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FISH AND WILDLIFE SERVICE
Albert M. Day, Director

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SECTION OF ANADROMOUS FISHERIES

ALASKA FISHERY INVESTIGATIONS

Mitchell G. Hanavan, Acting Chief

GENERAL

Research was concentrated on southeastern Alaska pink salmon, the major fishery. Phases of the pink salmon program were: Fresh-water survival and spawning, identity of races, fishing intensity and gear, and ocean survival. A lake fertilization experiment at Karluk and Bare Lake and minimum programs on Karluk-Bristol Bay red salmon and herring were continued.

RESEARCH PROJECTS

Spawning and fresh-water survival of pink salmon.--The escapement of 112 pink salmon in Sashin Creek (Little Port Walter), smallest spawning escapement in 17 years, paralleled the continuing decline in abundance of even-year pink cycle in Southeastern Alaska.

To determine the effect on survival of crowding and exposure to salt water, intertidal spawning studies were continued in the Big Port Walter study stream with installation of four pairs of screened pens in the fall of 1950, covering tide levels of plus 4.0 to plus 10.5. One of each pair of pens was stocked with three ripe females and three ripe males while the other received six fish of each sex. There was no survival to fry stage at plus 4-foot tide level where nests were covered with salt water 70% of the time; good survival occurred at plus 6-foot level where nests were covered 30% of the time, and survival was not greater above this level.

Analysis of temperature units, measured in spawning gravels of Sashin Creek, and annual survival rates of pink salmon fry for the past 10 years indicates a high increment of temperature units usually coincides with a high survival rate and that temperatures during the latter part of the incubation period may be more critical than temperatures in the fall and early winter. This analysis is being expanded to determine if a similar relationship exists between survival and temperatures of flowing stream waters.

Seven migrant counting stations were operated successfully during the spring migration of salmon fry. This was the third consecutive year of operation for four of the stations, and gave a measure of changes in abundance of fry of brood years 1948, 1949 and 1950. Counts show substantially increased fry production and survival rates at two stations, little change at the third, and a decline at the fourth. The production of 1950 brood fry was good, and, unless offset by poor marine survival, 1952 runs should show the first even-year cycle increase since 1942.

Identity of races.--Between July 21 and September 5, 1950 17,527 pink salmon were tagged in Icy Strait and Upper Chatham Strait. The 14,500 fish tagged before the season's opening on August 15 came from traps hung early through cooperation of the industry.

Stream recoveries from all sources totaled 614 tags, with the area of capture extending from Dyea in North Lynn Canal to Snake Creek on Etolin Island. Stream recoveries represented 3.5% of tags applied; recoveries from the commercial fishery were 6,473 or 37%. Migratory patterns as shown by stream recoveries and by those from the commercial fishery were very similar, and are almost identical to those found in previous tagging experiments. These show in general that the fish move through Icy Strait, pass southward into Chatham Strait and then eastward into Frederick Sound and Stephens Passage. Minor offshoots lead into Lynn Canal and South Chatham Strait.

Fishing intensity and gear.--A study of daily pink salmon catches by traps is being made to determine changes in the time of spawning migration and, if possible to correlate these changes with biological and meteorological factors. Since the area presenting the longest series of historical data is the eastern section of Icy Strait District in Southeastern Alaska, these data were chosen as the first series to be analyzed. Three periods, embracing different conditions of the fishery, are included:

1) Years preceding 1924, when there was practically no regulation of the fishery and the complete pattern of the run is available,

2) Period beginning with passage of the White Law in 1924, when closing dates for the fishery were established. In 1928 regulations were extended to provide both an opening and a closing date. From 1924 through 1946 opening dates were never set sufficiently late to provide protection for the early part of the run but the closing date did protect the latter part. For this reason data on the latter part of the runs are incomplete during this period.

3) From the year 1947 to the present, the opening date has been set late in the season, thereby providing protection to the early part of the migration. In this period data are truncated at both ends of the season.

The problem is to develop methods of handling truncated data to provide indices that will be comparable over the years. Pearson frequency distributions are being fitted by the method of moments to data for the years 1908 through 1923. As a single type of these distribution functions has not been found that gives the closest fit, a choice of distribution must be made and methods of determining parameters of distribution selected. Apparently either Type I or Type IV will be the best type of curve to use.

Ocean mortality of pink salmon.--Experimental designs of traps for capture were developed and various shapes of clippers for more efficient fin removal were tried during the winter. The University of Washington School of Fisheries provided samples of red salmon fry.

The 1951 fry-marking program began on Herman Creek, in Behm Canal, on April 3. When operations at this location were concluded on May 9, 95,805 pink salmon fry had been marked. All operations were then shifted on April 14 to Old Tom Creek, east side of Prince of Wales Island, where the fry migration was more prolonged. Marking was concluded at this location in late June with a total of 124,002 marked fry.

Work at Old Tom Creek included experiments, which continued into mid-July, 1951, on rate of fin regeneration following various treatments of marking scars. Observations indicate starvation caused a high mortality in late stages of the holding period; clogging of the small mesh screen of the holding pens prevented entrance of food organisms. Improved design of traps and clippers made the marking program successful to a large extent. Improvements to traps for more efficient operation under high-water levels are being considered. Attempts will be made to obtain factory modification of the shape of clipper which proved most effective in the field.

Karluk red salmon and lake fertilization.--The Karluk counting weir was removed October 9, 1950, with a total red salmon escapement of 758,000. The spring escapement was average for the past five years; the fall escapement was 75% larger than the five-year average. Statistics of escapement and run follow:

	Escapement	Catch	Run
Spring	379	278	657
Fall	379	226	605
Total	758	504	1262

Scale reading of the 1948 and 1949 collections indicates the 1951 run will depend mainly on the number of 6_3 and 6_4 fish returning from the 1945 spawning.

Escapement in 1951 has been low, with a count of 254,418 to July 20,1951.

A two-way counting weir was maintained at Bare Lake until September 8, 1950; 551 adults were counted into the lake and 10,698 red and 1,134 silver fingerlings were counted out.

Commercial nitrate and phosphate fertilizers were introduced into Bare Lake on July 13. At two-day intervals until September 6, temperatures and secchi disc readings were taken and determinations made on pH, oxygen,

soluble phosphorus, and nitrate nitrogen at zero, three and six meters. Light and dark bottles of lake water were set out regularly to measure oxygen production rate. Plankton counts of Bare Lake samples were made during the winter. The fertilization study continued with operation of a two-way weir at Bare Lake outlet in the spring of 1951. Fewer adults and fingerlings were counted than in 1950, but fingerlings were larger in both age groups represented. The current program includes chemical analysis of the lake water, bottom fauna, plankton, and resident fish obtained by seining.

Alaska herring.--Principal activity consisted of sampling the catch and collecting catch data for major fishing areas. Catch data were used to determine relative abundance while age composition data were used to assess recruitment and mortality.

Fishing intensity in the 1950 season remained at about the same level as in recent years; a summary of operations follows:

District	Plants	No. of Vessels	Fishing Period	Catch	Remarks
Kodiak	4	16	6/15-10/15	353,058	Quota of 275,000 bbls. applying to Oct. 1, taken by Sept. 28, resulting in a 2-day closure.
Prince William Sound	4	16	6/15-8/27	193,551	Quota of 180,000 bbls. applying to Aug. 10. Catch to this date was 177,000 bbls. Fishermen abandoned district on Aug. 27 because fall run failed to appear.
Southeastern	4	15	6/15-9/25	107,270	Quota of 150,000 bbls. not taken. Operations terminated in September because of herring scarcity.

A comparison of sverage catch per boat day in Southeastern for the 1950 season with average catch for combined years of 1943 through 1948 gave an abundance index of 36 in which 1945 is the base year at 100. As measured by the index there has been a marked decline in abundance in this district since 1947, when the index was 163.

Percentage age composition for the 1950 season based on 2907 scale readings of Kodiak herring, 2460 of Prince William Sound herring and 2897 of Southeastern herring follows:

	Year Class	1948	1947	1946	1945	1944	1943	1942	1941	1940
District	Year Of Life	3	4	5	6	7	8	9	10	11
Kodiak		1	52	9	7	13	4	4	4	5
Prince William Sound		12	10	15	14	38	6	4	1	-
Southeastern		3	23	14	22	33	3	2	-	-

Reduction in size of the Southeastern Alaska quota for 1951 was recommended to the Director. This reduction was based on poor recruitment received from the year classes of 1945 through 1948 and declining abundance as revealed by the catch-per-unit analysis.

In an effort to improve accuracy of the catch-per-unit analysis, log books were issued on an experimental basis in the 1950 season. Analysis of returns showed determination of catch-per-hour of fishing time was possible, a marked improvement over catch-per-boat day now in use. A revision of the reporting form was made from improvements suggested in the trial run and a log book was issued to each boat captain in 1951.

Sampling of the 1951 catch is being conducted in all districts. Field reports show fishing has been very slow at Kodiak with a catch of only 33,000 barrels as of July 28. Of this amount about 28,000 barrels have come from Chignik on the south side of the Alaska Peninsula, a distance of about 200 miles from processing plants. Fishing in Prince William Sound has been fiar (95,000 bbls.), but very poor in Southeastern (39,000 bbls.). Preliminary age composition indicates the 1947 year class has been the most important contributor in all districts.

Bristol Bay red salmon.-- Only minimal work was carred on in Bristol Bay during the year: The fish ladder at Brooks River falls was opened in the fall of 1950 and proved efficient during the 1951 season just concluded.

Mr. Eicher cooperated with Fishery Management personnel in the 1950 and 1951 seasons in maintaining continuity of aerial visual and photographic surveys of spawning grounds.

Scale collections made in the early years of investigations were read on a sample basis and much of old unclassified data was organized for use. Mr. Eicher continued development of statistical treatment of fluctuations in Bristol Bay red salmon populations; apparently these populations are in an extremely aberrant cycle of years with respect to size and age at maturity.

Age analysis.--The 1950 adult salmon scale collections have been mounted. Virtually all fingerling salmon collected in 1950 have been measured and scale samples mounted.

Bristol Bay adult salmon collections were aged as follows:

Age Group	Naknek No.	Naknek %	Brooks Lake No.	Brooks Lake %	Egegik No.	Egegik %
4_2	-	-	-	-	-	-
5_2	52	7.4	17	3.8	-	-
5_3	24	3.4	8	1.8	2	0.9
6_2	3	0.4	1	0.2	-	-
6_3	571	81.4	371	83.8	53	24.3
6_4	2	0.3	-	-	7	3.2
7_3	14	2.0	10	2.3	-	-
7_4	33	4.7	34	7.7	155	71.1
8_4	3	0.4	2	0.4	1	0.5
	702	100.0	443	100.0	218	100.0

Migrants at Brooks Lake were aged as 85% 2's, and 15% 3's.

Karluk and other Kodiak Island adult salmon collections have not been entirely analyzed, but preliminary work indicates age frequencies will approximate the following:

Age Group	Karluk %	Karluk Mouth %	Bare Lake %	Red River %
4_2	-	-	1	1
5_2	-	-	92	1
5_3	23	38	1	81
6_3	46	12	5	12
6_4	9	44	-	3
7_3	-	-	-	1
7_4	20	4	1	1
	98*	98*	100	100

*2% accounted for in age groups not listed

Samples of migrants analyzed from Bare Lake were 55% 2's, 44% 3's and 1% 4's. Karluk migrants have not been aged.

A study of growth characteristics of various age groups from the Naknet collections as determined from adult scales was started. Measurements on scale cards were made for the seasons from 1950 back to 1943 of either the entire sample available or of a stratified sample of the total number. Results indicate the fewer the years in the ocean before maturity, the larger the first ocean growth zone. Comparison by year class shows largest growth was made the first year in the ocean by the segment of the year class returning the earliest after migrating to the ocean; the least growth by the segment staying at sea the greatest length of time. For instance, the average first-ocean growth zone for the segment of the 1943 year class caught in 1947 as $4_{2's}$ is 35.0mm. of projected image, for the $5_{2's}$ caught in 1948 is 32.2mm, and for the $6_{2's}$ caught in 1949 is 31.2mm. This decrease in first ocean growth with age is consistent in all years studied to date. Additional back and current seasons are needed for comparison, as well as a study of fresh-water growth, and other ocean growth zones to determine if they also vary in a similar manner.

