to be a study of the distribution and migrations of the species and races that support the fishery. This is the fundamental problem of defining the stock that the fishery depends upon. Incidental to this problem, the age and growth, as well as the life history, of each species should be worked out to facilitate interpretation of the basic catch statistics.

An extension of the racial investigations already begun may yield information on the existence or non-existence of subdivisions of the varíour species but some form of tagging program will necessarily be involved. Efforts in this field, using strap tags clamped to the preoperculum, have so far been fruitless. Over 4,000 tagged tuna were released but not one was recaptured. However so little time has been spent on this problem that it cannot be said to have been thoroughly explored. These species are difficult to handle without injury so that the technique of tagging must be developed probably along some entirely new approach.

Progress in the tuna work will depend upon the activation of an adequate staff with sufficient funds and equipment to attack the problems involved on a scale that will bring results. Separate segments of the tuna investigation can not be taken up individually and pursued independently with any hope of accomplishing anything concrete within a reasonable period of time, no matter how well planned such a program might be. The tuna fisheries are so valuable that they may be expected to expand as far and as fast as the methods of fishing will permit. A sound basis for conservation must be established and the collection of data must evolve and expand with the fishery. Past experience with other fisheries has proven the danger and economic loss involved in waiting until depletion has occurred before the fishery biologist is called in.

MACKEREL

Three species of fish occur in California catches which are known as mackerel. The Pacific and Spanish mackerel (*Pneumatophorus diego* and *Scomberomerus sierra*, respectively) belong to the same family of Scombridae. The Horse mackerel (*Trachurus symmetricus*) belongs to the family Carangidae in which are found the yellowtail and amberjack. The Pacific mackerel furnishes the bulk of the California mackerel catch, averaging 95.5 per cent of the mackerel catch of California for the years 1938 to 1942 inclusive.

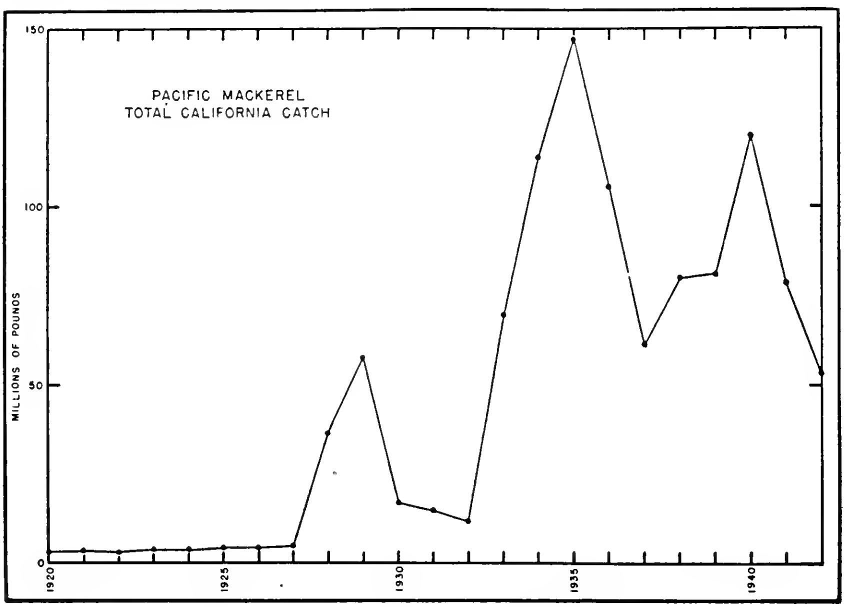

FIG. 33. Pacific mackerel. Total California catch.

The present California mackerel fishery began in 1928, with large-scale canning (Croker, 1933). Landings reached a peak in 1929. The ensuing business depression resulted in a falling off of the landings but the total catch recovered again by 1933. In 1935 landings reached a total of 146,427,000 pounds (Fig. 33, Table 9).

This last growth of the fishery was associated with a marked increase in number of boats which increased greatly the intensity of fishing (Fry, 1937.2). In an analysis of boat catches, Fry found a decrease in average catch per boat per season in 1935 and 1936 over that found in 1934. His analysis was based upon purse seine catches only, and was carried through 1938. Results of this work have been published only through 1936. The fishery was primarily confined to the months of May to October; and the boat catch analysis was based on this period. The summer fishery practically ceased after that year.

After a two-year decline in total landings, the catch rose again in 1938 and continued its upward trend until 1940. The years 1941 and 1942 again showed a decrease over 1940. Boat catch figures are not available for these last years for comparison with the former trend, and the complex changes that have occurred in both methods and seasons of fishing will require careful analysis before comparable figures can be obtained.

Since the fishery started to rise, there have been three peaks in total catch (Figure 33), followed by three depressions. The first depression can be ascribed to economic conditions through the period 1930-1932. The second and third declines cannot be similarly explained. While Fry ascribes the decline of season's catch per boat in 1935 and 1936 over 1934 to over-fishing, the subsequent rise in total catch from 1937 through 1940,

TABLE 9

California Catch of Pacific Mackerel
1920-1942

(Catch in Pounds)

Year	From California waters	From Mexican waters	Total
1920	*2,997,308	*50,732	*3,048,040
1921	*2,914,613	*60,646	*2,975,259
1922	*2,466,762	*29,166	*2,495,928
1923	*3,553,954	*38,495	*3,592,449
1924	*3,227,300	*13,234	*3,240,534
1925	*3,506,103	*16,316	*3,522,419
1926	3,610,098	13,192	3,623,290
1927	4,728,903	11,736	4,740,639
1928	35,251,298	11,196	35,262,494
1929	57,985,134	1,405	57,986,539
1930	16,530,100	1,264	16,531,364
1931	14,220,329	----	14,220,329
1932	12,473,556	----	12,473,556
1933	69,613,951	969	69,614,920
1934	113,519,210	266,198	113,785,408
1935	145,266,298	1,160,904	146,427,202
1936	98,827,800	1,714,079	100,541,879
1937	60,832,354	104,347	60,936,701
1938	79,846,761	1,254	79,848,015
1939	80,908,469	382	80,908,851
1940	120,503,612	----	120,503,612
1941	78,167,200	----	78,167,200
1942	52,505,454	21,131	52,526,585

* All mackerel species recorded together. From 1926 on the figure given is for Pacific mackerel only.

and the many complications involved in the mackerel fishery require that this conclusion be qualified.

At present dip net boats, purse seine, and ring net boats account for most of the mackeral catch. These types of gear are quite different in size, and mode of action; and are often competitive. Use of boat catch figures requires that these methods of fishing be reconciled statistically in order to make valid comparisons between years. The changes in gear that have occurred in the mackerel fishery since 1928 render such a task difficult. Undoubtedly, the result of such an analysis would require a great deal of manipulation and "correction" of data. Great care must be exercised under such circumstances not to "correct" the data to the point that the resultant relationships measure the corrections and not the reactions of the original variables.

The changes in relative amounts of each type of gear used to fish mackerel, the complex and sometimes competitive relation of purse seine to dip net gear, as well as the vacillations of the purse seine fleet between tuna and sardine, as well as mackerel fishing, would make any analysis based upon only one type of gear very difficult to interpret over an extended period, and of no significance over a short period.

Distribution of Pacific Mackerel

The Pacific mackerel occurs along the Pacific Coast of North America from the Gulf of California to British Columbia. The largest fishery is confined to the relatively small area between the Mexican boundary and Pt. Concepcion. Landings at Los Angeles Harbor dominate the mackerel fishery, and with San Diego have furnished an average of 97% of the mackerel landings since 1933.

Monthly landings of mackerel in California show an annual period of scarcity that may extend from December to May or June, or in some years may be of shorter duration. A similar annual period of scarcity has been noted for the Atlantic species of mackerel, and has given rise to much speculation (Croker, 1933) (Sette and Needler, 1934). So far as published records go, this period of scarcity has yet to be satisfactorily explained.

Due to the absence of fisheries of any significance in the rest of the Pacific mackerel's range of distribution, solution of this problem involves a great deal of field work. Results of tagging operations to date indicate, however, that it is associated with the annual movements of the stock; and undoubtedly is associated with spawning.

Fluctuations in Catch

The fluctuations in size of annual catch may be associated with a number of factors. One of the major problems of the mackerel investigation must be to determine, if possible, the cause of these fluctuations, or at least associated factors, providing the future fishery bears out present indications that the Pacific mackerel fishery will be as variable as are the mackerel fisheries in the North Atlantic (Sette, 1943.) The total catch of the Atlantic mackerel fishery has varied from year to year in an erratic manner from 174 million pounds in 1830 to 5,665,000 pounds in 1910, apparently without regard for economic demand. The California mackerel fishery so far appears to be of similar character; and it may be expected to vary widely from year to year in its production, especially if the abundance of older fish decreases and the fishery comes to depend upon one or two year classes.

Assuming that the fluctuations in abundance of Atlantic mackerel were due to the varying success of survival of young fish, Sette (1932 to 1943) set up a program of investigation based upon a quantitive determination of the intensity of spawning and abundance of young mackerel, as related to the sizes of ensuing age classes. These, combined with other factors associated with the movements and availability or abundance of mackerel in the fishery, were used as a basis for predicting each year the next season's mackerel catch. The value of such predictions to the industry is obvious if they can be made accurate enough to give a true measure of the catch in the coming season.

Confining a program to laying a foundation for predicting future catches would require an assumption that either fluctuations in abundance are entirely due to natural causes, and while predictable are not subject to control, or that while the abundance of adults may be affected by the fishery, the variations in survival of young are so great that the decrease in potential spawning capacity due to a decrease in abundance incident to fishing is of small moment in comparison. It has been assumed by some (Hjort, 1914) (Sette, 1943) that the decrease in total number of eggs spawned may increase the rate of survival to the point where a greater recruitment results from a lighter spawning.

None of these theories have ever been validly applied to fisheries or developed from complete and detailed investigations of sufficient scope to prove or disprove them. Therefore, rather than base the future program upon a theory, it is considered most desirable to look first toward the acquisition of enough biological information on the natural history of the species to be able to determine which course is most desirable to follow in the interest of both the maintenance of the species as well as of its fishery. The fishery must be studied in all its phases and must be related to the life history of the mackerel, its migrations, races, and habits.

Program to Date

The mackerel program has been necessarily devoted so far to a study of only a few phases of the biology of the species, and of the statistics of its fishery.

Catch Statistics

As mentioned above, an analysis of boat catches was made by Fry (1937.2), based upon purse seine and lampara catches. This analysis was extended to cover the period of 1933 through 1938, and showed a drop in the average season's catch per boat in 1935 through 1938. The changes that have taken place in the mackerel fishery make it impossible to work out a simple measure of abundance based upon boat catch that would be comparable from year to year. Beginning with small lampara boats, the method of fishing mackerel grew into a purse seine fishery. It was discovered by someone that mackerel could be taken very cheaply by small boats by chumming with ground bait, and scooping the fish out of the water with a long-handled braile. This fishery began as a daylight operation, but was finally found to operate best at night. The dip net fishery has developed until its production forms the steady backlog of mackerel for the canneries, with the purse seiners and lampara boats filling in when other fish are scarce, or when mackerel are most available.

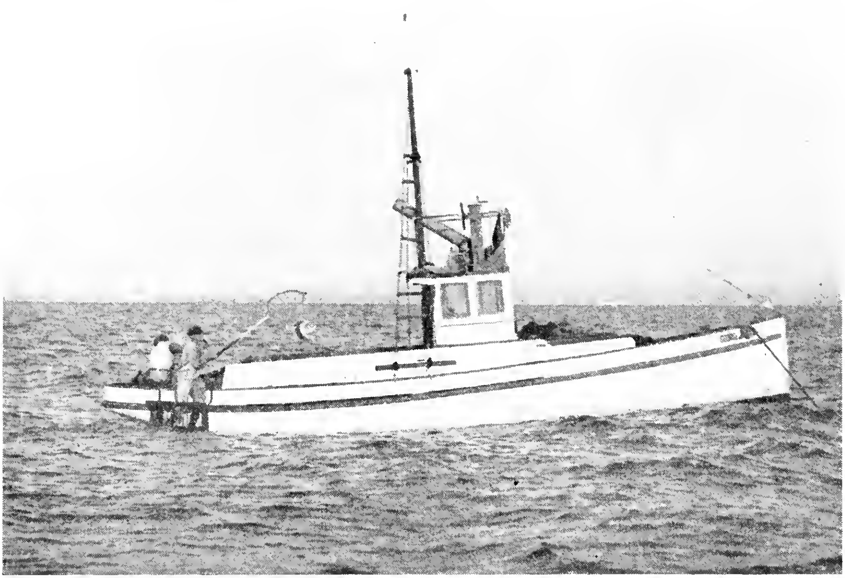

FIG. 34. Dip netting mackerel off Newport, California.