CENTRAL VALLEY FISHERY INVESTIGATIONS

Oliver B. Cope, Chief

SHASTA SALMON MAINTENANCE PROGRAM

During that part of fiscal year 1951 in which this project remained attached to the Central Valley Fishery Investigations, field activities were confined to preparations for impending salmon migration studies and to routine collection of water temperatures and other physical data. Considerable attention was given to plans for systematic testing of the push net, a device developed on this project for collecting downstream migrating anadromous fish. On August 1, 1950 the project was transferred to the Branch of Game-fish and Hatcheries, but, in accordance with instructions from the Director, activities of the project followed plans previously developed for the fiscal year.

The project had as its biggest objective during the year the use of the push net for (1) testing efficiency of the apparatus by comparison with the tow net, (2) mapping horizontal and vertical distribution of salmon seaward migrants in Sacramento River, and (3) obtaining data necessary to calculate the number of immature salmon moving toward the ocean from the Upper Sacramento River.

The report of Frederick K. Cramer, in charge of this project, for May 1951 indicates that:

1. In daytime tests, with turbidity at less than 24 inches, and at a speed of five feet per second, the push net caught 26.5% more fish than the tow net in 90 trials.

2. In daytime tests, with turbidity greater than 24 inches, and at a speed of five feet per second, the push net caught 50.0% more fish than the tow net in 24 trials.

3. After all daytime tests were combined, the push net caught 27.6% more fish than the tow net in 150 trials.

4. After all night tests were combined, the push net caught 40.9% more fish than the tow net in 66 trials.

5. After all tests were combined, the push net caught 35.8% more fish than the tow net in 216 trials.

With regard to horizontal distribution of seaward migrants where collections were made, it was found that the distribution was quite uniform. Tests for vertical distribution at night showed that 52% of the fish were within two feet of the surface, and 78% within four feet of the surface. In daytime tests, 16.6% of the fish were in the upper two feet, and 83.2% were in the upper four feet.

UPPER SACRAMENTO RIVER SPORT FISHERY EVALUATION

Field creel census work on the Upper Sacramento River was terminated in the spring of 1951 at the end of the fourth year. Preparation of a final report covering the entire survey is the only remaining unit demanding attention.

The plan for using three men on the project in order to intensify sampling during the year could not be followed because of the death of Eugene S. Cupernell; however, a program almost as complete was followed to the end of the season.

Services of Robert Dinsmore, statistical analyst, were had for three weeks during the winter. In this time he worked on analysis of Sacramento River creel census data and developed a method for calculating catch, hours fished, and number of fishermen, and variances for these figures, to cover the original creel census method used on the project.

Poor weather during the late fall and winter months reduced fishing effort for both salmon and steelhead below that of the previous three years. In November and December effort and catch were so low comparisons with other years are not feasible.

King salmon angling effort in July and August was greater than in 1948 and 1949; catch per hour was low for July 1950 and high for August 1950. In October, the lowest effort of the past three years was expended; the catch per hour was 21% higher than that for October 1949 and 13% lower than that in 1948. January and February, months of poor weather, saw low efforts and catches.

In the trout fishery, catch, effort, and catch per hour were lower than usual in the summer months. In October, the fishing effort was high, but catch and catch per hour were the lowest in three years. Poor winter weather kept the effort very low through February, and catches were low.

Fishing effort in the striped bass and catfish fisheries was lower than usual this year.

MIDDLE AND SOUTH ATLANTIC FISHERY INVESTIGATIONS

Clinton E. Atkinson, Chief

ATLANTIC SALMON INVESTIGATIONS

Two crews, each consisting of a biologist and a student aid, surveyed the Sheepscot, Ducktrap and Narraguagas Rivers, Tunk Stream and and Little Falls Stream in the State of Maine. Preliminary observations show that beaver dams and a lack of sufficient summer flow are two of the chief obstacles to successful rehabilitation.

A water control dam was built at Hobart Lake outlet to provide extra storage for Little Falls Stream experimentally used for studying restoration problems. All Atlantic salmon runs were small, reflecting extreme drought conditions.

Under terms of the agreement, entered into by the Fish and Wildlife Service, the Atlantic Sea-Run Salmon Commission and the University of Maine on July 9, 1951, headquarters for the Atlantic Salmon Investigations was moved to Beaufort, North Carolina.

SHAD INVESTIGATIONS

Since the shad investigation field program began in March 1950, an opportunity has been had to observe and study two shad runs in the Hudson River and one run in the Connecticut River. Also, a limited amount of work was done on the Delaware River.

Connecticut River.-- In 1950, biologists of the Service and the Connecticut State Board of Fish and Game tagged 258 shad at the mouth of the Connecticut River and 1094 backrunning shad in Windsor Locks Canal; in 1951 they tagged 985 shad at the river's mouth and 1000 backrunning shad in the same canal.

Preliminary analyses of the egg sampling program, conducted on the river in 1950 and 1951 to determine spawning areas, show that shad eggs are found from a few miles above the river mouth to Holyoke Dam, the present upper limit of the shad run.

The 1950 survey of the river found young shad more abundant in the portion of the river extending below Holyoke Dam for six to eight miles and in the vicinity of East Haddam than at other locations.

Nearly 1000 young shad were fin-clipped in Windsor Locks Canal when they began moving to the ocean in September. Marking operations will be made on a larger scale in the fall of 1951 to check scale readings and the home-stream theory.

In 1951, log books were distributed to shad fishermen to obtain daily catch records, and an extensive sample of scales, lengths and weights of shad were taken on the river.

Delaware River.--A preliminary investigation of this watershed was made in 1950 to aid in formulating a plan for studying shad populations of the river. Biologists contacted fishermen along the bay and river to determine their methods of fishing, length of season, and importance of the past and present fishery. It was determined that, since so few shad get above the present polluted area, no investigation constructed around the commercial catch would be feasible.

Since the future of shad runs in this river depends upon the effect of proposed dams outlined by the Interstate Commission on the Delaware River Basin, the most profitable undertaking seems to be to determine present spawning and nursery areas of shad in the watershed. In the current survey, commercial eel traps located along the river are used to sample young shad as they move down the river. From data collected it will be possible to determine the relative importance of various sections of the river so far as shad juveniles are concerned.

Winyah Bay.--The Service and the State of South Carolina studied the shad fishery of Winyah Bay and tributaries. Daily catch records for 1951 and those of past years were obtained from about half of the Bay fishermen. From March 1 through March 25, 1951 catches were sampled for sex, scales, lengths, and weights of fish. These and related data will be analyzed and tabulated to determine any changes in the fishery in future years as a result of changes in fishing regulations contemplated next year.

Hudson River.-- Field crews were stationed at the lower end of the river and on spawning grounds. To estimate the size of the shad run, shad were tagged in the mouth of the Hudson River below the commercial fishing area. Shad tagged on the spawning ground gave a check on accuracy of results of taggings at the river mouth. A greater number of tagged shad were permitted to escape the fishery so their migration could be traced.

Both crews contacted shad fishermen along the river and distributed log books to those fishermen who were willing to record in them time of fishing, number of tags recovered and total catch of each lift of the net. About a third of the fishermen maintained the desired records.

During the course of the run, shad catches were sampled to determine sex ratio, age, length frequency, and weight.

Returns in 1950 in the river amounted to 40.3% of the 250 shad tagged that year at the river mouth. This tagging and log book records showed that the shad run entering the Hudson was composed of 456,000 individuals; 306,000 of these were caught and 150,000 escaped the fishery. Tagging on spawning grounds indicated that 154,000 individual fish escaped the commercial fishery; this figure agrees closely with that determined from the tagging at the river mouth. These population estimates indicate the total fishing mortality on shad in the Hudson River was about 67% for the 1950 season.

During the shad run in the spring of 1951 shad were again tagged at the Hudson mouth to determine the number in the total run and to calculate the number escaping the commercial fishery. Of considerable interest this year was the effect of the closed period on the number of fish escaping the fishery. Last year there was a weekly closed period of 36 hours while in 1951 it was 72 hours.

Total catch figures for 1951 are not completely compiled and tabulated; a preliminary check of Service figures and those from the New York Conservation Department and the New Jersey Division of Fish and Game shows the Hudson shad run this year totaled about 395,000 fish as compared to 456,000 in 1950. This year's catch amounted to approximately 239,000 and about 156,000 escaped the fishery. Thus, fishing mortality in 1951 was about 61%. Though the amount of gear was less and the number of days of legal fishing were fewer, i.e., less fishing effort, the shad run was enough smaller this year that fishing mortality decreased only 6%.

The percent of females in the total run was less in 1951 than in 1950; in 1950 there were 61.7% females in the total catch of shad and 46.2% in the escapement; in 1951 there were only 50.6% females in the total catch and 37.5% in the escapement. The number of roes calculated to have escaped the fishery in 1950 was 69,307 while in 1951, despite lower fishing effort, the estimated escapement was only 58,408. The probable result is that fewer eggs were deposited this year than last year.

The return of shad tagged in the Hudson from localities outside the Hudson have shed some light on their ocean migration. After spawning, which was heaviest in May, and leaving the river mostly in June, some shad, according to tag recoveries, migrated along shores of Long Island and northward to Maine. After one tag recovery off Portland, Maine, on August 8 and another north of Gloucester, Massachusetts, on November 11, no more recoveries were made until last March, April and May when they were made all along the coast from Mann's Harbor, North Carolina, to Raritan Bay, New Jersey. Some tags were recovered in the mouths of Chesapeake and Delaware Bays. Delaware Bay recoveries probably explain the continued shad fishery there, even though spawning in Delaware River has been negligible during the past several years. Much of Delaware Bay catch is probably made on Hudson River shad.

Though tags were recovered in mouths of several streams, or rather bays into which streams empty, not one tag was returned from a spawning ground in any other stream than the Hudson. This indicates that shad return to the same stream each year for spawning. Returns in the Hudson in 1951 from tags affixed in the river in 1950 totaled 155.

The juvenile shad sampling program started by the New York State Conservation Department was expanded during the 1950 season. A comparison of catches made at the same stations as those made in 1949 shows young shad abundance to be about 10% less in 1950.

During the summer, experiments were carried out in catching, holding and marking young shad. Results show these fish are not as delicate as previously supposed. They can be hauled in small containers for several hours with low mortality if water temperatures are below 62° F. Very little mortality resulted in two hours from field fin-clipping experiments. No mortality occurred in four weeks from fin-clipped shad at the Beaufort, North Carolina laboratory. Some shad clipped in March are alive at the laboratory; mortalities on fin-clipped shad have been no greater than those on unclipped ones. These experiments were begun to determine if it is feasible to clip fins of young shad in order to identify them later, as has been done for many years with salmon and trout.

Plankton tows for shad eggs to determine spawning areas, made throughout the spawning period, showed the heaviest spawning area, as measured by eggs collected, was between Germantown and Hudson. Above and below this area fewer eggs were taken; none were found above Coxsackie or below Kingston Point. This finding agrees fairly well with previous spawning ground studies.

An analysis of part of the Hudson River water temperature, alkalinity, color and turbidity data from Poughkeepsie Water Department from 1915 to date shows water temperatures for June through October were above normal for the years from 1939 through 1944. Of 30 months in that period temperatures were above average for 27 months. It is not known whether this

affected survival of young shad during that period; it may have worsened already poor conditions because of pollution.

An examination of water flow records of the Hudson River for the years 1919 through 1948 shows great fluctuations in all months except August; no trends have been found which could have affected shad.

Fishing effort, shown by unit net days, increased with some irregularities from 4,176 unit net days in 1924 to 28,424 in 1947 and has dropped only slightly since that to 22,440 in 1950. The catch per unit net day was 22.6 pounds in 1924, reached a peak of 210.9 pounds in 1936 and after that declined with some irregularities to 45.9 pounds per unit net day in 1950.

The figures may be altered if statistics for each gear can be obtained, but the general situation will be unchanged. This analysis shows that after 1939 fishing effort increased while catch per unit of effort declined which, in turn, indicates the total shad run did not increase, as indicated by total catch up to 1945, but may have been decreasing and that overfishing may have played a part in the decrease. After 1945 total catch and catch per unit of effort dropped considerably while total effort dropped only slightly. The catch in 1950 was only a little greater than in 1935, but almost three times the effort was required to land it.

Two Service biologists devised a method to read from shad scales total age of shad and the number of times they have spawned. This method involves the use of transverse grooves to determine the first few years of age which are the most difficult to read.

According to readings of scales from shad caught in the Hudson in 1950 the largest percent of shad return to spawn for the first time at four years of age, with the largest percentage of females returning first at five years of age. The biggest percent of roe shad in the sample were spawning for the first time, while a slightly greater percentage of males was spawning for the third time. These data are of value in determining cause and effect relationships that affect the fishery.

Records of ship traffic on the Hudson River since 1923, tabulated from U. S. Army Engineers' records, do not show any correlation between ship traffic and shad production during the period examined. As traffic decreased to a low in 1933, probably because of the depression, the shad catch picked up five years later. Ship traffic increased from 1933 to 1939 but this is not reflected by a decrease in shad production; actually, shad runs increased in size during those years. From 1943 to 1945 ship traffic on the Hudson decreased considerably because of changed transportation methods as a result of the war, and it is matched by a drop in shad production also. Thus, if ship traffic has any effect on shad survival, other factors overshadow it.

The Service and the New York State Department of Health began a cooperative water-quality study on the Hudson in the summer of 1951. Tabulated results from the July sampling show that dissolved oxygen values below those considered essential for healthy fish life exist in all areas between Chelsea and Troy. The only previous pollution survey covering this part of the river was that which the New York Conservation Department made in 1936. A comparison of 1950 samples with the earlier ones shows the pollution load has increased considerably since that time and is at a point where it can seriously affect shad production.

NORTH PACIFIC FISHERY INVESTIGATIONS

Clifford J. Burner, Chief

TREND OF THE FISHERY

The runs of salmon passing Bonneville and Rock Island Dams in 1951 are well above average and may surpass the record year 1947. Through May 31, 1951 the count of chinook salmon at Bonneville was 114,770; at Rock Island, 6, 164. In 1947, the record year since counting began at Bonneville Dam in 1938, the counts were 133,562 at Bonneville and 6,428 at Rock Island for the same period.

RESEARCH PROJECTS

At Bonneville Dam.--The staff continued to operate by-pass traps and to record data on age at migration. The catch in the traps makes known the daily, seasonal, shore to shore distribution and brood distribution of salmonoid fishes enroute to the sea. During the year employees lift the traps, measure the small fish and then release them to continue their seaward migration; they also take scales from a representative sample of these fingerlings for the purpose of determing the age and size at migration of the four species of salmon, and also steelhead trout.

Efforts continue to influence migration routes with a string of lights. The string consists of series of lights connected to mechanically operated switches in such a manner that the lights appear to move as on a thater marquee. Use of this apparatus in the past has met with some success, but this was limited by the turbidity of the water. Present efforts are directed toward overcoming this difficulty by using brighter light or a different type of light.

Efforts continue to determine the effect of turbines and draft tubes upon fingerling migrants. Modifications and improvements of trapping methods are progressing. During the spring chinook runs in April and May 1951 Messrs. Weber, Gauley, Craddock, and Schlotterbeck investigated reports of large numbers of dead salmon below Bonneville, but observed no great mortality.

Temperature Studies of Columbia and Willamette Rivers.--Collection of water temperature data of the Columbia and Willamette River systems was continued in the 1951 season. Messrs. Weber and Schedin assembled data for completing the manuscripts, "Temperature Regime of the Willamette River." This survey is a continuation of a seasonal study begun in 1943, when the loss of a great many blueback salmon seemed linked with higher than average river temperatures.

Trends of Abundance - Catch Statistics.--Columbia River catch and escapement statistics are being brought up to date. Preliminary data on the 1949 commercial catch show a total landing of 20,232,617 pounds. The 1946-1950 average was 29,149,480 pounds. The 1950 catch summary is under way. The catch-per-unit of effort is being brought up to date following the pattern set by Silliman in Fishery Bulletin 51, "Fluctuations in Abundance of Columbia River Chinook Salmon 1935-36." Average weights, season and locality for Columbia River salmon (after Floyd Bryant method) applies to catches in pounds (figures obtained from State agencies). Mr. Gangmark continues this work.

Direction Control of Fishes.--Messrs. Silliman, Weber, Collins, and Burner at Vancouver, B.C. on May 17 witnessed a demonstration of the Vang "Magnetron" direct current converter utilizing ignitron tubes de-ionized and re-fired by thyratron tubes in conjunction with condenser discharge, thereby enabling the operator to pick the phasing of current and release high voltages over external short periods of time (less than 1/1000 of a second). This machine appears to be a versatile research tool for use in work with sound waves, light waves and electric impulses and their effect upon migration of fishes. The demonstration proved the machine extremely effective in directing fingerling sockeye by causing them to swim to a positively charged plate. (Delivery of a "Magnetron" converter installed as a portable unit in a Service vehicle was made in December 1951. Laboratory and field tests are planned around this machine. It seemingly has large-scale possibilities in connection with guiding fish past high dams.

Preparations are being made for field experiments to examine the influence of physical and chemical water characteristics upon direction of salmon migration.

SECTION OF INLAND FISHERIES

CALIFORNIA-NEVADA INLAND FISHERY INVESTIGATIONS

Reed S. Nielson, Chief

GENERAL

Tremendous overwinter losses of trout occur in most streams in the

United States. In an effort to explain this loss, native and hatchery trout have been stocked in four experimental stream sections at the Convict Creek Experimental Station. These four sections have a total length of one mile, and water flow and fish movements can be controlled. Experiments planned over several years propose complete drainage and removal of the fish for counting each fall and spring, recording of stream flow, air and water temperatures, velocity, snowfall, and ice formation, and observations of the fish to determine the extent of their winter activity. Traps will be installed to determine the extent of the migration of the trout and to obtain specimens for food and disease analysis. Changes which occur in the insect fauna during the winter due to migration or to the action of anchor ice will also be observed.

SURVIVAL OF TROUT

Experiments at Convict Creek compared survival of stream resident brown trout and hatchery-reared, catchable-size rainbow trout for the period April 1950 to April 1951, under controlled natural conditions using four experimental stream sections with a total length of one mile. One section contained natural population of brown trout, one section 50 percent each brown and rainbow, and two sections rainbow only. The population density was equal in all sections based on one trout per 30 square feet of stream bottom area. All trout were weighed, measured, and marked by amputation of the fins. An approximately equal survival of species was indicated, but the unaccounted deficit was very high, roughly 50 percent. The actual recovery of dead fish during the year was 12.3 percent of the total loss. Hatchery trout suffered the heaviest known losses following the initial introduction and in early spring when water temperatures were steadily rising from winter lows. There was no positive evidence, but escapement from experimental sections, predation, and illegal fishing in the area probably caused the unaccountable loss. Improved methods of retaining fish in the stream sections are now under investigation. More manpower will be necessary to make the needed monthly checks on survival. The second year of study began April 1951 and will follow the same pattern.

WINTER STREAM STUDY

A study of stream conditions during the winter was conducted through the period January 2 to March 31, 1951 at Convict Creek. The usually mild winter had negligible snowfall and short periods of low temperature. The formation of anchor ice was both damaging and beneficial. Prolonged formation seals off the stream bottom making food unavailable for trout. Dissipation causes the release of food organisms, and increased stream volume and flow resulting from ice melt and collapse of ice barriers disturb the stream bottom. Food-fish interrelationship demonstrated a normal feeding activity of trout with an abundance of Ephemerida, Diptera, and

Oligochaeta available to trout. Oligochetes, rare in summer, were exceedingly numerous in sandy, easily disturbed bottom material. They formed an essential part of the diet of trout and were readily digested in 32° F. water. A superabundance of stream bottom organisms was noted. In general, trout were very active throughout the winter; were caught on every type of bait and lure used, fed activly, and passed the winter in good condition with only minor losses that could be associated with low temperature or lack of food. Stream resident brown trout were in better condition than hatchery-reared rainbows at the conclusion of the study. No losses were observed when the stream appeared to be a mass of slush. The known and unaccountable loss of trout overwinter was high, about 50 percent, but was nearly equal for brown and hatchery reared rainbow trout. The mortality of rainbows increased following termination of winter and rose steadily with increased water temperature. No post-winter losses of brown trout were observed, and there was no evidence of bird or mammal predation. Excapement of trout from the experimental stream sections was possible when the screens were solidly frozen and water overflowed these structures. However, observations indicated that migratory activity was limited when water temperatures dropped below 42° F. Immigration should equal emigration.

PRODUCTIVITY OF HIGH SIERRA LAKES

Phases were completed of preliminary surveys of all ten lakes in Convict Creek Basin. Hydrographic surveys and maps of these were completed, including morphometry, complete mineral analysis of water, growth rates of trout and their condition, thermal gradients, percentage-volume curves, and Secchi disc readings. The Quality of Water Branch, United States Geological Survey, Salt Lake City, Utah, made a complete chemical analysis of water samples taken from mid-depth in each lake. Mineral constituents of lake waters were very low. Total dissolved solids ranged from a low of 19 ppm in Lake Dorothy to a high of 77 ppm in Convict Lake. The growth of trout apparently paralleled the level of mineral content in the various lakes. Seven lakes contain populations of brook trout only, and in these only three year-classes were found. The growth of trout in these lakes was nearly uniform during the first two years, but varied in the third year. Populations were artificial or the life cycles were limited to three or four years. The numerous fry and fingerlings seen in these lakes indicate a successful spawning of brook trout. Four-year rainbows were found in Dorothy and Convict Lakes, with Convict Lake fish exhibiting the more rapid growth. Five-year rainbows in Mildred Lake indicated a growth equal to the four-year fish in Lake Dorothy and the three-year fish in Convict Lake. An examination of 900 stomachs collected from fish from all the lakes shows that aquatic organisms volumetrically and numerically form a major part of the diet, with Diptera being the dominant group. Plankton (crustacean) was found in all stomachs except specimens from trout taken in Dorothy and Witsanapah Lakes. Fish were found in the stomachs of large brown trout from Convict Lake and made up to 40 percent of the total stomach content of these fish. Terrestrial forms comprised 13 percent of average stomach content, but varied from lake to lake with the greatest numbers being taken in high altitude lakes.

COLORDAO COOPERATIVE FISHERY RESEARCH UNIT

William C. Beckman, Leader

Inventory of biological, physical, and chemical characteristics of reservoirs with fluctuating water levels.--Basic information on reservoirs in Colorado is entirely lacking. Before any management plans can be developed it is necessary to know what various biological, physical, and chemical factors have an influence on fish production. Thus, the program of the Unit began with an inventory of the reservoirs.

In June 1950, a two-man crew began an inventory of Lone Tree Reservoir, and a year later another two-man crew returned there to continue the investigation. Jackson Lake Reservoir was added to the program in 1951.

Particular attention was given to spawning periods of various fishes. It appears that one of the chief contributory causes to poor fishing in many reservoirs is inadequate reproduction of game species. If the water level could be maintained for about two weeks to allow spawning and hatching of fry and their development to a point where they could swim, some improvement in fishing would probably occur. Some arrangement can probably be concluded with many water companies regarding temporary water level stabilization if a definite period can be specified.

Utilization of rough fish.--A project is in operation to test various sized mesh gill nets with expectation that it may be possible to allow sportsmen to use certain sized nets for taking rough fishes with little or no damage to game fish populations.

Stream improvement.--Temperature records are being taken at two areas. Pingree Park has a small stream where trout are relatively abundant, but small. Stream temperatures may be a contributing factor. The second area, with a similar problem, was at the Rocky Mountain Experimental Forest area at Frazer. Recording thermographs were installed at both stations and records will be analyzed.

Cooperating agencies of the Colorado Cooperative Fishery Research Unit, headquartered at Fort Collins, Colorado, are the Colorado Agricultural and Mechanical College, the Colorado Game and Fish Department, and the United States Fish and Wildlife Service.