With all of these changes in the fishery, and considering that all types of gear now operate, a uniform measure of fishing effort will be most difficult to develop. An analysis of changes in season's catch, based upon one type of gear, could not be accepted unless the effects of the other types of mackerel gear, as well as of the demand on the catch were assessed. Moreover, the relation between mackerel landings and effort expended upon sardine or tuna fishing must be evaluated, to make due allowance for possible competition between the various species for attention.

A possible solution to the problem of measurement of abundance of mackerel is presented by the nature of the fishery. Under certain circumstances the total catch of mackerel may be the best measure of its total abundance since the available capacity of the net fleet is always far beyond that necessary to produce the catch landed. To a degree, the greater the abundance, the greater is the effort expended; that is, more boats will fish for mackerel.

Many complicating factors may nullify the utility of this measure. For example, a flood of fish usually results in the imposition of catch limits on the boats by the plants. The catch would then be limited by the capacity of the plants to process the fish, and by neither the capacity of the fleet nor the amount of available and expended effort. This and other factors such as those mentioned above (pages 120-121) would affect the catch per unit of effort just as much as they would total catch; and both quantities must be corrected for it.

Migrations

Since the mackerel fishery is concentrated in but a fraction of the range of distribution of the species, the movements of mackerel are especially important. Like all fisheries, the future stability of the fishery and hence its potential productivity depends largely on the size of the population contributing to the fishery, as well as on the rate of replacement and migration of that portion fished.

Relationships between the various schools exploited each year may be determined most accurately and easily by tagging and observing the movements shown by the returns. Both internal tags such as have been used in the sardines, and external metal tags clamped to the opercle or cheek bone have been used. The former have proven more successful, although much valuable information has been obtained by the simultaneous use of both types.

The first Pacific mackerel were tagged by the Bureau of Marine Fisheries in 1935, but large-scale tagging did not begin until 1937. Up to the present a total of 76,519 tags have been put out, including 1,627 double-tagged specimens (both external and internal tags on the same fish), and 12,426 external or opercular tags. The tagged fish have been released along the coast from San Roque Bay at about 27° N. lat. to Monterey (between 36° and 37° N. lat.). Eleven fish were tagged in 1940 off the Columbia River by Dr. John Hart of the Canadian Fisheries Board in the course of sardine tagging. The center of tagging and region in which most tags have been released is in the center of greatest fishing intensity between Pt. Dume on the north and Pt. San Juan on the south, and west to Santa Catalina Island.

Tagging mortalities and survival rates of fish from tagging have been tested by holding tagged and control fish in live boxes.

Progress reports on tagging experiments have been published (Fry, 1937.1, 1941; and Fry and Roedel, 1939). The results of the later experiments are in the process of analysis and returns are still coming in. They show that different groups of fish enter the fishery at various times during the season. Each of these groups seems to act differently in relation to the fishery. These differences result in variations in availability that mean wide variations in the amount of catch taken from each one. Apparently the schooling instinct is highly developed in this species and as a result, the problem of measurement of abundance is greatly complicated as in the sardine by varying availability.

Returns of tagged fish have proven that fish caught in Monterey are later found in southern California. In fact, one was taken off Lower California. One fish tagged off the Columbia River was recaptured off southern California. Returns from Lower California tags show a recapture of about 1 per cent of effective tags. Over 50 per cent of the tags released in some southern California experiments have been recaptured.

While a considerable number of tagged mackerel have been released by this Bureau since mackerel tagging was started, the design of the experiments has not been such as to yield the desired information. The fishery is seasonal and is confined to only a part of the region of distribution of the fish. Tags have been released off southern California and Monterey during the fishing season. The experiments off Lower California were also carried out during the southern California fishing season, not from faulty planning, but because that was the only time the research vessel was available for the work. In order to determine the relationship between the stocks in different parts of the range of distribution, tags must be put out throughout this area during he entire year, if possible. If this program has to be modified, the changes must be such as to keep the tagging work as close as possible to the ideal. A wide distribution of tags is particularly necessary for mackerel because of the seasonal and geographical limitations of the fishery, as compared with the range of the species.

On the other hand, much information can be obtained from an intensive tagging program carried on in one locality. On the theory that such a concentrated program should sample all stocks passing the point chosen, it should result in a distribution of tags throughout the population. However, without the use of a widespread program there is no way of determining whether or not such a distribution has occurred. Probably some combination of these two approaches to the problem will be needed.

Rate of Decline

The difficulties encountered in relating the population fished to the total population, discussed above, are particularly grave in using tagging returns to determine rates of mortality. The short-comings of past tagging operations that render them inadequate for determining migrations and inter-relationships between the different sections of the mackerel populations also apply to the determination of mortality rates. Greater dispersion of tags, both geographically and seasonally, must be attained to provide a basis for the necessary calculations.

The returns of tags obtained during the same season the fish were tagged have been used to estimate the size of population available to the fishery at that time. Considerably more data are needed, however, to check results before their reliability can be assessed.

Racial Studies

In two or more populations where little or no interchange occurs, peculiarities of bodily structures such as relative length of head, number of fin rays, number of scales in the lateral line, etc., are perpetuated by in-breeding. These characters which may differ between localities are used to define independent subpopulations, usually known as races. Work in this field is carried on in biological investigations of commercial fisheries, usually in the fervent hope that something useful may eventuate. The results obtained by the very nature of conditions in the ocean can only be of qualitative nature. In practically all cases in commercial fisheries, such information is very useful, however, as substantiating evidence for demonstrating separation or lack of separation between the fish inhabiting various regions. Differences between stocks of fish shown by the methods classified under this line of work are not usually distinct enough to stand alone. For practical applications, other evidence is necessary.

Approximately three thousand mackerel have been examined so far for racial characters. The best characters found were the position of the so-called "haemal stay" in the series of haemal arches beneath the vertebral column and the proportion of head length to body length (Fry ms.).

The distribution of these two characters indicates that the mackerel found in the area from Cape San Lucas into the Gulf of California are so different from mackerel taken off southern California that there must be practically no intermingling of the two stocks. The fish taken in the Sebastian Viscaino Bay area are intermediate in character. Some groups from this area are much like the southern California fish; and tagging has shown that they do mix.

Judging from these results, the mackerel inhabiting the Mexican coastal waters north of Abreojos may be part of the California mackerel stock. The tagging experiments take on added significance as to whether or not they substantiate the analysis of characters used to separate the different races of mackerel. Since they also show some connection between the fish of the two areas, it remains to be determined how intimate the relation is.

Slight racial differences are also found between different schools or groups of schools in southern California. These, however, are of an entirely different order of magnitude than those found between southern California and the Gulf of California.

The racial material gathered so far must be worked up, and analysis completed. It will be of value for interpreting tagging results. Unless tagging returns prove to be at variance with the major results of the racial work, there appears to be little justification for spending a great deal more time on this phase of the investigation. Population problems that may be approached through the study of variations in anatomical characters can usually be solved more accurately by tagging. That method appears to offer the greatest promise of quantitative results for this species.

Growth

Determination of the age and rate of growth of a species is a basic requirement for assessing the potential productivity of its fishery. The age at maturity may be used to set a minimum size limit and the rate of growth when related to mortality rates will determine the most efficient level of fishing intensity. The determination of age is necessary to follow the size and reactions of the various age groups as they enter and are subjected to the fishery each year.

Material has been gathered and preliminary analyses have been made, using otoliths to determine the age. Fry has been able to read 90 per cent of the otoliths obtained. However, no measure of the accuracy of these readings has been attempted. The ages, as determined, have been checked with the only series of length frequencies that could be followed through. These have been carried through for a period of nine years and correspond closely with the otolith age readings.

Mackerel scales show promise of being more easily used for age readings, but are difficult to obtain because they are so deciduous. An effort must be made to utilize the scales since the otoliths have not been entirely satisfactory in the determination of age of older fish.

Age studies indicate that the mackerel mature at two years of age, and at this time weigh about 320 grams, or approximately three-quarters of a pound. With fishing mortality averaging around 50 per cent within the last few years, the two-year old fish dominate the catch, and the four-year group is the oldest one taken in significant numbers. In some years fish of one and one-half years of age have dominated the fishery.

It has been suggested that size limits be imposed on the mackerel fishery to prevent the capture or landing of fish younger than two years. Enforcement of such a limit would be difficult in the case of purse seiners and lampara boats. Moreover, it is apparent that until material now in hand has been analyzed, it is impossible to tell how much benefit would be derived from such a regulation. An overall catch limit will require a sound statistical and biological basis before it can be accepted as a remedy for the fluctuations in total yield.

Catch Samples

A good sample of the type of fish supporting a fishery can be obtained from the catch itself. Such samples of the mackerel catch have been gathered in San Pedro since 1929, and more recently from Newport and Santa Monica Bay. The method developed has been based upon an attempt to get a series of samples of fish from each area in which the fleet is operating. These can then be weighed by the total catch made in that area in order to make the samples representative of total landings. Samples of 50 fish are taken from loads under 10 tons which include most scoop net boat loads; and 100 fish are taken from loads over 10 tons. The latter are mostly purse seiners or lampara boats. Otoliths are taken from one fish in 10, if fish are plentiful, or one in five if fish are scarce. Eight boats are sampled from each area each week, if possible.

Fig. 35. A group of dip net mackerel boats in Fish Harbor, Terminal Island.

The method of sampling has been limited by available personnel. No tests of adequacy have been made. This deficiency should be corrected. There is some question, however, whether we can afford a large enough staff to concentrate the required effort upon this phase of the investigation while some of the more fundamental facts of life history remain to be solved.

Spawning and Early Life History

Enough work has been done with plankton nets to determine that mackerel spawn off southern California between February and July or August. The eggs float in the surface layers mostly above 50 meters depth (see Sette, 1943.1, on Atlantic mackerel). Spawning occurs close to shore, within the 100 fathom line. The heaviest concentrations of eggs have been found south of Oceanside, although spawning has been found as far north as Pt. Conception and as far south as the Gulf of California.

Progress so far consists of identifying the eggs (Fry, 1936) and defining the southern range of distribution of spawning and its season. No quantitative work has been done yet, nor has the work been carried far enough to limit the spawning area. The catches of larvae appear to be small, and may be evidence of active avoidance of the nets. Sette (1943.1) considered that he was able to obtain quantitative samples of Atlantic mackerel larvae up to 22 mm. (seven-eighths of an inch) length but these results were obtained with larger nets than those used so far in the California investigations.

While it is possible that fluctuations in the catch of mackerel may be associated with variations in survival of young as hypothesized by Sette for the Atlantic species, it is first necessary to examine the relation of the mackerel supporting the California fishery to the stock in the rest of its eastern Pacific range before an intelligent approach to the problem can be made. If possible, a survey of spawning areas should be made that will accurately define the areas utilized, and indicate their relative importance. This would be necessary as a basis for quantitative work if it becomes desirable to take that up. This in turn will depend upon the results of the population studies.

Future Work

The mackerel investigation plainly shows the lack of an adequate staff. Something has been accomplished in several different approaches to an investigation of the fishery, but not enough to reach definite conclusions. As soon as possible, the data gathered so far must be analyzed and brought up to date. It is especially important that a study be made of the adequacy of the sampling methods now used on the catch. The work required in the tagging program has been indicated, and should be attempted as soon as boats are again available for field work. The statistical analysis of boat catches and revision of the method of collecting the basic catch figures are also important. Some measure must be obtained of the quantities of mackerel landed with sardines and not separated in the catch statistics. Moreover, a further study of methods of measuring the changes that occur in abundance must be made, keeping in mind the possibility that the total catch may be the best measure of the size of the available population.