DORENA DAM EXPERIMENTAL LABORATORY

Harlan E. Johnson, Chief

GENERAL

The Dorena Dam Experimental Laboratory, Dorena, Oregon, was established in the summer of 1950, in cooperation with the States of Oregon and Washington and the United States Corps of Engineers, to determine if it is possible to incubate, hatch and rear salmon and trout in water obtained from Dorena Reservoir, a flood-control project of the Corps of Engineers. The experiments will probably continue for two years.

Water from three levels (765', 785' and 805' elevation) in the reservoir is available in the hatchery during the summer and early fall. For the remainder of the year water from only the lower intake is assured. During the summer and fall, fish of all species handled are reared in water from the lower and the upper intakes and also in a mixed supply.

Laboratory equipment includes 22 deep troughs and 24 circular tanks, 6 feet in diameter, for rearing fish, a cold storage plant, feed preparation equipment, laboratory bench, office and storeroom all in a building which the Corps of Engineers provided.

SALMON EXPERIMENTS

Spring chinook salmon.--A group of 1949 brood fingerlings obtained from a State hatchery were reared from September 1950 to April 1951 with satisfactory results. Kidney disease caused some mortality in the spring. Eighteen thousand green eggs received in September 1950 were almost a total loss because of high water-temperatures during the incubation period. A third lot, received in January 1951 when just ready to start feeding, has done very well and will be held in the several water supplies during the summer.

Fall chinook salmon.--Green eggs received in September 1950 suffered very high mortalities in egg and fry stages because of high-water temperatures. Surviving fingerlings are in good condition and will be released in July 1951.

Silver salmon.--Initial mortality, probably caused by transportation, was high in a lot of green eggs received in December 1950. Thereafter mortalities and growth were satisfactory until an infection with unidentified myxobacteria caused severe mortalities in part of the lot during May. Fish from this lot will be held for over-summer rearing. A second group of green eggs obtained in January 1951 also had a high initial mortality but then did

well until released in May. A lot of eyed eggs, also received in January, had low mortalities until the myxobacteria took a heavy toll in May, just before the fingerlings were planted.

TROUT EXPERIMENTS

Cutthroat trout.--One lot of eyed eggs was received in March 1951. Early mortalities were higher than desired, but the fingerlings are now doing well and will be reared over the summer.

Rainbow trout.-- A group of eyed eggs was received in March 1951. Early mortalities were also high in this lot but now have become normal. Remaining fish will be held for summer rearing.

EASTERN FISH-CULTURAL INVESTIGATIONS

Chief (Vacancy)

Shenandoah River fishery.--Since some dead fish were found in the Shenandoah River during the fall of 1950, more intensive studies were carried out. Conditions were very unfavorable for five miles below the Merck Company. In September conditions below the Viscose Company were deteriorating; however, they improved in October. Tests made in the spring and early summer of 1951 have indicated that conditions were favorable for bottom fauna and fishes in the river except immediately below the Merck and Viscose plants.

Trout of Shenandoah National Park.--Observations were made on natural spawning of native brook trout in part streams, and a detailed report made. Results indicate that ample spawners were present in the majority of streams despite the fact that the streams had been subjected to heavy fishing pressure.

FISH NUTRITION INVESTIGATIONS

Arthur M. Phillips,Jr. (Cortland, New York)
John E. Halver (Seattle,Washington)

TROUT (CORTLAND)

The Vitamin Requirement of Trout.--The study on causes and corrective measures concerned with the so-called "blue slime" disease of brown trout was continued. Both dried brewer's yeast and beef liver were effective

in reducing mortality and increasing growth rate of trout. There was no difference between 5 and 8 percent yeast or 20 and 33 percent beef liver. Adding dried egg white to a yeast-fortified diet resulted in reduced growth rate and increased mortality of trout. The incidence of "blue-slime" disease was greatest among those fish fed diets lacking yeast or liver and was very high among those fed dr d egg white. These experiments show that biotin is concerned with growth of trout and support the contention that it also plays a part in the "blue-slime" disease.

The Use of Dietary Supplements.--Experiments consisted of adding various oils to the diet of brook trout to determine their effect on growth rate. Both salmon and cod liver oil resulted in an increased growth rate of the fish when added at a 3 percent level. Increasing the amount of oil to 5 percent caused a reduced growth rate. Adding cottonseed oil at either a 3 or 5 percent level resulted in almost no growth of the fish and in a large increase in mortality. This result is probably due to a contaminant of the oil which was toxic. Adding corn oil had no effect on growth or mortality.

The addition of these oils to the diet definitely changed the physical characteristics of the body fat of the oil-fed fish as measured by iodine number. Adding the oils also caused an increased deposition of fat in the fish's body.

The fact that corn oil was shown to be neutral in that it did not affect growth or mortality yet was shown to be absorbed by the fish by the iodine number and amount of fat in the fish's body opened a new line of attack on effective factors in salmon and cod liver oil. Experiments are in progress in which various effective portions of cod liver oil are being added separately to determine which, if any, of these known factors cause growth rate increase. Vitamin A, vitamin D, and cod liver oil concentrates are being added separately and in combination to various diets.

Developing and Testing Practical Diets.--Experiments in utilizing dried distiller's solubles in the diet of trout were continued. It was found that this product at a 12 percent level produced good growth and low mortality at a cost lower than that of the standard diet containing dried skim milk. This product was less effective at a 24 percent level. These experiments were conducted in the warmer water of our experimental set-up and confirm earlier results found in our colder waters.

A commercial frozen fish food produced fair results for an 18-week period after which the trout were anemic. The production cost was very high in comparison with standard diets.

The Effect of Metabolic Products on the Carrying Capacity of Ponds and Troughs.--In continuing this work a closed system was used in an attempt to determine the effect of the removal of metabolic products on the survival of trout. An ion exchanger was effective in removing the products, as measured by ammonia, and greatly extended the survival time of

the fish. Activated charcoal was ineffective. Removal of the products and increased survival time of the fish indicate harmful effects of the products of metabolism.

The Use of Radioactive Isotopes in Trout Nutrition.--Laboratory facilities for this new project have been completed and actual use of isotopes was undertaken in June. Work has been started to determine the utilization by trout of minerals dissolved in water. The study has not progressed to a point where reporting is possible.

Cooperative Field Program with Cornell University and the State of New York.--Two groups of brown trout, one slow grown and the other normally grown (regulated by water temperature), were stocked. A third group was planted which consisted of two-year-old slow-grown fish of a size approximately equal to the normal one-year fish. Again, chemical changes were noted in the fish after planting in that the fat content decreased and the body fat became softer as indicated by the iodine number. Results were similar to those previously reported.

The program is being continued along similar lines with the exception that another group of fish is being held back in their growth rate by means of restricting the amount of food they receive. These fish will be stocked next spring.

The experimental results of this laboratory are completely described in the annual report which the State of New York Conservation Department, Albany, New York, publishes.

SALMON (SEATTLE)

This investigation is quartered in the Fisheries Center, University of Washington, until completion of the new research laboratory now under construction at Willard, Washington, on the Little White Salmon River. The new laboratory, scheduled for completion in October 1952, will have laboratory and hatchery space for any physiological, chemical or nutritional problem.

Completed research is divided into three problems:

(1) A vitamin-test diet, consisting of purified protein, carbohydrate, lipid, minerals and vitamins, for chinook salmon was developed and fish were held on the diet for 20 weeks. (A paper covering this work was submitted to the Journal of Nutrition in November.)

(2) The effect of xanthopterins and vitamin B_{12} on anemic chinook salmon. No effect was found with xanthopterins; vitamin B_{12} and folic acid were found to give a definite hematopoietic effect on experimental animals under conditions of experiment. This work will be included in a paper by Norris and Halver summarizing previous and current work on hematopoietic effect of xanthopterins on anemic chinook salmon.

(3) Determination of biotin requirement of chinook salmon. Fish were made anemic by inclusion of avidin in the diet. Samples of livers and carcasses of fish on definite crystalline biotin aliquots in the diet were removed and stored at -10°C. for subsequent analysis to determine maximum liver and body storage of biotin. Assays and results should be tabulated by January 1, 1952.

Water analysis of the new laboratory site, proposed hatchery sites, and Dorena Dam has been completed. Dissolved gases followed at Dorena Dam for periods of increasing water temperatures. No abnormal concentrations or accumulation of toxic materials were found during the experimental period covered.

Plans for continued research in the current year include:

(1) Determination of the qualitative vitamin requirement for chinook salmon by feeding a vitamin-test diet minus one vitamin for each series of troughs and a comparison with a complete diet and liver control diet;

(2) Isolation and identification of tryptic enzymes present in chinook salmon;

(3) Completion of assays and analytical data now in progress covering biotin work;

(4) Histological comparison of salmon on a vitamin-test diet and salmon on liver control and hatchery production diets.

GREAT LAKES FISHERY INVESTIGATIONS

James W. Moffett, Chief

In the search for methods of controlling the sea lamprey, emphasis has shifted from mechanical to electrical devices. Although past researches have demonstrated the usefulness of dams and weirs for control of the sea lamprey, cost of construction and operation are so high as to make it imperative to seek less expensive methods.

Outstanding success was achieved in 1951 in blocking the upstream movement of spawning-run sea lampreys with two types of electrical barriers--an alternating-current screen developed by staff members with contractual assistance of research engineers and a commercially manufactured screen employing pulsated direct current. Both will be given further tests under a variety of stream conditions to ascertain necessary structural modifications in different situations. Methods for the more satisfactory diversion and trapping of useful migrating fishes need to be developed. The cost of installing electrical barriers is much less than that for installing weirs and traps in most situations--especially in large streams--and operating expenses are infinitely smaller.

Tests made during the winter of 1950-51 with equipment designed to kill recently transformed sea lampreys during their downstream movement toward the lake proved electrocution of these young individuals technically feasible but economically unsound because of the enormous current required. A type of current that is lethal at much lower wattages must be developed before this kind of control structure can be recommended as practical.

The survey of streams tributary to Lake Superior to locate spawning runs of sea lampreys, to estimate suitability of streams for reproduction of sea lampreys, and to locate sites for control structures was continued. Other research on the sea lamprey included feeding experiments to determine actual destruction of fish during the parasitic phase and a series of screening experiments in an attempt to locate a specific toxicant that might be used to kill larval lampreys in silt beds.

Researches on fish populations have been concentrated on lake trout, principal victim of the lamprey, and on stocks of commercially important species in Green Bay, an area in which fishing pressure has risen enormously largely as the result of an influx of operators from other areas (especially Lake Huron) that are no longer productive.

Surveys on Lake Michigan have demonstrated that abundance of small lake trout, as well as of fish of marketable size, has declined greatly. The take of "baby" lake trout per net in small-mesh gill nets in 1950-51 amounted to only a little more than 10 percent of that in the early 1930s. Statistical studies of the Lake Superior trout fishery have revealed an alarmingly rapid decline in the catch per unit of fishing effort. In the face of this decreasing abundance, production has been maintained only by a sharp increase of fishing intensity. That over-fishing may be a factor in the declining abundance of trout in Lake Superior is indicated by the high return rate of tagged fish. These same marking experiments have brought out strongly the interstate and international character of the problem of conserving lake trout. Within a few weeks trout tagged on the Keweenaw Peninsula (Michigan) were retaken as far west as the Duluth area (Minnesota) and as far north as the Slate Islands in Ontario (Canada).

The great upturn in fishing pressure in Green Bay has not given rise to as many difficulties as might be expected since it came about at a time when abundance of principal species was well above normal. Conditions must be followed carefully, nevertheless, for with a return to a more nearly normal abundance stocks may prove inadequate to support operations at their present level. Sound conservation and management of this important and productive fishery will require intimate biological and statistical knowledge of populations.

MICROBIOLOGICAL LABORATORY

Dr. Stanislas F. Snieszko, Director

Fish population study in aquaria.--(under supervision of Ralph P. Silliman).--The experiment, begun in early April 1951, continues. After three months, populations of Lebistes (guppy) are increasing.

Sulfonamides in tissues of trout.--It has been found that the quantity of medicated feed containing sulfonamides affected greatly the tissue concentration of sulfonamides in treated trout. This observation has a considerable practical significance showing that fish treated with sulfamerazine should be fed moderately but not insufficiently.

Treatment of ulcer disease in trout.--Chloramphenicol and terramycin gave very satisfactory results. Ulcers healed in the treated adult brook trout, and mortality was brought to zero after a three weeks' treatment. Part of this report on the first successful treatment of ulcer disease was published in Science.

Treatment of a "fin rot" type disease.--Brown trout fingerlings with a "fin rot" type disease were treated with copper sulfate, salt, sulfonamides, antibiotics and yeast. Not striking, but best results were obtained by feeding diet enriched with brewer's yeast or sulfonamides. This indicated that the disease was caused by a low-grade infection caused by nutritional deficiency.

Physiology of Hemophilus piscium and Bacterium salmonicida.--Experimental support was secured for the theory that melanin is the pigment produced by B. salmonicida. Fermentation reactions were run with 29 carbohydrates. B. salmonicida was found to be remarkably consistent in its fermentation characteristics. Both microorganisms were grown for the first time in a completely chemically defined medium. Of all known vitamins, biotin, thiamine and para-aminobenzoic acid were required for growth of B. salmonicida. Work on growth factors required by H. piscium was completed, and results were written up and are now in press.

Effect of pond fertilization on number of bacteria.--Relationship was found between fertilization and number of saprophytic bacteria in pond water.

Diagnostic service.--Diagnostic service is steadily expanding in the number of cases diagnosed and in the type of services rendered. Work is in progress on a large number of unknown bacteria which were isolated from warm water and cold water fishes in various states.

SALMON CULTURAL LABORATORY

Roger E. Burrows, Biologist-In-Charge

GENERAL

On March 15 the salmon cultural activities were transferred from Leavenworth to Entiat, Washington, where training of fish-cultural employees will be continued, and diet, disease and other fish-cultural problems, including testing of, holding, spawning, hatching and rearing methods, will be investigated and reported on. The Service's program for the upper Columbia River will determine the species and numbers of salmon to be reared from year to year at Entiat.

FEEDING TRIALS

In September the laboratory staff completed 24-week and 12-week feeding trials designed to develop better diets for salmon and submitted a detailed report. The 1951 feeding trials are in progress.

EGG AND FRY INCUBATION EXPERIMENTS

Three types of vertical incubators were constructed for testing in an effort to eliminate disadvantages of standard hatchery troughs. In one type, shallow pans, placed one above the other, were tested to determine their practicability for retaining both eggs and fry throughout the incubation period. In the second, a screened-bottom basket contained in a deep pan, also designed to utilize vertical space by placement of one pan above the other, was evaluated. The third type consists of a cabinet in which high humidity would be maintained without a direct flow of water over the eggs and the fry. Both shallow pan and basket types of vertical incubators proved satisfactory for eggs and fry. However, certain alterations and improvements are indicated. The high humidity cabinet proved satisfactory for eggs, but would not maintain fry.

EVALUATIONS OF REARING EQUIPMENT

Four, each, of 3, 4, and 5-foot diameter circular tanks have been assembled and installed. Experiments will ascertain the size of the circular tank necessary for retaining normal growth rate in chinook salmon. Experiments to determine hydraulics of various pond types have been delayed because of difficulties in procuring a consultant to design model studies.

TEMPERATURE STUDIES

Equipment necessary to determine the effect of water temperature on egg, fry, and fingerling development has been purchased. Installation is now in progress. Egg experiments are scheduled to start in September.

IN-TRAINING LABORATORY COURSE

An in-training course at the laboratory, which began on February 14, ran until mid-June. This is the third year this course has been offered. The object is to train Service fish culturists in the most efficient methods and procedures and latest techniques for use in hatcheries.

WESTERN FISHERY DISEASE INVESTIGATIONS

Robert R. Rucker, Chief

GENERAL

Quarters are in the new Fisheries Center building at the University of Washington at Seattle. One room is supplied with 15 fish troughs piped with thermostatically controlled water, facilities for carrying on bacteriological work, an area for microscopy, and a refrigerator and incubators. There is also an area in the general bacteriology laboratory where media are prepared and equipment is washed and sterilized. Individual office-laboratory rooms are also furnished.

RESEARCH PROJECTS

Assistance was given Federal, state and private fish hatcheries on disease problems. The major fish disease problem being studied is at the Service's Winthrop and Leavenworth, Washington, stations. Sulfa drugs and antibiotics have proved of no benefit. Organisms are isolated on occasion and shown to be pathogenic, but these cannot be demonstrated from a signifi-

cant percentage of diseased fish. It is believed the true cause of the disease condition is yet to be found. This disease is being investigated by inoculation studies, culturing and examining fish for bacteria and making a histo-pathology study of the fish.

Dietary gill disease was studied by examining chinook salmon fingerlings fed published "synthetic" diets as the control fish. These diets, lacking in pantothenic acid, were fed to produce the disease. Material was collected for a later histo-pathologic study of this deficiency.

YELLOWSTONE FISHERY INVESTIGATIONS

Oliver B. Cope, Chief

Tagging trout in Yellowstone Lake tributaries was one of the major activities of the field seasons falling within this fiscal year. At the beginning of the year, tagging was completed on spawning runs of 1950, and the following totals were tagged that season: Pelican Creek, 1880; Chipmunk Creek, 1500; and Arnica Creek, 965.

These tagged fish had been recovered in the following numbers up to June 30, 1951:

	1950 Recovery		1951 Recovery		
	Anglers	Molly Island (Pelicans)	Anglers	Trap	Molly Island (Pelicans)
Pelican Creek	62	14	5	1	1
Chipmunk Creek	19	24	6	5	1
Arnica Creek	43	0	1	48	0

Tagging in the 1951 season has been modified from the 1950 plan. Grouse Creek in the south arm of the lake has been substituted for Chipmunk Creek because of its sustained flows in mid-summer. Pelican Creek and Arnica Creek have been used again, and a new area, Yellowstone River at the Cascades, has been used. The Cascade fish have been tagged to trace movements of spawners from Yellowstone River up into Yellowstone Lake. A summary follows of tags placed on fish up to June 30, 1951:

Locality	Number of Tags	Recoveries from Fishery
Pelican Creek	1100	15
Grouse Creek	800	1
Arnica Creek	900	39
Yellowstone River (Cascades)	300	32

In general, tag returns of 1950 indicated adults were moving about the lake to a much lesser extent than those of 1949. It is too early to make a comparison involving fish of 1951.

Counts of spawners entering major tributaries were continued in 1951. The general pattern shows a paucity of spawners in most streams, compared with most years. This is reflected in the number of eggs taken by hatchery personnel, and it is expected that less eggs will be available in 1951 than in any year on record. Those streams entering the south arm of the lake are holding their own, but those better exposed to the fishery on the north end are supporting few spawners this year.

Creel census activities in the two seasons falling within the fiscal year differed slightly in scope and method. The 1951 creel census efforts cover Yellowstone River between Canyon and Fishing Bridge, an area not censused in 1950. A new system of complete and incomplete censuses for the lake shore line was adopted in 1951. Sampling frequency at Fishing Bridge and West Thumb docks was reduced.

Analysis of 1950 creel census data indicated approximately 149,000 fish were taken from Yellowstone Lake during the four-month season. The angling effort expended for these fish was about 200,000 hours. Best success was recorded for guide boats, with an average for the season of 1.88 fish per hour. Rental rowboats claimed 0.46 per hour, and lake shore fishing yielded .64 per hour. Fishing Bridge accounted for approximately 9,000 fish for the season.

Thus far in 1951, fishing appears on a par with that of 1950, although there are signs that angling in West Thumb may not be sustained throughout the season as it was in 1950.

Studies on stream biology of black-spotted trout in Arnica Creek were resumed on May 6, before spawners ascend the stream. Traps were improved, and a total couny of upstream and downstream migrants should be obtained this year. The spawning population appears higher this year than last, and the number of immatures and small adults that overwintered in the stream appear greater than last year.

At the end of the fiscal year all preparations had been made for an intensive series of Peterson tests by means of electrical shocking. Resulting data on population size and mortality rates applying to various size groups in Arnica Creek Will give a clearer picture of the efficiency of the stream as a producer of fish through natural processes.

The sucker, Catostomus catostomus, in Yellowstone Lake and tributaries is the object of a special study by Mr. Richard Graham, a graduate fishery student at Montana State College, who began a two-year study on the life history of this sucker in this drainage. Suckers have been seen entering Pelican Creek and Arnica Creek this year, and at unusually early dates.

The descent of ripe adults into Pelican Creek in May 1951 suggests for the first time that these suckers do not have to use Yellowstone Lake to complete their life cycle. A small tagging program was inaugurated in the sucker study to trace movements of adult fish.

Scales from the trout fishery are being collected routinely. At the end of the season there will be 1,000 samples from each of the two important fishing areas in the lake and a large collection from the river fishery. These will be compared for age with large samples from spawning migrations in three study streams.

SECTION OF MARINE FISHERIES

GULF FISHERY INVESTIGATIONS

William W. Anderson, Chief

GENERAL

The Gulf Fishery Investigations is conducting a comprehensive fishery and oceanographic survey of the Gulf of Mexico using the research vessel Alaska; one phase of the program, the study of the physical oceanography of the Gulf is conducted by the Office of Naval Research, through the Department of Oceanography of Texas Agricultural and Mechanical College.

Objectives.--The first objectives of the program are to establish the chemical composition and the current patterns of the Gulf. These chemical and physical aspects of the program are to provide an understanding of the origin and movements of the complex food chain which, finally, supports various fishes frequenting these waters. This information will lead also to delineation of areas of greatest fertility, and to movements of eggs and larvae into or away from these areas. The importance of this in survival of juveniles is obvious.

The second objective is the collection of organisms, other than fish, for taxonomic and distributional studies with their ecological interpretations. This objective is pursued largely through cooperative agreements with institutions and individuals peculiarly qualified to handle the special organisms involved. In this case the Gulf Fishery Investigations acts as a collecting and liaison agency.

One aspect of fishery biology, which has been largely neglected, is the study of the organics in sea water and the relation of these organics to behavior and survival of marine organisms. It is now possible to measure

quantitatively specific organic compounds dissolved in the sea water--compounds which are extremely important in the distribution and abundance of plankton on which all larger forms depend. The study of these factors and their ecological significance is being given much effort.

Progress.--Cruise plans have been worked out in cooperation with the Texas A. and M. Department of Oceanography to give a maximum number of sections perpendicular to suspected major currents in the Gulf of Mexico. The plan is laid out to cover the entire Gulf in three cruises, so planned as to cover each area once in each season of the year. The three cruises of the Alaska since April 1951 covered about 7000 miles, occupied 125 stations, and completed the initial coverage of the entire Gulf.

The Department of Oceanography of Texas A. and M. College is processing and analyzing all data pertaining to water temperatures, bathythermograph recordings, meteorology, etc. The Gulf Fishery Investigations has run the 1156 salinity determinations for all three cruises and turned the results over to Texas A. and M. College for analysis.

Plankton collections have been made by conventional methods and by means of a high speed sampler and a newly devised continuous sampler. The latter methods are still in the experimental stage but results are promising.

Fish eggs and larvae have been sorted from all plankton tows. Work is in progress on identification. This latter may take a long time to complete since little background information on the early life history of many Gulf fishes is available. Total volume of plankton was determined for each sample and the relative abundance of various groups of organisms recorded.

In comparison to areas like the California coast or the North Atlantic, plankton in the Gulf is sparse. Tows in those areas produce 8 to 10 times more plankton than comparable tows in the Gulf. It has become evident, too, that a greater abundance of plankton exists over the continental shelf than exists in waters beyond the shelf. A preponderance of fish eggs and larvae also has been found within the 100-fathom contour.

Analyses for inorganic phosphate and nitrate have been completed on a total of 371 samples obtained on the first three cruises. It has become evident from these analyses that phosphate and nitrate concentrations are extremely low at all levels inside the 100-fathom contour. In that portion of the Gulf outside the 100-fathom contour, extremely low concentrations of phosphate and nitrate exist in surface waters, but rise steadily to a maximum between about 450 to 600 fathoms, below which their concentrations decrease slightly.