A foundation must be laid for evaluating the relative importance of natural fluctuations in the abundance of this species, as compared with those changes resulting from the effects of the fishery. While several marked cycles in abundance have occurred, it is as yet impossible to determine how these changes are related to possible changes in the entire population. The mackerel population which supports the California fishery must be defined by tagging, supplemented if necessary by racial studies. Methods must then be devised to measure fluctuations in this population. These fluctuations must be related to changes taking place in the catch. When these have been associated with changes in the fishery, it should be possible to determine whether or not the program should be limited to setting up a basis for predicting natural fluctuations to aid the industry in planning operations, or whether it should be broadened to include regulation for the purpose of stabilizing the catch. If necessary, the time-consuming sampling of landings will be curtailed to permit more rapid progress on other lines of investigation of more basic importance such as migrations, growth, and the early life history.

SHARK

The soupfin shark fishery in California has developed as a result of the demand for Vitamin A. This demand has grown out of the shortage of supplies formerly obtained from the cod liver oil in the North Atlantic, and from the recently developed popularity of vitamins. It was found in 1937 that the Vitamin A potency of the soupfin shark liver oil is from 50 to 100 times greater than that of the cod liver oil. The prices of the livers to the fishermen, therefore, have risen as the competition for the raw product developed. As a result, the fishery grew from one of minor importance in 1936 to one of the most valuable fisheries in California in 1938.

The landings of shark in California are shown in Table 10.

TABLE 10

California Shark Landings

Year	*Pounds*
1930	647,297
1931	593,162
1932	850,888
1933	471,030
1934	526,202
1935	555,117
1936	471,861
1937	913,105
1938	7,513,541
1939	9,160,249
1940	7,813,000
1941	7,511,595
1942	3,417,493

The fishery at first was carried on by hook and line. It was not long, however, before it was discovered that these shark could be taken in greater numbers in "diving" gill nets. With the increase in price of the shark liver oil to a maximum in 1941, more and more boats outfitted with nets; and by 1940 there were literally miles of these nets in use on the fishing banks. As a result, it is not surprising that the catch of soupfin shark decreased sharply after 1941.

Program to Date

Investigation was started by the California Division of Fish and Game in 1941. A contract was signed with Stanford University to carry on the analyses of Vitamin A potency of the liver oil. Difficulty was experienced at first because of the loss of the staff members assigned to this problem through the draft; but it was finally stabilized and at present a report upon the results of the Vitamin A survey is in preparation. This report will cover only the preliminary survey of the problem, and there are still many phases of the investigation that should be continued. Lack of a research vessel, combined with the high cost of the individual shark, has prevented extensive investigations at sea. The work has been confined, therefore, to a study of the relationships of the Vitamin A potency of the liver as it varies from season to season, between the different regions, and with the differences in size and sex. The catch has also been sampled in many localities to determine regional and seasonal differences in proportion of sexes, sizes taken, and stage of maturity. Some boat logs have been collected, and all samples of the catch have been accompanied by interviews of the boat captains. These records are only sufficient to indicate roughly the changes that have occurred in catch per unit of effort of the diving gill nets.

It has been found (Ripley manuscript) that the Vitamin A potency of the soupfin shark liver oil and the percentage of oil in the livers, as well as their total Vitamin A content, increase with size and weight. Sexual dimorphism is shown in the average higher potencies and total Vitamin A content of the livers in male fish than in females of the same size.

In both sexes the Vitamin A potency and total content are associated with sexual maturity. The potency of the male livers increases slowly up to 155 cms. (61 inches) length, then rises rapidly with greater length. In females the rapid rise does not occur until a length of 170 cms. (67 inches) has been attained.

The smallest mature males found so far were 135 cms. (53 inches) long. At a length of 160 cms. (63 inches), an average of 90 per cent males are mature and all are mature at a length of 170 cms. The smallest mature females found were 150 cms. (59 inches) long. At 170 cms. length, 90 per cent were mature; and 100 per cent were mature at 180 cms. (71 inches) length. The range of sizes over which the fish mature cover the size range in which the rate of increase of Vitamin A potency of the livers is accelerated.

Soupfin shark are viviparous. Fertilization is internal and the young are carried by the female in the uterus throughout embryonic development. The Vitamin A potency per gram of liver oil, as well as the percentage of oil in the livers of adult females varies with the stage of development of the young carried by them. During early stages of development the livers tend to have a high oil content and low vitamin potency per gram of oil. Females bearing well-developed young or which have just given birth to their young tend to have small livers of low oil content but with very high potency per gram of oil. Apparently this variation in potency is not associated with a significant change in the total vitamin A content of the livers of shark of the same size.

Fertilization of the eggs takes place in the spring apparently a short time after the young are born. The gestation period extends over about one year. Each female produces from 16 to 54 pups, the number increasing with size.

Relation of Sharks to the Fishery

The total catch along different sections of the California coast shows that the northern California fishery has been successful in the fall and winter. The central California fisheries have produced shark between August and the following February. In contrast to these fisheries located north of Pt. Conception, the Santa Barbara and Los Angeles regions have produced their principal catches between March and August.

Further differences have been found in the distribution of sexes in the fisheries in the different regions. In northern California approximately 97 per cent of the samples examined have consisted of males. These were taken for the most part in depths greater than 20 fathoms. In the central California and Santa Barbara fisheries, males and females are equally represented. In the latter area, however, a preponderance of females was found in catches made in depths less than 30 fathoms. Samples of catches in the Los Angeles region which were confined to the Catalina Island fishery, consisted of 99 per cent females and were all made in depths less than 20 fathoms.

Measurement of shark landed from the various areas indicates that few fish under 160 cms. total length are taken by the large mesh gill nets. However, in central California and Santa Barbara regions considerable numbers of shark between 100 and 160 cms. (39½ and 63 inches) in length are captured in the smaller meshed sea bass gill nets. These nets are operated close to shore often in the kelp beds. These sharks have been proven to be worthless for Vitamin A and their capture represents a loss to the fishermen if they cannot be returned to the water alive.

Catch Per Unit of Effort

The value of the individual shark and the intensity with which these fish have been sought indicate that changes in total catch should reflect changes in relative abundance. Data suitable for measuring changes in abundance of shark are fragmentary. Boat logs have been collected from the few boats which keep usable records. In addition, trip records have been obtained through interviews of boat captains during periods when the staff was collecting samples of the shark landings. These are not numerous enough to be representative of all regions of the coast of California but enough are available from Eureka to give some indication of the course the fishery is following. The Eureka trips upon which data were obtained are shown in Table 11, with the average catch per 1,000 fathoms of diving gill net fished for 20 hours for the last three years.

TABLE 11

Shark Catch Records from Eureka

Year	*Number of trips*	*Average number of shark caught per 1,000 fathoms net fished for 20 hours*
1942	33	55.4
1943	45	17.7
1944	21	1.4

The decline shown is more than 97 per cent between 1942 and 1944. Figures for other sections of the coast show a similar decline between 1942 and 1943 but figures are lacking for 1944.

In view of the decline in total landings which has occurred over the period covered by the decline at Eureka in catch per unit, and which has taken place in spite of a continued increase in total amount of fishing through 1944, actual depletion is indicated. Even though the records of catch are unsatisfactory, the uniform decline in yield reported along the entire west coast from California to Washington substantiates the fragmentary records of catch per unit of effort that have been obtained.

Future Program

Vitamin A has been a widely accepted product, with a good market for some years. Its recent popularity has coincided with the discovery of natural high potency oils, as well as of methods for concentration of the vitamin from lower potencies. A canvass of opinions of the industry indicates that the future of this market is bright if a supply can be obtained. It is a source of additional income to the fishermen and if the fishery could be stabilized, would provide a useful means of maintaining the income of the larger numbers of fishermen expected in the future along this coast. The possibilities of conservation must be explored.

The fishery has been developed within two years from an incidental activity to one of intense concentration of large numbers of boats. Reacting as might be expected in the case of a fish of slow growth and with a slow rate of reproduction, it has completed its cycle of over-exploitation and apparently reached an advanced stage of depletion in the course of eight seasons. Drastic measures will probably be required if the production is to be brought back and stabilized.

While there seems to be no factual basis for making predictions as to the future of the Vitamin A industry, reduced prices for Vitamin A with postwar deflation will no doubt be reflected in lower prices to fishermen for the raw product. The total potential value of the soupfin fishery will probably be much less than the values attained at the peak of production. Neither the potential value of the fish to fishermen, its basic value to the nation as a whole, nor its potential productivity warrant the establishment of an elaborate program of investigation. Sufficient data should be gathered, however, to serve as a basis for intelligent control.

The first objective must be to straighten out the Bureau's shark landing records and to analyze them as far as possible to check conclusions arrived at tentatively by the catch and trip data samples. This will involve a separation of liver landings from carcass landings. To be comparable with other fisheries statistics the landings should be converted to a round weight basis. However, it is doubtful if conversion factors could be applied without introducing, if not magnifying, any errors that there might be in the basic data. Within the last year the practice of buying livers from fishermen on a potency basis has introduced another difficulty in keeping records straight in that fishermen have had to store their livers sometimes for several months before sale. Confusion has arisen when the sale was made as to the making out of fishermen's receipts; but a check of dealers' books will no doubt provide an adequate correction for any deficiencies in the regular records. In addition to the analysis of port records, the experience gained must be used to establish, if necessary, adequate methods for obtaining usable records of the fishery in the future.

Final formulation of control measures as well as of total catch limits will require knowledge of the nature of the distribution and migrations of soupfin along the entire coast. If feasible, marking must be done to accomplish this. This may also be the best approach to an estimate of age and rate of growth. How far the program can be extended into these fields will be determined by the possibility of obtaining enough sharks to accomplish anything.

Unless destruction of enough young has taken place to reduce markedly the numbers of maturing adults, there may be some hope of a recovery of the stock within a relatively short interval, to a point where adult sharks will again be available. To preserve the fishery, these sharks must be protected. They will represent the progeny of parents now probably dead. Without some protection, their destruction might mean the death of the soupfin shark fishery for many years to come.

As a first measure of protection, minimum size limits have already been recommended to the industry—155 cms. (61 inches) for male, and 165 cms. (65 inches) for females. This measure, even if observed, will not preserve the fishery. In view of the collapse noted last year, complete closure for several years would probably be the most effectual way to promote a rapid recovery. This closure, if imposed, should be followed by a limited total catch based upon data that can be accumulated during the closed period.

OTHER FISHERY PROBLEMS

An almost endless list of problems awaits investigation before California's fisheries can be assured of being maintained upon a businesslike basis, and before all regulations can be put on a sound foundation. Most of these problems are concerned with species which supply the fresh fish markets such as the flatfish, barracuda, rockfish, anchovy, shad, catfish, crab, lobster, abalone, and other shellfish. To this list must be added the kelp and agar fisheries of southern California. The latter is a war development that may not survive in peace times, but the former is a well established industry that may be expected to continue to thrive as long as a supply of raw material exists.

One of the great needs at present is a quantitative survey of all of our abalone and other shellfish grounds along the entire coast.

Practically all of the species listed above require development of methods, not only for the collection of data from the commercial industry, but also for measuring the sport catch as well. The marine fisheries form one of the largest attractions to sport fishermen in this State, and their drain on the stocks of many of the localized species may be expected to increase in importance as the popularity of this fishing increases after the war. One need only mention the abalone and its virtual disappearance from many sections of the California coast to appreciate the importance of the sport fishery.

The essence of any research program is continuity. Effective work cannot be done where personnel is continually shifted from one job to another. Therefore, with the choice of principal lines of research made, the staff assigned to those problems must be permitted to stick to their assigned tasks until results are obtained. It must be recognized, however, that intermittent demands may require data not available without some work. Moreover, small problems are continually arising that should be looked into. Regularly assigned staff members must not be diverted as trouble shooters. It appears that if such small short-term investigations prove to be of sufficient number under normal conditions, a man will be delegated to work on them to the exclusion of everything else unless temporary help can be planned to fulfill this function.