Bottom profiles covering cruise routes have been prepared from echo recordings. To these profiles are being added chemical, physical, and biological data to facilitate analysis.

Pelagic fishes were taken by trolling between stations and on stations during three cruises. Most of these fish were taken inside the 100-fathom contour, the most abundant of which was the little tuna (Euthynnus alletteratus), followed by dolphin (Coryphaena hippurus), and king mackerel (Scomberomorus cavalla). Beyond the 100-fathom contour few fish were taken; of these sharks predominated, followed by the dolphin. Records maintained of size, sex, and state of gonad development furnish information on distribution and spawning periods.

Results to date lend weight to the theory that, in general, waters of the Gulf of Mexico beyond the 100-fathom curve are relatively sterile. It may be stated tentatively that the economy of our fisheries is closely associated with that portion of the Gulf lying inside the 100-fathom contour, the inshore waters, and contiguous land areas.

Red Tide Research.--- The immediate cause of "red tide" has been ascribed to a tremendous abundance of the dinoflagellate Gymnodinium brevis Davis which may be found in enormous numbers in heavily affected areas. A toxic substance of unknown nature, which is associated with the organisms, causes the death of fish.

Since the organism involved--at least for the last red tide--is known, the primary objective of the program is to determine what factors bring about an overgrowth of plankton in general and of Gymnodinium brevis in particular.

A "bloom" begins as a local phenomenon, and the factors which start it may be confined in what we term "cells of water". To establish the validity of this, the vessel Pompano is used in examining the "micro structure" of sea water in very small areas. This is done by analyzing large numbers of samples of water and their contents as closely together in time and space as possible.

A second approach to the problem involves development of the fundamental mathematical structure of the growth and expansion of a population of organisms in one of the "cells of water", mentioned above.

The third approach concerns a physiological study of the dinoflagellates to determine critical factors regulating their growth and reproduction. Once these factors are established, their existence in the open sea and in "cells of water" will be studied.

Sampling over a prearranged series of stations extending from the rivers to the 100-fathom contour for a study of the local oceanography, nutrients, and plankton, has been completed. Data collected are being analyzed. Phosphate concentrations in this area are in agreement with those found elsewhere in the Gulf inside the 100-fathom contour.

All plankton collected during the past year has been examined and data have been set up on punch cards for analytical studies.

A recent small-scale blooming of dinoflagellates in the Indian River section of Florida provided a testing ground for these newer ideas on plankton blooms, which were found to be applicable.

Culture studies on nutritional requirements of dinoflagellates and other marine organisms have been continued at the Service's Beaufort, North Carolina, laboratory.

ICHTHYOLOGY LABORATORY

Isaac Ginsburg, Systematic Zoologist

Mr. Ginsburg spent the greater part of his time on the fishes of the Gulf coast of the United States and such related species as were necessary for an understanding of the Gulf species.

NORTH ATLANTIC FISHERY INVESTIGATIONS

Herbert W. Graham, Chief

TRENDS IN THE FISHERIES

Haddock.--Heavy scrod landings from Georges Bank continued through the summer and fall of 1950 because the successful 1948 year class contributed large numbers of two-year-olds. Landings of large haddock remain low. Nova Scotian banks are also yielding large amounts of scrod. The result is a nominal increase in haddock landings over last year's.

Yellowtail Flounder.--Landings for the first half of 1951 were considerably below those for the same period in 1950. Over recent years catches from Georges (southwest part) have steadily increased while those from southern New England have declined.

Rosefish.--The Gloucester strike accentuated the decreasing landings in the summer of 1950. The Gloucester landings for the first half of 1951 were almost twice those for the same period in 1950.

A survey of old Portland landing schedules indicates a continuing trend of large boats operating farther to eastward on Nova Scotia banks; however, the northern Gulf of Maine still supports a fleet of medium and small Maine trawlers.

Trash Fish.-- Landings in the first five months of 1951 were only half of those for the same period in 1950. As a result, the concern of conservationists over trash fishing lessened.

RESEARCH PROJECTS

Haddock.--A 14-man advisory committee to the United States Commissioners for the Northwest Atlantic Fisheries Convention voted on March 21-22 that these Commissioners use the Service recommendations on mesh size as a basis for discussion at the international meeting.

At the first meeting of the International Commission for Northwest Atlantic Fisheries at Washington, D.C., on April 2-10, this issue received considerable attention. The Commission concluded that protection of haddock of sizes now destroyed at sea should be attempted, but that not enough data were available to establish beyond reasonable doubt that protection of undersized haddock now being landed is economic. The Commission agreed that before any regulation goes into effect a means of assessing the effect of regulation should be available, such method to measure characteristics of Georges Bank stock before and after regulation.

Canadian and American advisors met at Woods Hole, Massachusetts, to formulate a program of research. Present were Needler, Smith, and Martin of Canada and Walford, Dahlgren, Royce, Schuck, Taylor and Graham of the United States. They outlined a program, and the North Atlantic Fishery Investigations assumed responsibility for most of it. The program includes a study of:

1. Amounts of small haddock destroyed at sea, including total poundage and numbers of each age and size destroyed before and after regulation.

2. Mortality rates--fishing, natural, and total--before and after regulation.

3. Total poundage contribution of year classes of known abundance before and after regulation.

4. Growth rates of young before and after regulation (i.e. with present thinning and after cessation of thinning).

The following will also be undertaken:

1. Determination of a mesh size which would release a maximum of those sizes which are now destroyed on Georges Bank, but which would, at the same time, retain a maximum of the sizes now landed.

2. Preparation of a suggested regulatory measure.

In order to institute this program the following has been started:

1. Sampling at sea on commercial trawlers.

2. Assembling data on mesh selectivity; determining mesh sizes now used, fish sizes now being taken, amount of shrinkage, etc.

3. Studying the last three years' census data of the Albatross III and continuing a census of haddock in Georges Bank.

(Material was presented to biologists at St. Andrews on September 17).

Yellowtail Flounder.-- Investigations which began in 1942 have been terminated. A report is in manuscript form.

Rosefish.--Value of old data has been established and questionable data have been set aside. The number of length measurement samples were increased to better show trends of the fishery.

The placing of a port interviewer at Rockland, Maine, now makes it possible to sample production of all fishing areas.

Work at Gloucester, Massachusetts, includes extensive sampling of rosefish ovaries from various areas to establish the length of the incubation period. Results so far indicate distinctly different times of egg fertilization in different regions. This is the best evidence yet that total population is not homogeneous but is comprised of a number of separate populations.

Egg counts from two areas--southern Gulf of Maine and central Nova Scotia region (XXI H)--show different fecundity values for these two areas.

Accumulated copepod ectoparasite incidence data for 1938-1950 are being reviewed to determine the validity of their use as a mark of rosefish population unity or migration.

The use of otoliths for aging mature rosefish is being tested.

Census.--Two cruises were made to Georges Bank and southern New England Banks. There are now three years' data for the summer season and one year's data for Georges Bank for the spring season.

Progress has been made in analysis of data since the Albatross III was loaned to the Office of Naval Research. Further analysis of data in relation to depth, bottom type, and subarea has been undertaken. Summer census work this summer on the vessel Delaware has been planned.

Herring.--Investigation has been continued with financial assistance of the Maine Sardine Packers Association and the Maine Department of Sea and Shore Fisheries. Determination, by serological methods, of latent infection of Ichthyosporidium hoferi in herring is inconclusive and the experiments must be repeated with modified techniques. Experiments to observe the effect of

fungus in captive herring were unsuccessful because it was impossible to locate schools of herring near Boothbay Harbor. Repeated attempts were made to transport live herring, but the mortalities were excessive.

Lobster.--Experiments to determine effects of various types of lobster tags on moulting processes were continued from last year.

Trash Fishery.--The following estimated composition of landings from Provincetown, Massachusetts, to Stonington, Connecticut, was based on sampling: Red hake, 29 percent; eelpout, 21 percent; skates, 15 percent; whiting, 11 percent; other trash species, 17 percent; and other food species, 7 percent. The New Bedford fleet is not exploiting either young or mature individuals of important edible species (other than whiting), but large numbers of small yellowtail flounders were landed at Provincetown, and at least one small load of butterfish was landed at Point Judith. The sampling of landings continues.

Tuna.--Tuna age and growth were determined by a study of stained vertebrae. Weight records show large differences in size composition between areas (Bahamas to Nova Scotia).

A complete series of counts and measurements of body proportions was obtained on 160 fish. Gaps over a complete range of sizes will be filled during 1951. Tremendous differences are evident in the length-weight relation between months. A survey of European literature has been completed. Known areas of occurrence have been plotted, to which questionnaires added many new data. A pilot tagging operation (by numbered hooks) was completed at Bimini and Cat Cay, B.W.I. South of this area Coast Guard planes traced the migration route of giant tuna. Collecting plans for the 1951 season include length-weight, data on the young of the year, morphometry, and search for tag returns.

PACIFIC OCEANIC FISHERY INVESTIGATIONS

O. E. Sette, Director

The most significant finding of the year was the discovery of more abundant tuna and plankton in the convergence zone adjacent to the upwelling of nutrient-rich waters along the equatorial current system. This finding, together with results discussed below and data soon to be analyzed, will advance knowledge of potential fisheries in the region between the Hawaiian Archipelago and the Phoenix Islands far beyond that of other Pacific regions. The findings, in summary, follow:

Purse seining for tuna was completely unsuccessful, not only because of clearer water and smaller and faster schools, but also because of greater prevalence of rough seas than off the west coast of America, where

purse seining is commonly practiced. This occurred despite construction and use of a longer, deeper, and lighter linen seine. A last thorough trial of purse seining in Hawaiian waters began in July 1951, with Captain Joseph Vilicich commanding the John R. Manning.

Bait fishing for tuna in the Phoenix and Line Islands was impractical because bait is the limiting factor; supplies found to date will not support clipper fishing, although there may be enough for operation of small sampans.

Long-line fishing was successful in the Phoenix and Line Islands and near regions of upwelling adjacent to equatorial currents. Catches made were better than the average of Japanese long-lining in the western Pacific and better, also, than the average in the Hawaiian area.

A gill-netting project, carried on in cooperation with the Territorial Division of Fish and Game, began in July 1951. First trials indicated a few skipjack could be caught at night in dark-colored linen nets, but catches were far below commercial quantity. Further trials of the best types of nets are planned.

The Hawaiian area was given special emphasis in all studies in the late spring of 1951. In addition to gill netting and purse seining, special oceanographic studies were commenced to relate observed conditions with trends in fish abundance.

Four complete hydrographic sections (temperature, salinity, phosphate, and oxygen determinations) were made of the equatorial-counter equatorial system; in addition, temperature observations were made of surface and subsurface waters on almost all runs of all vessels. Part of the data is in process of publication. Complete analysis and interpretation of the data, however, have been delayed because world authorities disagree on fundamental behavior of equatorial currents, and a thorough interpretation requires either development of a substantially new theory or proof that a recognized authority is in error.

Productive areas of this part of the Pacific Ocean have been found to be associated either with land or with equatorial upwelling. In both places the numbers of zooplankton and small fishes are larger than those in intervening seas. A rather striking finding, the significance of which is not yet understood, is the fairly uniform composition of the plankton population in different longitudes and in different seasons of the year.

The growth of yellowfin tuna is very rapid; the average gain is 60 pounds in one year among commercial sizes of Hawaiian catches, which range from two to four-year olds. Data accumulated on other species have not been analyzed.

The spawning period of yellowfin tuna in Hawaiian waters extends from early June to mid-September, which coincides with the season of good fishing. Big-eye tuna, while common in the Hawaiian region, were not in spawning condition, although nearly-ripe females were encountered south of the Caroline Islands in July and August, and were taken south of the Hawaiian Islands in the counter equatorial current region in November.

The food of yellowfin tuna when taken near land was 47% fish, 32% crustacea, and 21% squid and octopi; when far from land it was 65% fish, 32% squid and octopi and 3% crustacea. A surprising amount of small planktonic crustacea and fish was found in fairly large tuna.