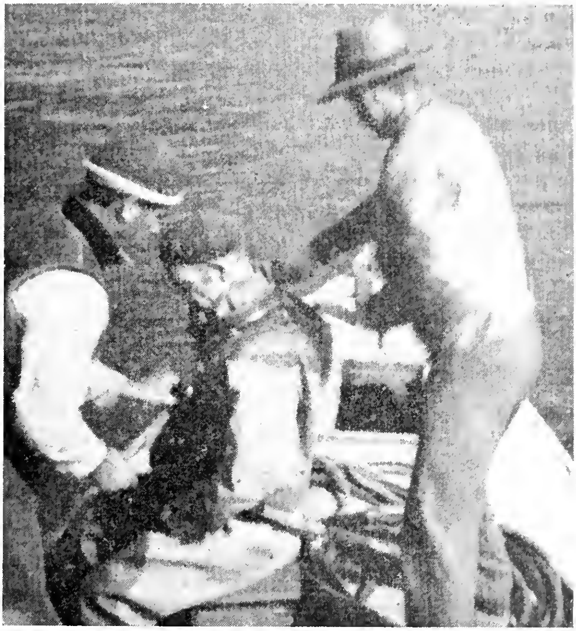

FIG. 36. Preparing for abalone diving. A diving suit is necessary for investigations below low tide level.

Technological Work

The need for investigations to discover means of improving methods of packing fish, and of handling and shipping fresh fish, as well as to improve methods of catching various species, has been brought out by the observations of the staff, as well as by requests made from time to time by the industry. Such work might be considered a direct subsidy to the industry; but the benefit that would be derived from elimination of much spoilage and from increased quality of the product would pay large dividends directly to conservation. This work will require the services of a chemist, and the establishment of a laboratory either at San Pedro or in the San Francisco area. It is proposed not to go into this matter on a large scale, but to feel our way along, first making an investigation of the problems involved in the fields outlined above.

Another branch of this work that should be studied is the possibility of developing methods of economically utilizing various species of fish that are known to exist in large quantities along this coast, but which, due to the peculiarities of the species, cannot be handled in the same manner as the fishes now being canned or reduced to meal and oil. Especially important in this regard is the anchovy which the sardine canners have not yet been able to handle. Development of such fisheries as this are important since they would not only provide additional employment for more fishermen, and probably an increased catch, but would also tend to relieve the strain that is now concentrated on such species as sardine.

Some work has already been done in this line incidental to the other investigations. Equipment made available on the M.V. "*N. B. Scofield*" was used to determine improved methods of preserving tuna catches on fishing boats. This work has encouraged the use of freezing apparatus on practically all tuna vessels. As a result, the catches brought in are, for the most part, in excellent shape and the spoilage of fish has been cut down. Another service to the industry was performed just before the war with a reconnaissance trip to search for albacore. Some explanation for Thompson's discovery of the relation between albacore catches and high temperatures was discovered in that the fish were found to occur mostly in the warmer true ocean water and not in the cold areas of upwelling close to shore.

Work of this nature could be greatly extended, but must be carefully planned to be effective. It must be kept within the bounds of the Division's field of legitimate activity.

SUMMARY

A program for the Bureau of Marine Fisheries is outlined in order to explain to the industry and sportsmen of California the purpose of marine fisheries research; to indicate some of the problems that must be solved to insure the conservation of our marine fish resources; and to indicate the scope of investigations that will be required.

Two branches of investigation are discussed: biological research upon which is founded the conservation of each species; and technological research which provides for more efficient utilization of the species by improving products, and for eliminating waste by improving methods of capture and handling. The biological investigations are considered first.

In the normal course of exploiting a fishery, each increase of intensity of fishing effort is usually followed by a drop in the catch per unit of effort, in the average size of fish caught and in the numbers of older fish taken. Increased efficiency of boats has in most fisheries permitted an expansion of activity to distant grounds. All of these adjuncts of a growing fishery do not prove depletion since they are present from the beginning. They will become stabilized if the fishing intensity is held constant.

Depletion is defined in two ways. It may be thought of as a reduction in numbers of fish as a result of fishing beyond the point at which the boats can operate at a profit; or biologically and more accurately, it may be defined as that condition of a fishery where the intensity of fishing has become so great that the surplus of fish resulting from the excess of growth and spawning over loss of fish through natural causes is smaller than the fishery could produce. Under a less intense fishery the fish

would be permitted to grow longer and more adults would be left to spawn. Marine fishery research studies all of these factors with the object of determining the level of fishing intensity that will produce the greatest continuous and stable catch.

Research effort must be distributed on the basis of the total value or yield of each species and on the need of each species for protection. These two considerations determine the order of precedence of investigations of California fishes as follows: Sardines, salmon, tunas, mackerel, sharks, drag fisheries and shellfish. Others will be undertaken as soon as the more critical problems can be cleared up.

Records of the weight of each species of fish landed in the State with area of capture, port of landing, type and amount of gear used and sale price are the basis of the investigation of the fisheries. Efficient methods are required of maintaining a check on the accuracy of the records. They must be adjustable to the continual changes taking place in the fishery.

Research on the sardine and its fishery shows that a decrease in catch per boat per month has occurred since the 1935-36 season and has levelled off at about 70 per cent of the 1932-33 value. An increase in the 1942-43 and 1943-44 seasons is tentatively ascribed to a reduced fishing effort. The total catch has remained near the average of 500,000 tons per year in California since 1935.

Formulation of a conservation program for sardines requires a more accurate analysis of catch per unit of effort probably based upon boat log records. A further study by intensive tagging of reactions of the fish to fishing, of variations in the amount and distribution of spawning, and of the amount of fish taken by the bait fisheries will also be needed.

The salmon investigations are designed at present to discover methods of adjusting plans for irrigation and power developments, especially in the Central Valleys area, to permit the survival of the fish. Provision of adequate flows in some streams may increase the runs using those spawning grounds. The building of either Table Mountain or Iron Canyon dam in the Sacramento will probably result in the loss of about 40 per cent of the Central Valleys salmon. Obstructions which prevent the upstream migration of salmon to spawning areas are being located. The principal problems of this nature are listed with action recommended. A basis for providing an adequate escapement of spawners to each spawning area will be obtained from a study of the relation of the life history and migrations of salmon to the fishery. Installation of screens designed to protect small salmon, with by-passes to permit them to continue their downstream migration when caught in a diversion ditch above a screen, is advocated wherever required. The more important diversions are listed with measures recommended to control them.

Tuna investigations have been limited so far to a study of the classification of the different species that are fished by California boats. A broad investigation of each species is proposed to determine the relation between fish from different areas, and to study rates of growth and nature and extent of migrations. This will be taken up as soon as possible. It must be carried out over a wide area of the eastern central Pacific and must be coordinated with similar work now being planned by other fisheries organizations.

The Pacific mackerel (*Pneumatophorus diego*) produces the bulk of California's mackerel catch. Landing records show that the landings have fluctuated widely in recent years between a maximum of 146,407,000 pounds in 1935 and a low of 52,527,000 pounds in 1942. The many changes in fishing methods during the last fifteen years make the study of variations in fishing effort difficult. The total catch is suggested as the best measure of abundance. Studies of mackeral migrations by tagging and of the distribution of races by variations in anatomical peculiarities must be carried far enough to determine the relation of the fish taken in California to the mackerel off lower California. Further studies of growth rates, distribution and amount of spawning and variations in size of the different year classes are also required as a basis for conservation measures. The principal task must be to determine through those investigations the relation between the natural fluetuation in abundance and those changes resulting from the effects of the fishery.

The soupfin shark fishery developed rapidly after 1937 to an annual yield of over 10,000,000 pounds with a value of over $1,000,000 per year to the fishermen. It has shown a rapid decline since 1942 which is apparently due to the intense fishery developed with such efficient gear that whole schools can be practically wiped out. A study of the distribution of these sharks shows that mature females bearing young are concentrated in the shallow waters of southern California during the fishing season there. An equal distribution of sexes is found off central California and a concentration of males is found off northern California. The vitamin content of the livers of the females below 165 cms. (65 inches) long and males below 155 cms. (61 inches) long is so low that it is wasteful to take them. At 160 cms. length (63 inches), 90 percent of the males are mature and at 170 cms. (67 inches), 90 per cent of the females are mature. The vitamin potency of shark livers of both sexes is plainly related to sexual maturity and in the females it varies throughout the year with the state of development of the embryos. These fish are viviparous and have but one batch of young per year. The number of young for each female varies from 16 to 54, the number increasing with size. No measure of age or rate of growth has yet been found. If the soupfin shark fishery is to be conserved, further study of age and growth must be undertaken. Tagging must also be carried on to study migrations and the relation of the sharks taken in California to those taken farther north. A drastic limitation of catch may be required to protect the young now growing up and to provide a spawning reserve.

All fisheries are not discussed in detail but investigation of the crab and its fishery, of the drag boat fishery and the species upon which it depends, as well as of the abalone and other smaller fisheries, will be undertaken as soon as sufficient help is available. Lack of help at present also inhibits the increased activity required in the larger investigations.

A technological program is suggested to discover methods of improving the handling an processing of the fish catch. Development of methods of efficient utilization of such species as the anchovy which are abundant but are not now used in quantity are also proposed.

Essential to this necessary expansion of research activity is the establishment of another laboratory in central California to provide space for work on central and northern California species. The Terminal Island Laboratory will be required as a center for the investigations of tuna, mackerel and other predominantly southern forms.

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THE KETTLEMAN HILLS QUAIL PROJECT [1]

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INTRODUCTION

To many persons who know the Kettleman Hills of Fresno and Kings County, California, the idea that quail exist at all in the area will be novel. As seen from the west-side valley highway (State Highway No. 33), the country appears barren and devoid of all game life and habitat. Such is not the case, however, since from early times quail and other game have been hunted here.

The Hills are a long ridge about 700 feet above the surrounding plains, which itself is about 700 feet above sea level; the North Dome, with which we are concerned, is about five miles wide by 15 miles long. Under natural conditions, the only shrubby growth there was quail brush (*Atriplex polycarpa*); it was scattered throughout the hilly area. Short, annual weeds, such as filaree (*Erodium cicutarium*) and the brome grasses (*Bromus* spp.), furnish forage for bands of sheep which graze the area in the spring. This sheep browsing has locally damaged the quail brush, but quick reproduction of this cover occurs with protection from sheep.

According to C. W. Carstens of Fresno, who lived near the Hills as a boy, valley quail existed locally in large numbers about the few existing waters. Since springs were rare, quail were not found scattered throughout the area.

Attempts to find oil in the Kettleman Hills were made as early as 1899 by the Balfour-Guthrie Company, an English syndicate. From then on, until a producing well was brought in by the Milham Exploration Company in 1928, numerous attempts were made to develop oil. With the advent of the present oil development, water was spread virtually throughout the North Dome and a consequent boom in the quail population resulted.

Oil field men employed by the various companies took an interest in quail and other wildlife on the Hills, and by one means or another supplied water for the birds over much of the oil well area. Water used for fire protection at the wells and drilling sites was made available to quail by means of a "cracked valve" or drip, often supplemented by an open, concrete basin to hold limited quantities of water. Employees of the Standard Oil Company of California developed a standard, concrete

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1 Submitted for publication April, 1945. All quail work done on the Hills was part of the Federal Aid in Wildlife Restoration Project California 6-R, of which Mr. Glading was the Leader. Personnel who assisted at various times in the study were Project Assistants David M. Selleck, Fred T. Ross, Emerson J. Miller, and David E. Savage. Grateful acknowledgment is hereby made to the employees of the Standard Oil Company of California and the Kettleman North Dome Association, who by their interest and ready assistance made possible the present study. The staff of the Avenal High School aided materially in making their welding shop facilities available to the Quail Project. Mr. Hjersman was the first resident biologist on the Kettleman Hills project, starting active field work in June, 1942, and continuing to November, 1942, when he entered the armed services. In December, 1942, Mr. Enderlin took over Hjersman's position and has continued as resident investigator until the date of publication of this article.

drinking trough and placed these at many of the wells. The oil workers also planted tamarisk (*Tamarix articulata*) and tree tobacco (*Nicotiana glauca*) as shade and cover in the vicinity of some of these watering units.

Various oil companies now operate on the "Kettleman Hills North Dome" which is essentially the area included in the quail program. The two major companies, Standard Oil of California and the Kettleman North Dome Association, control over 90 per cent of the land concerned in the quail developments. These two companies have led in cooperation with the Division of Fish and Game in the present project.

In the spring of 1941, Mr. J. H. Sargent of the Kettleman North Dome Association in agreement with Mr. C. P. Campbell of Standard, asked that the whole North Dome area be made into a game refuge. The area was closed to hunting by Governor's order prior to the 1941 quail season. The two major oil companies agreed to allow the Division of Fish and Game to conduct field studies on quail and other wildlife and to allow trapping of quail for restocking and scientific studies.

Active field work was started in the Fall of 1941 when David M. Selleck of the Bureau of Game Conservation aided in making a quail water supply and cover map of the area. Mack P. Lee, a former employee of the Kettleman North Dome Association and past president of the Lemoore Sportsmen's Club, assisted greatly in finding the watering spots and in orienting the Fish and Game men on the Hills.

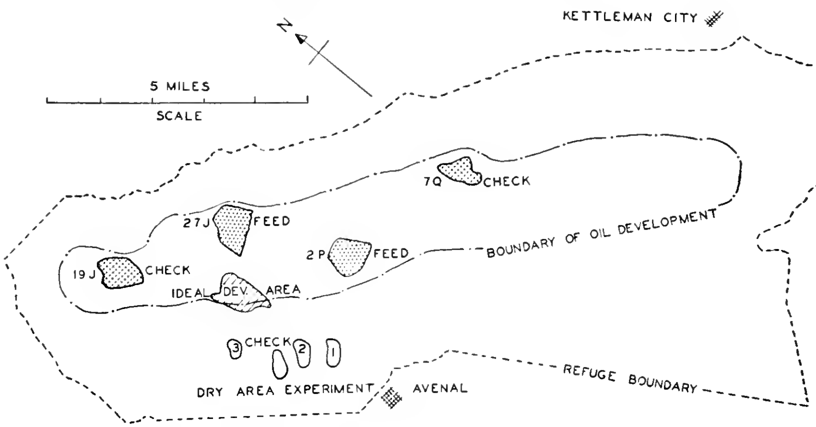

FIG. 37. Map of Kettleman Hills Quail Refuge showing experimental areas mentioned in text.

THE EXPERIMENTAL PROGRAM

The Quail Feeding Experiment

The operators of the Dune Lakes Club in San Luis Obispo County were successful in establishing and maintaining an extremely high population of valley quail chiefly by intensive predator control and artificial feeding (a report on this is in preparation). The Quail Project decided to test the economic value in managing valley quail of each of these two methods considered separately. An experiment to test intensive predator control as an independent method was set up at the Shandon Experimental area (report in preparation). At Kettleman Hills, the value of artificial feeding, considered by itself, was investigated.

Four areas, two experimental and two check, were involved in these feeding tests. The two experimental or "feed" areas (see Fig. 37) were designated 27-J Feed and 2-P Feed Areas, while the two check areas were the 19-J Check and the 7-Q Check Areas.

The plan of operation on these areas was to obtain relative counts of quail, quail predators, and quail competitors at regular intervals before and during the application of feed to the two feed areas. Census work was started in November, 1942, and continued to March, 1945. Feeding was started on the 27-J and 2-P Feed Areas on March, 1943. The feed was distributed in designated feed lanes in each area at the rate of one sack per week spread on each feed area. Feeding was done on Mondays, Wednesdays, and Fridays, about one-third of a sack being fed each day on each of the feed areas. The amount placed varied with the acceptance by quail.

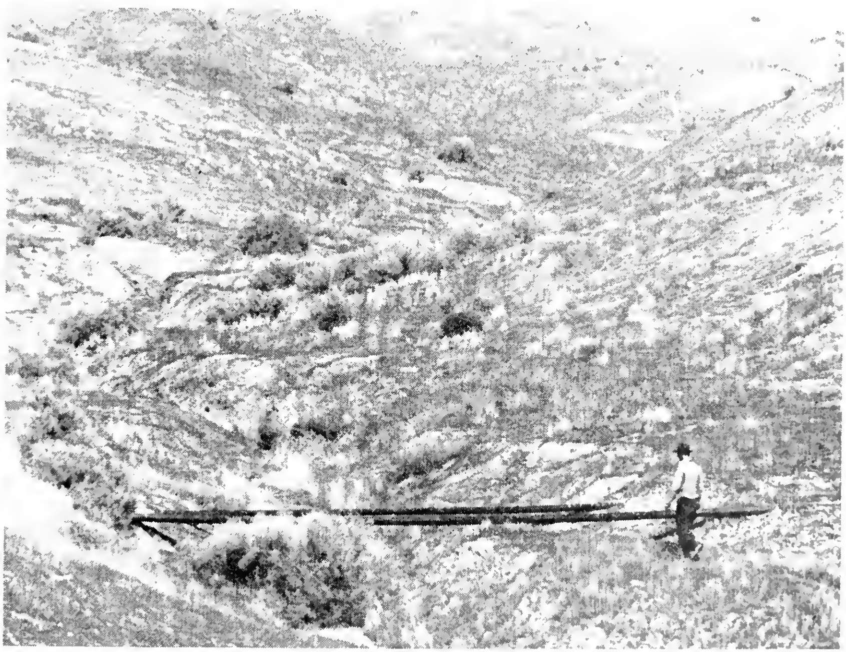

FIG. 38. Feeding lane in 27-J Feed Area. The low brush is the native quail brush (*Atriplex polycarpa*). This area and the 19-J Check Area are typical of the dry, north part of the Kettleman Hills North Dome.

The feed consisted of varying proportions of wheat grits, yellow corn grits, milo, grain sorghum grits, and steel cut oat groats. Due to war conditions, it was impossible to obtain a uniform mix, but in general, all of the above complements were present. During the young chick season of 1944, a standard, growing chick mash was fed together with the larger feed.

Following are the methods of censusing the quail and other species on the areas under observation.

Census Methods

At the start of the experiments in the fall of 1942, it was planned to conduct a horseback census in the fall of the two feed areas, the two check areas, the four water experiment areas, and the ideal development area. Such horseback counts were made in September, 1942, September, 1943, and November, 1944.

These quail counts were made using three men, horseback where possible. The areas involved in the counts were censused by the three men riding about 200 feet apart, covering the area as a unit in the same manner that a mower cuts a lawn. Counts were made of coveys seen and the results noted on a field map. For a detailed account of this census method see Glading, 1941.

In addition to the over-all mass quail counts, an idea as to the success of the feeding program was obtained by visual counts of young quail versus old during the summer. These ratio counts were made along "bird-walk-routes" (see next paragraph) in July and probably give some index of nesting success and chick survival.

In order to determine whether the feeding program would increase the population of seed-eating birds and other quail competitors, periodic bird and rabbit counts were taken along set routes in each of the four areas concerned in the feeding program. These counts were made on four successive days, using the following program:

1st day morning, 19-J Check Area, 27-J Feed Area
1st day evening, 2-P Feed Area, 7-Q Check Area
2nd day morning, 27-J Feed Area, 19-J Check Area
2nd day evening, 7-Q Check Area, 2-P Feed Area
3rd day morning, 2-P Feed Area, 7-Q Check Area
3rd day evening, 19-J Check Area, 27-J Feed Area
4th day morning, 7-Q Check Area, 2-P Feed Area
4th day evening, 27-J Feed Area, 19-J Check Area

The count consumed about one-half hour in each area. All birds seen were listed, although a summary is given later of only the seed-eating birds, principally crowned sparrows. Cottontails and jack-rabbits seen in the course of these walks were also tabulated. Similar comparative counts have been made by Grinnell and Storer, 1924, and others.

A check was made on the number of raptorial birds, principally hawks, by choosing a high "observation point" on each area as a lookout. These counts were made periodically according to the schedule given in the preceding paragraph. One hour was devoted to each area each day of the count. Where possible, individual hawks over the area were counted. Field glasses were used only to aid in identification and were not used to "reach out" beyond the boundaries of the experimental area. Results of the raptor count are shown in Table 1. Some species seen only occasionally, such as the owls, are. not listed since their number is too small to be significant throughout the whole series.

Periodic checks on the rodent population and its possible variation under the artificial feeding program were made by means of a "comparative rodent trapping" run on the 2-P Feed Area and the 7-Q Check Area. These counts were made by a modification of the method used by Townsend, 1935, and others.

Thirty-four trap sites for standard mouse and rat traps were placed in a straight line in each area. Care was taken that these lines, totaling 330 yards in length, were in comparable terrain as far as topography, cover, and water were concerned. The trap sites were staked out 30 feet apart along the lines, three traps each being placed in the first 33 sites, and one trap in the 34th, making 100 traps in each line. One trap in every six used was a standard rat trap; the remaining were standard mouse traps. Rolled oats, chewed into a sticky ball, and bacon were used at bait on alternate traps. (See Fig. 39 for photograph of trap lay-out.)

TABLE 1

Results of Raptor Counts Taken From Observation Points in Fed and Non-Fed Areas

Area	Dec., 1942		Mar., 1943		July, 1943		Dec., 1943		Mar., 1944		July, 1944		Feb., 1945	
	Accipters**	Other hawks	Accipters	Other hawks	Accipters	Other hawks	Accipters	Other hawks	Accipters	Other hawks	Accipters	Other hawks	Accipters	Other hawks
19-J Check	1	8	------	------	------	1	1	14	------	------	1	6	2	10
27-J Feed*	------	13	------	------	------	------	1	10	------	------	1	6	1	9
2-P Feed*	1	4	------	------	------	------	7	8	------	------	2	6	4	8
7-Q Check	------	3	------	2	------	2	2	15	------	2	3	11	6	9

* Artificial feeding started on these two areas March, 1943.
** Bullet hawks.

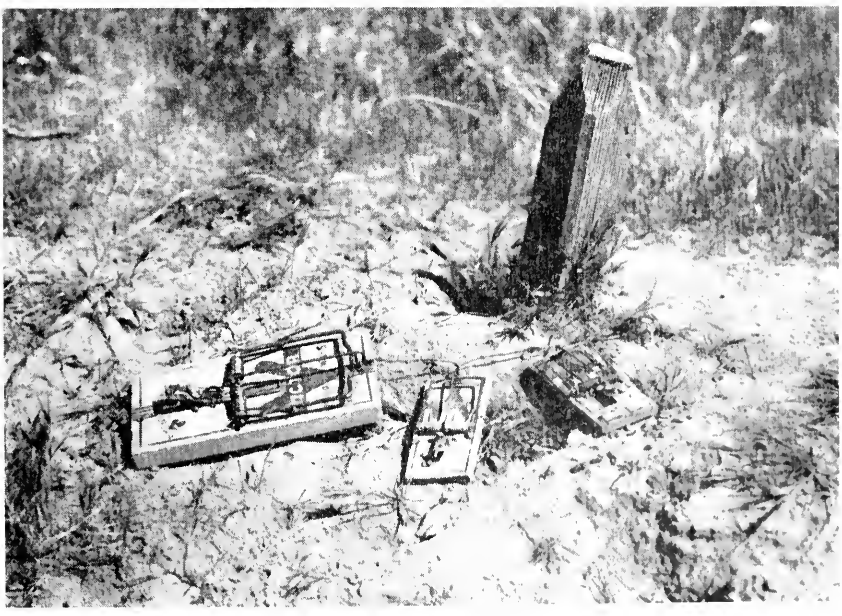

FIG. 39. Mouse and rattraps used in comparative rodent counts on fed and nonfed areas. A line of 34 stakes placed 30 feet apart, totaling 330 yards in length, was laid out in each area. Three traps were placed at 33 of the stakes, one at the 34th, making 100 traps per line. The lines were run for five consecutive nights (500 trap nights) in the spring and fall of each year.