A clear-cut difference was found between yellowfin tuna populations of the Hawaiian area and those of the North American west coast. Many more comparative measurement data were obtained and are being analyzed. Material on hand will permit comparisons among yellowfin tuna of the Line, Phoenix, Caroline, and Hawaiian Islands; big-eye tuna between the Caroline and Hawaiian Islands; skipjack between the Society, Marquesas and the Hawaiian chain; and albacore between the Caroline and Hawaiian Islands. Preliminary comparison of yellowfin data suggests differences among all areas.

A POFI observer accompanied six of the eight Japanese mothership expeditions for tuna. These expeditions, each including several catcher vessels, used long-line gear to catch tuna in the area south of the Caroline Islands between 134° and 167° east longitude and between 1° and 9° north latitude. Catches, which ranged from 1/2 million to 8 million pounds per expedition, were about 1/2 yellowfin tuna, 1/10 big-eye tuna, with the balance consisting principally of marlins and sharks. Much of the yellowfin catch was intended for export to American markets.

A study of tuna reactions is being conducted under contract with the University of Hawaii. The literature search, begun in January 1951, has been completed and the difficult problem of catching, transporting and retaining tuna is under way. Of over 100 tunas caught by trolling, only two yellowfins were successfully held in tanks at the Coconut Island laboratory. Skipjack usually lived less than 10 minutes while little tuna survived only three days. Dolphin, however, survived readily and feed voraciously. Studies of reactions of tuna to visual, olfactory, gustatory, sonic, and electrical stimuli will begin with specimens held in tanks.

A Fish and Wildlife Service fellowship at the University of Hawaii, under which investigations of the physiology of bait fishes are being conducted has shown minimum oxygen requirements of iao and nehu, two of the commonest bait fishes. Studies are in progress on metabolic rates and on effect of different water flows and quantity of fish, on the rate of oxygen consumption.

Two POFI vessels were at sea most of the year. The Hugh M. Smith completed six cruises which included oceanographic and plankton surveys, live-bait fishing, and long-lining. The John R. Manning completed four

cruises, all of which were trials of purse seine gear. The other vessel, the Henry O'Malley, was used for live-bait fishing until its sale. Porceeds have been budgeted for construction of a new vessel, the Charles H. Gilbert, on which the keel was laid July 5, 1951. She will be fitted for long-line and live-bait fishing and for oceanographic work.

SOUTH PACIFIC FISHERY INVESTIGATIONS

John C. Marr, Chief

GENERAL

The Service, the Scripps Institution of Oceanography, the California Division of Fish and Game, and the California Academy of Sciences, with the support of the Industry (through the California Marine Research Committee), are cooperating in a study of the Pacific sardine, which declined sharply in abundance after 1944. Goals of the collaborators include a determination of the variations in the amount and in the extent of spawning in the productivity of the area, in the prevailing current patterns, and in other characteristics of the marine climate off the west coast of North America, especially as these relate to the sardine. A summary of the Service's participation in this program follows.

RECRUITMENT

Spawning.--Two areas have been found to be important as centers of sardine spawning: a compact area of intense spawning around and to the south of Cedros Island, off central Baja California, and a much larger area of diffuse spawning off southern California. At the beginning of the 1951 season, spawning was confined to the area off central Baja California, gradually progressing north from that area. This progression appears to be associated with the northward progression of favorable spawning temperatures. The extent of the two spawning centers seems to ne influenced by the oceanographic conditions, particularly by the currents in each area.

In January and February, the cruises of the FWS Black Douglas followed the pattern of earlier years, since spawning was confined largely to the area off central Baja California, although some occurred off southern California during February. In March, spawning was heavier off southern California and adjacent Baja California than during March of either 1949 or 1950.

During April, the Service participated in a special cruise of the E. W. Scripps to study the short-term variation in abundance of sardine eggs and larvae. A five by five grid of 25 stations, spaced at four-mile inter-

vals, was covered three times at five-day intervals. Results of this project are not yet available.

Fecundity.--To estimate the numbers of fish in the spawning population by means of quantitative net tows, it is essential to know the numbers of eggs produced per female. With the cooperation of the California Division of Fish and Game, collections of gonads were made from fish taken in the commercial catch at San Francisco, at Monterey and at San Pedro during the 1950-51 season to determine the number of ova produced. In addition to these, samples were taken in a gill net off Mexico and from the summer bait fishery in Monterey Bay. A preliminary estimate of the numbers of eggs 0.4 mm. and larger in diameter (i.e. those which will be spawned this year) in three-year-old fish, based on only two specimens, indicated that about 100,000 eggs are produced annually per fish. The variability between individuals in numbers of eggs produced complicates the problem. Because of this, it will be necessary to make counts on a large number of females at each age to estimate with accuracy the numbers of eggs produced from a given stock of adults.

Distribution of other fish larvae.--One of the major contributions of the Service to the cooperative program is the determination of the kinds and relative abundance of the principal kinds of fish larvae in these waters. During the period February through September 1950 the principal species taken and their relative numbers were:

Kind	Percent
Myctophids	29.0
Jack mackerel	18.1
Rockfish	10.6
Vinciguerria	9.3
Pilchard	7.8
Anchovy	7.0
Hake	6.5
Bathylagids	4.5
Flatfish	1.8
Cyclothone	1.1
Miscellaneous	3.2
Disintegrating larvae	1.0

The largest concentration of larvae (total larvae) was found in the area off San Diego. Stations in this area produced 200 to 500 larvae. North of Point Conception, fewer larvae were found, usually less than 100 per station. Some stations off Baja California produced less than 100 larvae, while the stations in the Cedros area produced between 100 and 300 per cruise.

Natural mortality.--Numbers of sardines have been examined for the presence of the fungus, *Ichthyosporidium hoferi*, which is known to cause heavy mortalities in other fishes. No positive evidence was found of its presence in the sardine, although heart tissue from two fish showed small, unidentified, fungus-like cells which react to differential stains as do other fungi.

ABUNDANCE AND AVAILABILITY

Estimates of abundance.--Evaluation of the regression of total mortality rate on fishing effort results in an estimate of total population numbers. Such estimates computed for the sardine stocks for the period 1932-33 to 1949-50 showed considerable variation. The highest estimate is about 18 billion individuals, the lowest about 5 billion. Another estimate, based on tag recoveries, was about 15 billion. Estimates of stock size, independently computed from the tagging data, give an average population of about 20 billion. These data demonstrate that both recruitment and total mortality rates have been extremely variable, but that recruitment variation has had the greatest effect on catch.

Availability studies.--Sardine schools have been found at temperatures, at 50 feet, of between 10° and 21°C., with about three-fourths of these being observed in greatest abundance when temperatures ranged from 12° to 18°C. The analysis of relation of schools to salinity has not been completed.

Return per unit of effort 1950-51 sardine season.--Return per effort (based on the average boat catch per lunar month) dropped to 20 percent of the 1949-50 season at Monterey, 75 percent at San Pedro, and to 65 percent for all ports combined; this despite the fact that the total catch increased 5 percent.

Age composition.--For six consecutive seasons the Pacific Northwest pilchard fishery has been either negligible or non-existent. No 1951 summer fishery has been reported for British Columbia, Washington, or Oregon. Reports of schools of pilchard off Oregon and Washington in the summer of 1951 apparently were based on misidentified anchovies. Since the opening of the fall fishery in central California on August 1, 1951, there have been no landings from the San Francisco grounds and practically none from the usual Monterey fishing areas. Length and age data of the small catches made in central California have been obtained by the California Division of Fish and Game and the Service.

Sampling the commercial catch at Ensenada was undertaken. These samples are to provide information on the age and length composition, on the fecundity of sardines from this region. Similar material will be available from more southerly areas through cooperation of the Inter-American Tropical Tuna Commission.

Races.--Studies of growth rates indicate the presence of two types, one "northern", one "southern". It has not been determined whether these types represent real genetic differences, whether they merely reflect where the fish were spawned, whether they represent shifts in the distribution of the entire populations, or some combination of these.

SECTION OF SHELLFISHERIES

CHESAPEAKE BAY SHELLFISH INVESTIGATIONS

James B. Engle, Chief

Seasonal spawning and setting of oysters.--Production of seed oysters is the limiting factor in stabilizing the oyster industry in Maryland. Principal efforts in the Annapolis, Maryland, laboratory have been exploration of various areas to determine seed production potentialities and study of ecological features responsible for variations.

Spawning and setting conditions for the past ten years in Eastern Bay were reviewed statistically for the purpose of relating meteorological and other factors with fluctuations. In this particular area, some salinity changes adversely affected setting but not spawning. In dry years, when salinity was high in late spring and early summer, setting was light. However, salinity changes in the period did not greatly affect extent and quantity of spawning. Some evidence indicated survival of larvae to later stages of metamorphosis as a contributing factor to fluctuations in setting. In dry years fewer larvae complete metamorphosis to setting.

Spawning and setting in 1950, a dry year, fitted the above observations. Spawning was adequate, metamorphosis of larvae incomplete, and setting light.

Cleanliness of or amount of fouling, both organic and sedimentary, on cultch affects setting intensity. Clean cultch used in obtaining the potential setting rate in the above research in 1950 caught 1450 spat per bushel of shells as compared with 142 spat per bushel on shells fouled by at least one year's accumulation of organic and sedimentary material at one station.

An experiment designed to increase efficiency of old and fouled shells demonstrated a useful method. A plot of oyster bottom was divided into three sections. In one section clean new shells were scattered; in the other two sections were shells that were on the bottom at least one year and fouled. One section containing old shells was scoured just prior to setting time with an open or bagless dredge to knock off fouling. Using spatfall on clean new shells as a basis of optimum setting for the season resulted in the following setting rates:

1949 shells unscoured	80 spat per bushel
1949 shells scoured	132 spat per bushel
1950 shells clean and new	146 spat per bushel

These results demonstrated that shells fouled by one year's accumulation of fouling organisms and silt could be cleaned and made more efficient by scouring on the bottom with a bagless dredge. They showed also that clean shucking-house shells planted just prior to the setting period were the best cultch.

Spawning and setting of oysters on seed beds of James River, Virginia.--In joint research, staffs of Chesapeake Shellfish Investigations, Virginia Fisheries Laboratory and Chesapeake Bay institute observed spawning and setting of oysters on seed beds of James River, Virginia. The Institute worked with biologists of the other two laboratories in a hydrographic study of the river.

Sporadic light spawning occurred in the James River from the middle of June to the latter part of July, after which it increased in intensity until heavy spawning occurred about the first of September. Setting was light most of the summer but began to increase late in August. Total setting was relatively heavy in the 1950 season.

Condition of oysters.--Seasonal condition of oysters has a relation to marketable value and physiological reactions. The cycle is related to spawning. As reproductive processes develop, glycogen is reduced. The period of high glycogen content in oysters is about 6 to 8 months, usually November through May, and from year to year the amount varies. Glycogen in 1949 during the high-level period was about 30%, dry basis, in 1950 about 35%, in the spring of 1951 and about 38%. These figures reflect a slight improvement in oyster condition since 1949, when oysters were thin.

Total solids in general follow the glycogen cycle with one seasonal exception. When glycogen drops off during development of gonads, total solids remain high until actual spawning takes place and accumulated spawn is discharged. Developing gametes offset glycogen loss during the period just prior to the first major discharge of spawn.

Condition factor, a measure of yield in meats per volume of shell stock, showed a similar increase from 1949 to early 1951. With condition improved, the same volume of oysters in the shell yielded more pounds or pints of oysters in 1950 and 1951 than in 1949.

Chlorophyll cycles related to condition of oysters.--Seasonal changes in total phytoplankton were observed through 1950 and the spring of 1951. In 1950, spring and fall blooms were indicated by chlorophyll determinations. These blooms were coincident with periods of growth of oysters and in some degree with changes in condition of oysters. In Eastern Bay and also in some areas of Chesapeake Bay the condition of oysters is better where a greater amount of phytoplankton exists. In the spring of 1951 the bloom, although present, was not as pronounced.

Effect of mussel attachment on condition of oysters.--Mussels (Brachiodontus recurvus) form in huge masses on oysters in many areas in Maryland. Effects of this relationship on condition of oyster meats were studied during the spring of 1951. When oysters collected from the same bars and separated according to density of mussels attached to their shells were examined, oysters with more than 50% of shell area covered were poorer than those free or relatively free of mussels. Mussel-covered oysters, when

freed of mussels, would regain the loss in six weeks in the condition of meats. The amount of loss on the basis of condition factor was about 25% in the weight of meats. Rapid recovery of oysters freed of mussels indicates a competitory relationship which probably could be remedied by a device to kill or remove mussels from the oyster on the bottom.