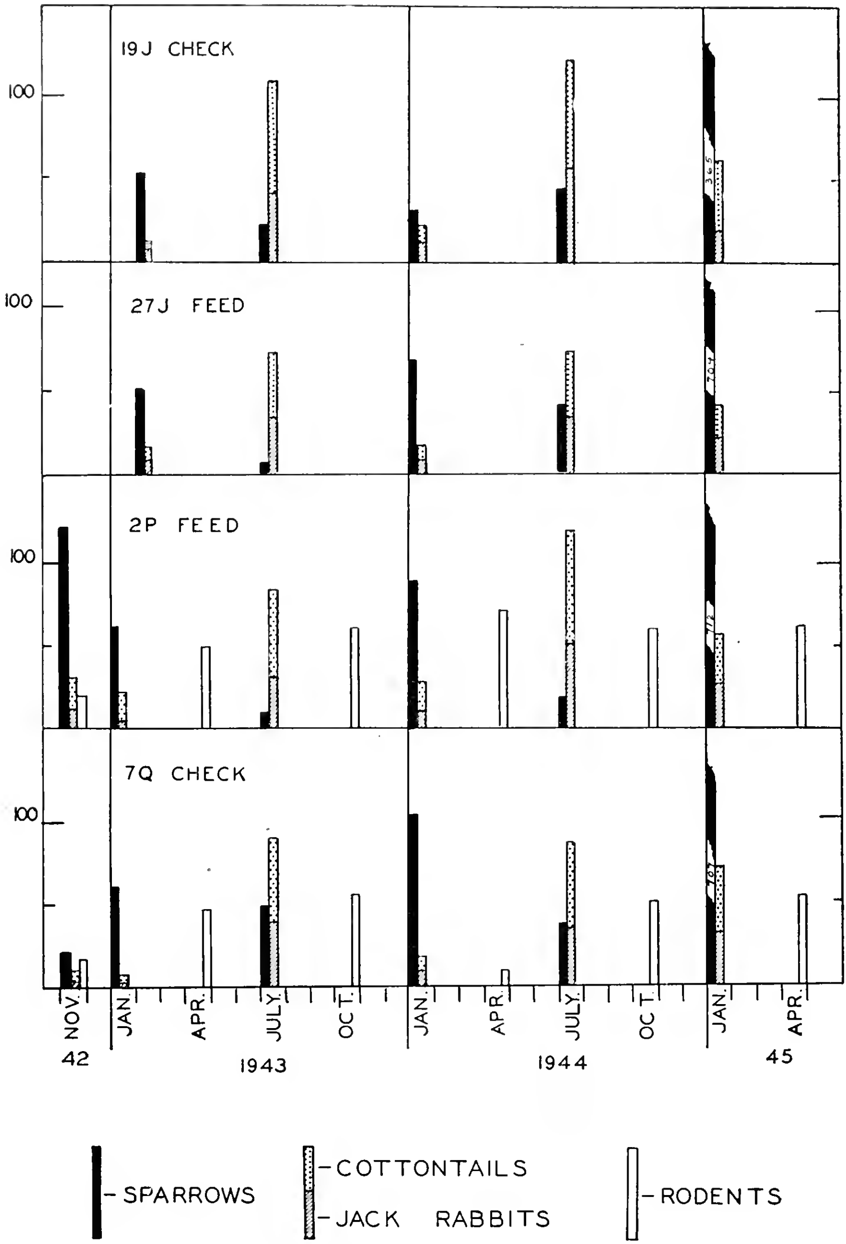

FIG. 40. Graph of populations of quail competitors on fed and nonfed areas. Solid bars indicate number of sparrows seen in passerine bird counts. Diagonal hatch bars indicate number of jack rabbits seen; dotted bars number of cotton-tailed rabbits seen during passerine bird counts. The open bars indicate number of rodents trapped in the comparative rodent trapping censuses. Feeding started on the 27-J Feed Area and the 2-P Feed Area March, 1943.

The traps were set each night for five consecutive nights in each trapping period, making a total of 500 trap nights. Only the total of rodents actually caught is shown in Fig. 40. "Sprung" traps were counted but not tabulated here, since much of the springing was done by birds in the late evening or early morning.

Possible mammal predators on quail were checked by means of track bed counts. Ten permanent trail spots each about ten feet long were chosen along pathways commonly used by coyotes, foxes, skunks, etc., in each of the four areas of the feed experiment. These were run for three successive nights in each area. The sites were visited the evening before each count was to be made and "dusted" by using a piece of brush. The following morning the sites were visited and a reading made of all tracks seen. A summary of all these counts is given in Table 2. Only coyotes, kit foxes, bobcats, house cats, and skunks are listed among the mammal predators. Roadrunners are also given. Many other tracks, such as rabbits, quail, and small rodents, were seen, but in general were too numerous to obtain any exact counts or comparisons.

FIG. 41. Predator track census spot. Ten such permanent trail spots were chosen in each of the experimental areas. The spots were "dusted" each night for three nights to make tracks register. A reading and tabulation of tracks was made the following mornings.

TABLE 2

Results of Predator Track Counts on Fed and Non-Fed Areas

Area	Feb., 1943		May, 1943		Aug., 1943		Feb., 1944		Aug., 1944		Feb., 1945	
	Mammal predators**	Roadrunner	Mammal predators	Roadrunner	Mammal predators	Roadrunner	Mammal predators	Roadrunner	Mammal predators	Roadrunner	Mammal predators	Roadrunner
19-J Check	7	1	5	2	8	7	16	4	11	7	11	7
27-J Feed*	6	1	4	5	8	4	19	3	14	5	12	5
2-P Feed*	11	1	7	5	9	5	15	5	11	7	12	2
7-Q Check	10	4	3	1	9	8	12	7	11	7	11	6

* Artificial feeding started on these two areas March, 1943.
** Mammal predators listed include coyotes, kit foxes, skunks, house cats, and badgers.

While it is possible that some predators tended to avoid such man-treated trail spots, a study of tracks leading to the census spots did not show that such was a fact. If any such avoidance was present, it was probably equal on fed and non-fed areas.

Results of the Artificial Feeding Program

A glance at the summary of quail censuses and the summary of old-young ratios seems to show that a small, but consistent increase of quail has been obtained by feeding quail on scratch feed. The gains made, however, are nowhere near as startling as those obtained at Dune Lakes under a program of artificial feeding plus predator control. In our experimental program of predator control conducted at the Shandon Experimental Area, much more startling results were obtained by one year's control of quail predators than are here shown by artificial feeding alone. This suggests that the Dune Lakes results were largely due to predator control, although the combined program could conceivably have been more effective than the sum of the two component parts—feeding or predator control,—applied separately.

TABLE 3

Mass Fall Censuses of Quail at Kettleman Hills on Fed and Non-Fed Areas

Area	Number of quail		
	September, 1942	September, 1943	November, 1944
19-J Check	283	231	231
27-J Feed*	145	163	200
2-P Feed*	321	421	410
7-Q Check	315	315	201

* Artificial feeding started on these two areas March, 1943.

While some readers might interpret the increase of quail under these artificial feeding conditions as an indication that feeding is a recommended practice for increasing quail, the authors feel that the results as shown at Kettleman Hills do not justify the costs. A comparison of the counts taken after feed was supplied with the 1942 counts in Table 3 shows a small increase indeed for an outlay of some 400 sacks of grain at an average price of three dollars per sack over the interval that feeding has occurred. It is possible that feeding would show greater returns in other areas less blessed with natural quail foods than Kettleman Hills, but it is our feeling that many other more effective and economical quail management methods should precede attempts at artificial feeding.

The comparative censuses of the various quail competitors such as small rodents, crowned sparrows, and rabbits likewise do not show any startling increase in these species under the artificial feed conditions at Kettleman Hills. A study of Fig. 40 shows that rodents apparently increased more on the 2-P Feed Area than on the 7-Q Check Area. These differences were minor in the winter counts, but the April, 1944 trapping period when roughly seven times more rodents were trapped on the feed area than on the check area, and the April, 1945 period when an even greater difference was noted, indicate that rodents increased under the feed program. It is possible that had not a part of the rodent population built up on the feed area been killed off by our trapping in the spring periods, the increment would have bred up and shown significantly on the fall counts. The figures as indicated by our trapping do reveal that feeding resulted in increases in the rodent population in the spring and point to the probable ultimate outcome of such artificial feeding.

No very great increases were noted in the populations of rabbits or seed-eating birds as seen by our counts. However, it is felt that large numbers of crowned sparrows were attracted by the artificial feeding. Visits to the feed lanes immediately after feed was scattered showed large flocks of Gambel sparrows and golden-crowned sparrows feeding on the scattered grain. These flocks evidently moved in from non-fed areas. They did not show up significantly in our comparative counts. No similar concentrations were ever noted on the non-fed areas.

A similar short-term, local attraction of cottontail rabbits immediately after feed was scattered was apparent. This factor also failed to show up on our index counts as summarized in Fig. 40.

Predators on quail and on other animals that might have been attracted by the feeding, such as the various hawks and fur-bearers, failed to show any appreciable increases on the fed areas. (See Tables 1 & 2.)

From these results, it would appear that we were not successful in building and maintaining a quail population much above normal by artificial feeding, nor were there any indications that populations of seed-eating birds built up permanently. Rodents, however, showed a significant tendency to increase or be attracted to the feed.

The Quail Watering Experiment

For a number of years, the Division of Fish and Game, the U. S. Forest Service, and other agencies have been placing quail drinking fountains in the drier regions of the state to extend valley quail range into areas that are good quail habitat except for water. Abundant quail water is found at Kettleman Hills in the vicinity of the oil wells. However, there is a belt around the edge of the Hills, away from the oil field, that seems to have abundant cover and feed, but has no water. This belt probably resembles the condition of the whole Kettleman Hills prior to oil development. No quail whatsoever are found in this area in the middle of the summer and early fall. With the advent of winter rains, however, some quail from the watered part move to this summer-dry area. In the spring, prior to the onset of summer drought, a few quail nest in this waterless belt. To test the best means of stocking such an area that has been recently supplied with new watering places, the following experiment was designed.

Four areas, each comprising about 200 acres, in separate, comparable canyons on the dry, northwest slope of the Hills, were chosen. One of these (control canyon) was to be left absolutely dry; the other three were supplied with artificial quail water. One of the three watered areas (Tank No. 3) was left alone after water was supplied (no quail were introduced to see if birds would move in naturally from other places occupied by quail); at another (Tank No. 1), a covey of 23 quail marked with numbered and colored bands was released as a group in October, 1942; at the remaining installation (Tank No. 2), 23 similarly banded quail were penned for several days in a coop which was placed at the water. Three to five birds were released each day after they had been penned for a week. Periodic checks were then made on quail use.

FIG. 42. One of the "vacuum type" quail drinking fountains used in the experiments to test ways of introducing birds into newly watered areas. This installation consists of a 50-gallon drum insulated in earth in a redwood box. The top bunghole of the drum is sealed airtight except when filling. A ¾" pipe leads from the bottom of the drum to a drinking basin under the shade in the foreground. The device operates on the same principle as a vacuum type chicken watering fountain.

During the first autumn that the experiment was run, the following results were noted. No quail were seen about either Tank No. 3 (the one at which no birds were released), or in the non-watered canyon. The 23 quail that were released as a group at Tank No. 1 all disappeared shortly. Of the 23 quail released gradually at Tank No. 2, some remained about the pen for a few days during the release period, but as soon as all were turned loose, no more were seen about the site.

Regular horseback quail censuses were made on all four areas during the fall and winter of 1943 and 1944. No birds were seen in the immediate vicinity of these watering places, although wandering coveys were in the general part of the Hills covered by the four watering experimental areas. In the summer, however, quail (not part of the banded release) were seen watering at all of the tanks at various times during the summers of 1943 and 1944. No birds would ordinarily be found in this area in the summer without some water supply to hold them.

It seems, in concluding this experiment on ways of introducing quail to formerly dry areas which have been recently supplied with quail water, that the best procedure is to let nature take its course. Provided that a stock of native birds is present anywhere in the vicinity (in our case, permanent water was no farther than two miles from any installation), native birds will use the newly placed water. In our experiments, two attempts to release birds at these new fountains resulted in failure, yet in the succeeding summers native birds availed themselves of the same watering installations.

Although birds were not found about these installations in the winter, it is felt that the new waters will bring about an increase in quail abundance which will result in more winter use of these areas. This has been the history in other parts of the Hills where new water has been added.

Ideal Development Experiments

An early diagnosis of the deficiencies in the quail environment of Kettleman Hills pointed to the lack of water and cover (particularly roosting cover) as the two main components that need attention in order to build a maximum crop of quail. With these two factors in mind, one area, 33-J or "the ideal development area," was chosen in which to conduct tests on the best species of cover for local conditions and to experiment with various methods of supplying water for quail. While many of our early experiments with water and cover were done in this area, tests were also made throughout the Hills at spots which looked as though the addition of cover or water or both would result in a new quail covey center.

Since this work started in the fall of 1942, and barely two years have elapsed since the planting program was well under way, it is too early to give definitive results on the quail population. However, in many cases where sufficient growth has resulted since the time of planting cover, new covey centers have become established. Of particular note is one new covey of roughly 50 birds which has appeared in a formerly barren spot in the ideal development area. Water had been available for birds at an oil well, but conditions surrounding the immediate vicinity were such that no cover was present or could be planted. By carrying the water in scrap pipe to a more favorable spot in a small canyon 150 yards distant and developing cover about the new drinking site, in two years a new covey center was created. Similar results were obtained in other places on the Hills where our plantings grew to an amount sufficient to furnish cover for quail.

Escape cover is, in general, ample over the part of the Hills encompassed by the oil developments. However, there are some areas in which sheep grazing has seriously damaged the native quail brush (*Atriplex polycarpa*). This damage is concentrated in areas of several hundred acres each in size surrounding the few watering places suitable for sheep. Our work has shown that protection from sheep grazing can result in restoration of the quail brush in two years. Additional protection given to the native quail brush by fencing small plots against rabbits will result in seedlings attaining a size which is sufficient to withstand rabbit browsing. Such fencing is deemed desirable only in small plots about watering installations, and even here only at certain drinking places known to be frequented by large rabbit populations.

In general, the native quail brush will furnish cover in two or three years if water is merely allowed to seep on the ground about the quail drinking fountains. This procedure is possible under Kettleman Hills conditions, since the oil companies have been very generous in allowing use of their water.

Most of our experiments in cover planting were designed to supply roosting cover. The local quail roost in the low *Atriplex polycarpa* (3-4′ high), but prefer higher, denser roost trees which probably furnish more protection from mammal predators. In our experience, the best roost tree for quick growth and maximum quail value at Kettleman Hills and the west side of the San Joaquin Valley generally is the evergreen tamarisk, or "tamarack" as it is locally known. Roughly 2,000 slips of this tree were put out to supply quail roosts. This tree was felt to be ideal in this area for the following reasons:

(1) It grows rapidly. (One of our plantings grew nine feet in one year.)
(2) It is hard to kill off once it is past the first year's growth.
(3) It requires but a small amount of water for survival after the first year.
(4) It grows very readily from a cutting if placed in moist earth.
(5) The cost of cutting stock is practically nothing since all that is required is to cut slips from already existing plants.
(6) It will not spread into adjacent range land in the absence of water since its seeds will not germinate unless fairly moist conditions are obtained. Such was the case at Kettleman Hills. It must be noted that this tamarisk will become a nuisance on irrigated lands in some sections of the state.

Tamarisk at the Hills has been found to supply excellent quail roost in two to three years, if growing in a moist situation. The growing habit of the tree may be modified to supply better quail roost by pruning the terminal shoot of the tree. No other trees were found to be anywhere near as successful or adaptable to Kettleman Hills conditions as were tamarisk.

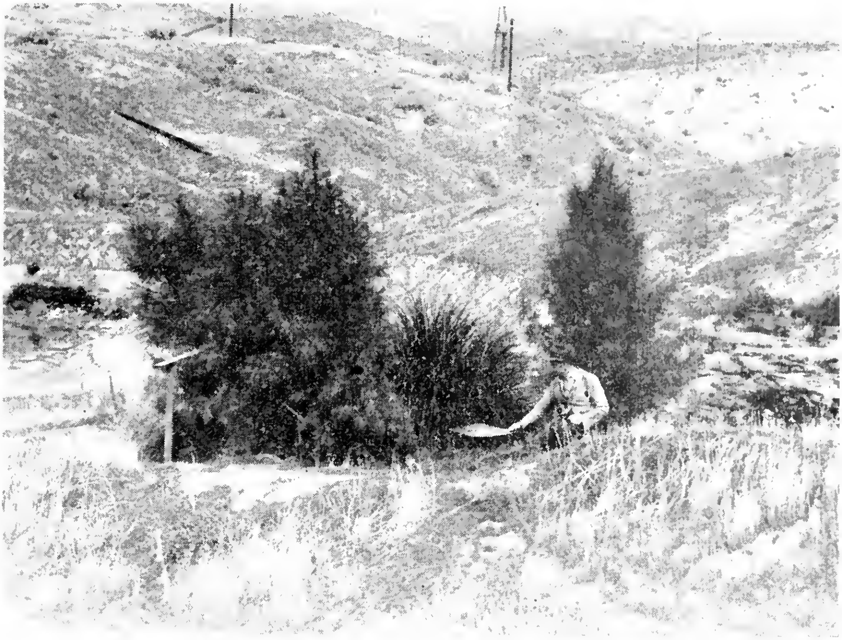

FIG. 43. One of the successful cover and roost tree plantings in the "ideal development area." The trees are evergreen tamarisk (*Tamarix articulata*). Pampas grass acts as additional ground cover at the water fountain. The plantings were made in January, 1943; picture taken March, 1944.

Various species of willows obtained from Fresno and San Benito Counties were planted, but required too long a time for dense growth to compete with tamarisk as a roost tree here.

Probably the second most successful roost-like cover plant tested at the Hills was Coast quail brush or lenscale (*Atriplex lentiformis*) obtained from Monterey and San Benito Counties. These plants provided excellent roost and escape cover after about two years' growth, attaining a height of seven feet in one case.

Other plants that were tested and which showed promise as escape cover locally were wild gooseberry, both wild and domesticated rose, various varieties of blackberry, pampas grass, mule-fat or arrow-weed (*Baccharis viminea*), and various species of cacti, both the flat-stemmed and round-stemmed varieties.

The gooseberry is a little slow to take hold, but ultimately furnishes excellent escape cover, the same being true of wild rose. The blackberry has a fairly high moisture requirement, and hence its use is limited to the vicinity of water. Pampas grass showed a very rapid growth when small clumps were planted, furnishing excellent dense cover about watering places. *Baccharis viminea* grows readily but many individual plants must be set out in dense clumps in order to obtain a thick enough growth to furnish sufficient cover.

All of the above species were planted merely by taking cuttings or sections from existing growth in neighboring localities. Some success was had by seeding various other plants, although this method is not considered as effective as is the planting of slips.

FIG. 44. Showing growth of introduced Coast quail brush (*Atriplex lentiformis*) planted August 29, 1942. Upper photograph, March 10, 1944 (18 months after planting); and lower photograph, November 1, 1944 (26 months after planting).

Cover species tested for growth from seed planting were the local *Atriplex,* which was tested under many conditions, screw-bean mesquite, and several shrubby species of buckwheat. The only one that did well was the native *Atriplex (Atriplex polycarpa).*

FIG. 45. An early quail water development at Kettleman Hills. Water lines used for fire protection at the oil wells were tapped with ¼" pipe and a basin placed nearby. It was found that quail used these installations more readily if the water was conducted to a spot having better quail cover.

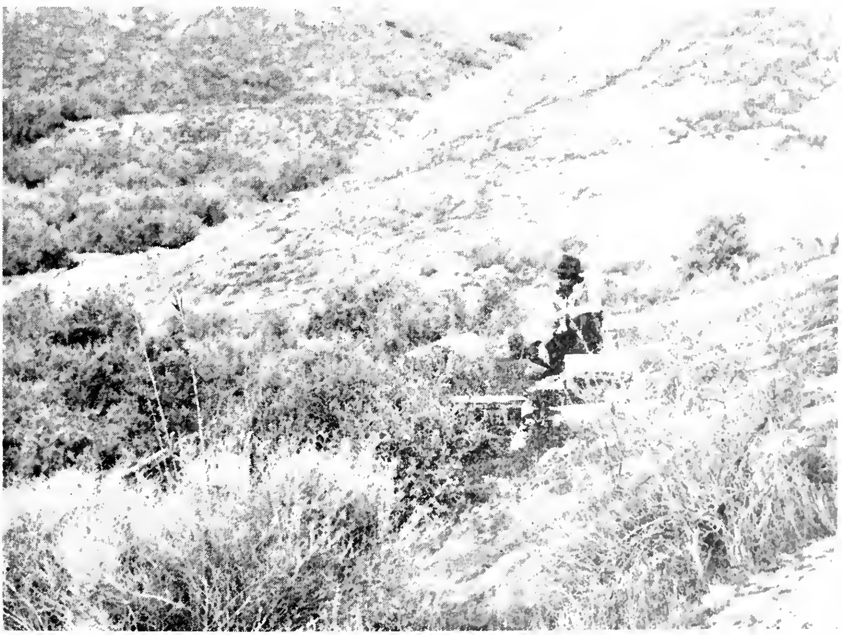

FIG. 46. Here water was carried several hundred feet in scrap pipe to a shaded drinking trough located in a spot better suited to quail. Drippings from the water basin resulted in enormous growth of the local quail brush.

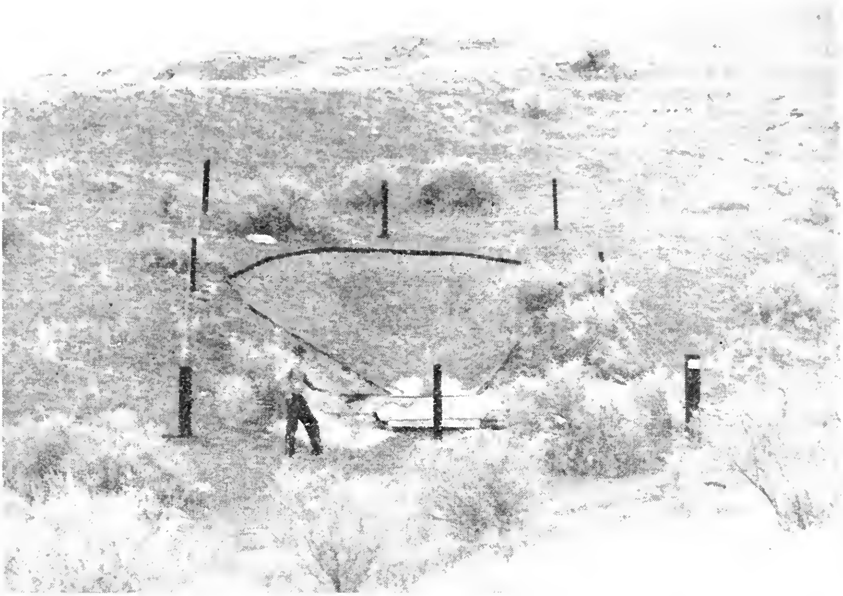

FIG. 47. A self-filling quail watering device, the "gallinaceous guzzler" at Kettleman Hills. The oiled-earth collecting apron collects winter rainfall into a 750-gallon subsurface tank, 30″ deep. A sloping trough is connected to the tank. Water in the trough and tank is in hydrostatic level. As the water level lowers throughout the summer, birds merely walk farther down the sloping trough to get their drink.

Several types of watering devices were developed and tested throughout the Hills. In general, water was supplied from high pressure lines of the two principal oil companies. We tapped these lines with $\frac{1}{4}''$ pipe and supplied high pressure valves which were left open only enough to allow water to drip into shallow, concrete basins. Roughly 50 new watering sites of this type have been placed throughout the Hills by the Division of Fish and Game.

While water was available at many of the oil wells, lack of cover and excessive human activity rendered much of this water valueless to quail. Consequently, much of our effort has been toward piping this water a distance from the bare area around the well to a clump of cover, or to some place where cover could be developed. Scrap supplied by the oil companies furnished most of the pipe for taking water to more advantageous situations. Most of the watering installations so placed were fitted with a valve which was left slightly open, thus supplying water for cover plantings about the drinking fountain.

In some areas, where water conservation was a problem, float valve installations such as have been employed by the Division of Fish and Game in other development work were placed on low pressure lines and tended regularly to see that the valves worked freely. The inverted siphon tank, which consists of a 50 gallon drum sealed at the top with an outlet into a basin of water, was also used. This inverted siphon tank works on the same principle that the ordinary vacuum chicken watering fountain operates.

Two self-filling watering units requiring little or no maintenance were placed in parts of the Hills not supplied with pipe lines. These devices are 750 gallon, concrete tanks placed underground. A sloping drinking trough is attached to the side of the tank, allowing quail to follow the gradually receding water to the level of the bottom of the tank. The units are filled by winter rainfall on oiled earth collecting aprons draining into the tanks. A complete description and specifications of these "gallinaceous guzzlers" will be found in Glading, 1943.

THE DEVELOPMENT PROGRAM

As a result of the experimental work conducted at Kettleman Hills, a long-time quail program on the Hills has been formulated. It is planned to use this area as a "natural game farm." Quail will be increased in number by the various technics developed in the course of the experiments here and in other experimental areas in the State. Cover and water will be supplied as far as economically possible throughout the North Dome area, ultimately looking forward to a large quail population from which the annual surplus may be removed for stocking other areas in Fresno and Kings Counties, and, as time goes on, throughout the State.

In general, in accordance with our findings, feed will not be supplied to the birds, except in pre-baiting selected spots for trapping birds to be transplanted to other areas. However, roost trees, principally tamarisk, and some loafing or escape cover, principally, *Atriplex lentiformis*, gooseberry, blackberry, and pampas grass, as well as water will be supplied where needed.

Any water developments that will be placed distant from existing coveys will be merely allowed to restock themselves naturally in accordance with our findings on the dry area restocking experiments.

Our first trapping of quail for transplanting will probably be done in the fall of 1945 or 1946, since it is felt that our development program has now reached the stage where we are justified in removing a limited number of birds for a general transplanting program.

SUMMARY

Experiments were set up at Kettleman Hills to determine whether or not artificial feeding of quail was practical. A slight increase in quail, and some negligible increase in rabbits, seed-eating birds, and predators was noted. An increase in rodents showed in our counts. It was not felt that the slight increase in quail justified the cost of artificial feeding.

Experiments were set up to determine the best means of stocking an area formerly devoid of water and quail to which water had been supplied. It was found that if quail are naturally present within two miles of such new installations, the best procedure is to "let nature take its course" and allow birds to move in from surrounding areas rather than to try to stock this area with birds planted from a bulk or gradual release.

The best means of developing quail on the Hills was found to be to rectify the two principal deficiencies found in this area; that is, lack of water and lack of roosts. Water was supplied principally by tapping

oil company lines, and roosts were supplied mainly by the addition of evergreen tamarisk.

The ultimate aim on the area is to make it into a "natural game farm." To this end quail management technics developed here and throughout the State generally will be applied, leading, it is hoped, to an increased quail population on Kettleman Hills from which an annual trappable surplus will be removed.

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A NEW FISH SCREEN FOR HATCHERY USE [1]

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Anyone who has raised domesticated trout or has managed them in natural waters knows how difficult it is to make them stay in their proper places. It seems that they are forever trying to get out of a hatchery pond, or out of a stream into an irrigation ditch. A great deal of thought has been given to these problems and many screens have been devised to keep the wandering trout at home. The latest, a modification of the self-cleaning revolving type, has recently been developed at the Mt. Shasta Fish Hatchery by Mr. Robert Murray, and offers great promise.

To begin at the beginning, about the year 1865, we find in "American Fish-Culture" by Thaddeus Norris the following description: "Seth Green, at Caledonia creek, that he may prevent the fish in his ponds from running up into the mill-pond that supplies them, has a water-wheel turned by the current at the head of the raceway, the edges of the buckets or paddles coming so close to the concavity of the frame in which it revolves, as to keep the fish from ascending, while those from above can descend between the buckets. Floating grass and leaves also pass without obstruction. This contrivance, however, although it will keep the large fish in the last pond, will not prevent those of pond No. 1 from running down into No. 2, and the fish of both from getting into pond No. 3, where the yearlings would be devoured."

[1] Submitted for publication, January, 1945. Photographs by author.

FIG. 48. The Murray fish screen in operation.

As Mr. Norris points out, the paddle-wheel at Caledonia Creek was not entirely satisfactory. It did pass floating grass and leaves, which a stationary screen would not do, but it also allowed the downstream passage of fish. It seems obvious that from this simple beginning some thoughtful trout-culturist devised the so-called "California rotary fish screen." The date of its invention is apparently unknown; it was described in CALIFORNIA FISH AND GAME for October, 1928, but had certainly been in use for some years previously. This revolving screen is little more than Seth Green's paddle-wheel covered by wire mesh. Thus fish cannot swim between the paddles, and floating debris is passed on downstream. This second step in the evolution of the revolving screen must have seemed like an ingenious device to its inventor but it had one very serious shortcoming. The paddle-wheel was naturally of the "under-shot" type and the debris which collected on the screen had to go down and under the wheel. This difficulty was partially met by a "draper board" which caught the debris at the lower edge of the screen and held it there until sufficient pressure was built up. Then this draper board suddenly released, swung down, and allowed the debris to float under the screen. The draper then returned to its position, but in this automatic cleaning process many fish must have been allowed through with the trash.

The next forward step in the evolutionary process of screen development was described by W. H. Shebley (State of California, Fish and Game Commission, 22nd Biennial Report for 1910-1912, pp. 42-43, with fig.), and has been called the "Requa Screen" after its inventor R. W. Requa. Although its published description appeared earlier, it is actually a more advanced design than the one discussed in the preceding paragraph. The Requa model had the circular screen and the paddle-wheel turning on separate axles, with the latter set in the flume box downstream from the former. The water passed through the screen

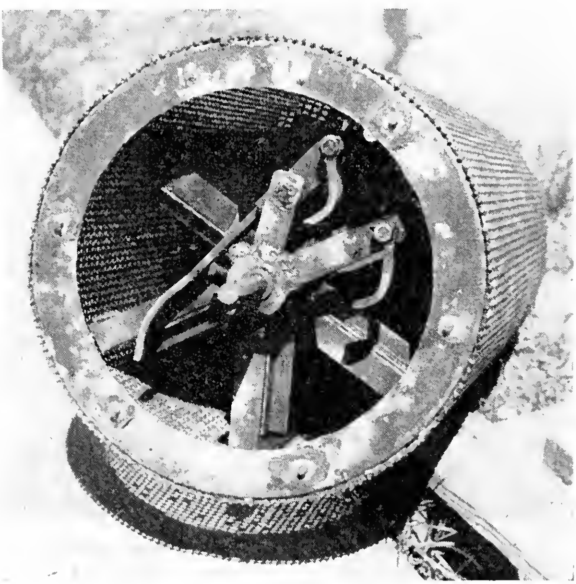

FIG. 49. End view of screen removed from mounting.

cylinder, then turned the paddle-wheel. The axle of the paddle-wheel had a crank at one end, connected to a drive shaft. The drive shaft had a pawl at the opposite end which engaged the teeth of a ratchet wheel on the drum of the circular screen. By this clever arrangement the paddle-wheel turned one way and the screen turned another. The debris which collected on the screen was carried up and over the top of the screen. With this plan of operation the screen could be sealed, fish-tight, by rubber drapers at the bottom and sides. Many of these assemblies were installed between the ponds at the Mt. Shasta trout hatchery and operated satisfactorily with one exception. Large fish would try to pass the paddle-wheel from the downstream side and would be injured or killed, just as a long bodied animal like a horse would be caught if it were try to enter a barn through a revolving door.

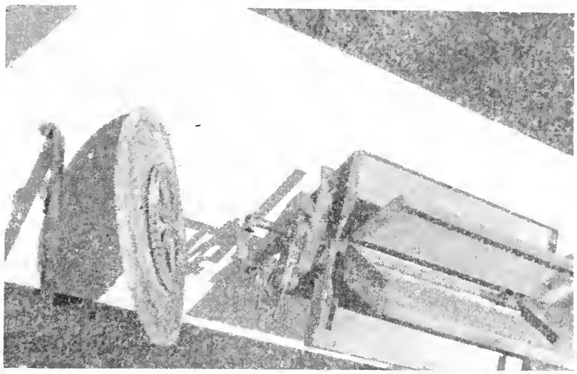

FIG. 50. Screen mechanism disassembled.

This point was brought to the attention of Mr. Murray and after some experimentation he arrived at a unique solution of the problem. The new "Shasta screen" is like its immediate predecessor in that the paddle-wheel turns one way and the screen itself turns another, but Mr. Murray has placed the paddles inside the screen cylinder. In this last respect it is like the earlier "California Fish Screen", but it is unlike it in the respect that they revolve in opposite directions. As can be seen in the photographs, either end of the axle rests in a rectangular hub which can be slid down in slots built into the side of the screen box. The screen can be easily adjusted to any height and it can be quickly pulled out for repairs. The level of the water above the screen is controlled by a dam board so that it is just above the level of the axle. The water pours over this dam board and down through the screen onto the "bucket" wheel. A fall of 4 inches is sufficient to operate it.

On one end of the "bucket" wheel shaft (see Fig. 49) is a cam which activates a pivoted lever. On the upper end of this lever is a pawl which engages the ratchet wheel fastened to the end of the revolving screen. This mechanism causes the screen itself to revolve in the opposite direction to that of the bucket wheel.

The advantages of the new "Shasta screen" are: first, that it cannot injured trout with its paddles; second, that it is so much more compact and easily moved; and third, that its rubber drapers at ends and bottom are always in view and can be easily inspected.

REPORTS

FISH CASES

January, February, March, 1945

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalones: undersize, overlimit, no license, closed season	21	$790 00	
Angling: no license, use license issued to another, illegally taken fish, false statement to secure license, 2 rods, night fishing, closed season, closed area, spear within 300 ft. of stream, take sunfish closed season	47	777 50	
Bass: 2 outfits, no license, undersize	14	275 00	
Catfish: selling undersize	2	125 00	
Clams: undersize, closed district, overlimit, no license	51	1,339 00	
Commercial: white sea bass aboard boat carrying round haul net, no license, failure to keep proper records	15	735 00	
Crabs: undersize	3	60 00	
Lobsters: undersize	2	30 00	
Pollution	1	50 00	
Salmon: spearing	3	150 00	
Sturgeon	1	10 00	
Trout: closed season, overlimit, snagging, below dam, gaffing	16	445 00	
Totals	176	$4,786 50	

GAME CASES

January, February, March, 1945

Offense	Number arrests	Fines imposed	Jail sentences (days)
Crane	1	$25 00	
Deer: closed season, female, spotlighting, doe, spike buck, forked horn deer district 1¾, allowing dogs to run deer, night hunting	28	2,400 00	
Deer meat: unstamped, closed season	15	810 00	70
Doves: closed season, overlimit, ship by parcel post	3	180 00	
Ducks: closed season, no license, overlimit, unplugged gun, after sunset, early shooting	39	1,142 50	
Firearms: refuge	7	190 00	
Geese: overlimit	7	570 00	
Hunting: no license, false statement to secure license	8	115 00	
Non-game birds	2	50 00	
Pheasants: hen, closed season, fail to tag, no tags	23	1,165 00	
Pigeons: closed season	2	90 00	
Quail: closed season	2	15 00	
Rabbits: closed season, no license	2	70 00	
Shooting from power boat	26	740 00	
Swans	7	440 00	
Tree squirrels	3	100 00	
Totals	175	$8,102 50	70

SEIZURES OF FISH AND GAME

January, February, March, 1945

Fish:	
Abalone	[illegible]
Catfish	[illegible]
Clams	[illegible]
Fish trap	[illegible]
Lobsters	[illegible]
Lobster r[illegible]	1
Lobster traps	[illegible]
Sunfish	[illegible]
Trout	[illegible]
White sea bass [illegible]	[illegible]
Game:	
Deer	[illegible]
Deer meat, lbs.	255
Doves	10
Ducks	160
Geese	22
Killdeer	1
Pheasants	20
Pigeons	5
Quail	1
Rabbits	3
Shorebirds	[illegible]
Swans	8

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(Continued from inside front cover)

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printed in CALIFORNIA STATE PRINTING OFFICE
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