Methods of determining oyster population changes.--Swan Point Bar, upper Chesapeake Bay, is being studied to measure effect of oyster fishing on maintenance of oyster population. Such factors as fishing mortality, natural mortality, natural recruitment, mass planting and fishing effort are recorded and will be evaluated to establish a production level and means of maintaining it.

Inventory survey of oyster resources in Maryland.--During the period October through December a joint team of the staffs of Chesapeake Bay Shellfish Investigations, Chesapeake Biological Station of Maryland, and Maryland Department of Tidewater Fisheries examined over 60 principal oyster bars in Chesapeake Bay and tributaries. Areas covered were in Chesapeake Bay proper, Tangier Sound, Potomac River, Choptank River and Eastern Bay.

The supply of marketable oysters was limited in most places for the 1950 harvest. Figures of marketed oysters, recently made available, substantiated this observation. The 1950-51 production was slightly less than 2.5 million bushels of oysters, a relatively low yield for the area. In most places the supply of small oysters in the 1951 52 crop was also limited. Oysters harvested this year, 1950-51, were the residue of the setting of 1947 and several preceding years. The light setting of 1949 and 1950 will affect crops for the next three seasons.

Oyster drills, working on the current (1950) spatfall, caused considerable damage to the generally light setting in 1950 in the Tangier Sound area.

Potomac River oysters were scarce but of good quality. Very little natural replacement stock was available. The outstanding condition detrimental to maintenance of bars was lack of clean hard cultch.

The Choptank River area, a major production source, had a limited supply of marketable oysters with a residue of smaller oysters available for the next season. The setting in 1950 was sufficient only to maintain the present low production rate.

Eastern Bay, portions of which are being developed as a seed area, had a sufficient supply of market oysters for current use in local shucking houses. The supply of small oysters is adequate for harvest in succeeding years. Setting in 1950, however, was too light to produce a surplus for seed transplanting this season. The setting, while too light for seed production, was ample for replenishing the stock on most of the local bars in this Bay.

Oyster planting in Rehoboth Bay, Delaware.--At the request of the Delaware Shellfish Commission, condition of oysters and oyster bottoms in Rehoboth Bay, Delaware, was determined in September 1950. Oysters were in good condition although limited in number. The Commissionreported some previous mortalities believed to be the result of heavy growth of red algae. Clumps of dying red algae, scattered and in small amounts, were found in open parts of the Bay. Recently killed oysters were not found. However, heavy growths of algae were present in several creeks entering the Bay on the western side. These clumps were in healthy condition and may be the source of contamination of open parts of the Bay when conditions are favorable for a rapid growth of plants. The association of algae with occurrence of oyster mortality needs further study.

CLAM INVESTIGATIONS

John B. Glud, Chief

BOOTHBAY HARBOR, MAINE

Productivity studies, designed to determine the bushels of soft clams which can be removed each year without causing depletion, were continued in Sagadahoc Bay and Robinhood Cove .

Weekly plankton samples in Meetinghouse Cove and Western Beach in the summer of 1950 demonstrated the number of larvae needed for good setting for comparison with the moderate setting of Sagadahoc Bay and Robinhood Cove. Weekly samples continued through the winter in Sagadahoc Bay and Robinhood Cove showed larvae present until the first week in January, absent until the first week in March, and then present through the spring, summer, and fall. Plankton studies in 1951 were concentrated in Robinhood Cove to follow spawning, larval dispersal and setting. Vertical and tidal series, taken and correlated with tides, salinity, temperature, etc., showed great variation with the tidal stage which indicated the importance of sampling at the correct stage each time. Larval peaks of 1950 occurred in mid-July and mid-September.

All clams taken in the population census have been measured for growth rate. Growth rate in the center of Sagadahoc Bay is much better than that in Bedroom. Maximum size as determined by the Walford method is 123 mm. in center; 70 mm in Bedroom; and 55 mm. at head of the bay. All agree closely with the maximum size observed. Differences in growth rate in Sagadahoc Bay suggest different races in mud and sand. Adjacent plantings of 10,000 marked clams were made in five areas to check the theory by comparing growth rate. Monthly samples will be taken until March 1952.

The Maine Department of Sea and Shore Fisheries and the Service planted seed clams from Western Beach at Wells, Scarborough, Sagadahoc Bay, Southport, and Jonesport in a series of 0.01-acre plots at 50 and 100 per square foot concentrations. Farms at Wells and Sagadahoc were successful; others failed because of the predatory green crab, Carcinides moenas, and the clam boring snail, Polynices heros.

The third population census of soft clams in Sagadahoc Bay and Robinhood Cove, completed in the spring of 1951, shows a significant increase in the center of Sagadahoc Bay. Results will be analyzed with catch records to determine the effect of the fishery. The census will be repeated next year.

NEWBURYPORT, MASSACHUSETTS

Clam Farming.--Clams were transplanted to six plots in November and December 1950 and to ten plots in April 1951; they were arranged to test survival and growth of various types of flats. Half of most plots were covered with chicken wire laid flat to keep off horseshoe crabs and green crabs. The plots are sampled monthly.

Clams transplanted in November 1949 to four fenced plots, four unfenced ones, and one covered by chicken wire have shown successful transplanting depends on the degree of predator control. Fences are keeping out horseshoe crabs, but not green crabs; they did not save enough clams to produce a volume increase despite good growth since transplanting. The plot covered with chicken wire, planted with 16 mm. clams, by May 1951 produced 10 nearly legal-sized planted clams, 9 legal-sized natives, and 516 small natives in one square foot; surrounding areas produced no legal-sized clams. Protecting natives, rather than transplanting, may prove the cheapest clam farming method. Chicken wire-covered plots have proved predations--not lack of spawning stock, overdigging or unsuitable soil or water--cause lack of clams on some Plum Island Sound flats.

Predator and Clam Ecology.--Habits and abundance of horseshoe crabs and green crabs are being studied because of importance in clam management. Over 700 horseshoe crabs have been marked, and only one has been recovered on searches of flats. Four green crab traps fished at 2-3 week intervals on different types of flats consistently catch more on muddy than on sandy flats.

Screen sampling of the native stock was continued throughout the year. Winter samples indicated low survival or scarcity of 1950 year-class clams, but by April and May this year-class appeared in concentrations up to 200 per square foot over large areas, evidently due to large-scale movement of clams 3 to 8 mm. in length. Trays one foot square, filled with clamless mud and put down and taken up at intervals since May 3, have collected in two weeks from 20 to 119 byssus-bearing clams 3 to 12 mm. long. A square-foot depression made on May 3 collected in six days detritus containing over 20,000

byssus clams with a modal length of 4.5 mm. By the end of June crabs had practically wiped out the 1950 year class, but the 1951 clams are appearing at the rate of 20 per square foot tray in two weeks. This large-scale movement of byssus clams means the population of a clam flat need not depend entirely on planktonic dispersal.

Mortality in 1950 and 1951 was not so severe as in 1949; very few rotting clams have been found. Rate of decay in flats tested was very slow even in summer. After 27 days shells of killed and buried clams were full of decaying mass; after 72 days traces of decayed flesh were still present. This condition indicates the mortality rate is possibly lower than previously estimated.

Several types of bacteria were isolated from apparently sick clams; inoculated clams held at Gloucester Hatchery, Boothbay Harbor, and in battery jars in Newburyport have all been non-pathogenic. Because of the lack of visibly sick clams this study is being held in abeyance, with media ready for further trials if severe mortality recurs. Histological studies revealed trematode sporocysts may cause parasitic sterilization or death of clams.

KINGSTON, RHODE ISLAND

The Greenwich Bay population survey was completed in the summer of 1950 and will be repeated in the summer of 1951. Larger quahaugs were more abundant in the eastern part. The fishery was most intensive in the southern and eastern parts of the bay.

Quahaug fishermen in Greenwich Bay are interviewed weekly for catch records and measurement. Length-frequency data agree closely with results of the population census made by means of a clamshell bucket.

Plankton samples were taken weekly in April and May; daily samples for the rest of the summer will follow larval groups from spawning to setting. Bottom samples are taken regularly to follow setting.

Hand-raking versus power-dredging experiment.--The second year of experimental fishing was completed in the autumn of 1950. Bottom samples were taken in each area in November 1950; data were analyzed and prepared for publication in the summer of 1951. Little difference was found in effect on bottom or associated bottom forms; breakage was greater by dredging but not serious in either case; size composition of catch and of the remaining population was determined in each area; illegal fishing in the control area prevents final conclusion on some parts of the experiment.

MILFORD, CONNECTICUT

Artificial propagation of several species of molluscs and preparation of identification slides are conducted as part of the Clam Investigations.

GULF OYSTER INVESTIGATIONS

Philip A. Butler, Chief

COMPLETED INVESTIGATIONS

This summer marks the close of a number of investigations covering different phases of oyster biology in this area. Data in process of analysis are grouped under the following headings:

Growth characteristics of individual oysters from time of setting until 30 months of age.

Comparative growth rates of cultivated and "wild" oysters from time of setting until 12 months old.

Growth characteristics of oysters exposed to different (simulated) tidal conditions.

Comparative growth rates in related (sibling) oysters.

Effect of natural and artificial light on shell pigmentation.

Setting rates of oysters and some related organisms in comparison with plankton, salinity and temperature records during three consecutive seasons.

Biology and growth of the oyster drill, Thais, maintained for 24 months under laboratory conditions.

Experimental Planting of Hard Clam, Venus.--Planting seed clams in this area has shown the impracticability of raising them commercially here. Blue and stone crabs dug up the initial planting of clams and easily shucked them; in ten days they destroyed 600 clams. Plantings were repeated in a new area and the clams were covered with 3/4 inch hardware cloth. After two months there was a severe, but erratic mortality. Clams of less than 1/2 inch in diameter were practically eradicated. Clams of 1 inch in diameter suffered 10-90 percent mortality in adjacent plots. Clam "boxes" recovered showed 20 percent loss for reasons unknown; a 25 percent loss was due to crabs (at least shells were broken into fragments), and a 55 percent loss was due to the oyster drill, Thais. Drills traversed 50 feet of barren sand bottom to reach plantings. One-inch clams still living showed 1 - 11 mm. of growth between June 6 and August 6.

CONTINUING INVESTIGATIONS

Oyster genetics.--The failure of oysters this season to accumulate significant amounts of spawn has prevented any marked degree of success

in breeding experiments to date. One larval culture derived from an hermaphroditic oyster is of interest. Approximately 25 percent of the stripped eggs were fertilized, and development proceeded apparently normally until formation of the fourth cleavage plane. After that the cleavage pattern was bizarre and the culture died out in 7 hours, although other cultures under similar conditions continued to develop normally.

Seasonal Reproductive Cycle.--The reasons for the poor reproductive season this year are unknown, but they apparently exist to some extent also in Apalachicola Bay and Mississippi Sound. Compared with the previous year, the accumulated oyster set in 1951 is 4 per unit area, 1950 - 40 per unit area and 1949 - 150 per unit area. This relative failure in set has been accompanied by moderate spat fall of the non-commercial oyster, O. equestris, which previously had been rare here.

Physiological speciation in C. virginica.--The validity of this theory is being examined. Growth rates and gonad development of oysters transplanted here from Chesapeake Bay are being compared with those of local oysters of similar age.

MILFORD, CONNECTICUT, SHELLFISH LABORATORY

Victor L. Loosanoff, Director

Spawning and setting of oysters in Long Island Sound.--Observations on oyster spawning and setting were conducted parallel with observations on physical and chemical conditions of the environment. The general plan is to determine what factors or combination of factors are responsible for success or failure of oyster setting.

The existence of physiologically different races of oysters within the general population of Crassostrea virginica was demonstrated experimentally. Experiments showed spawning temperature requirements of northern oysters are somewhat lower than those of southern groups. Oysters which originated in Massachusetts or Long Island spawned in Milford Harbor during the 1950 season, discharging all spawn accumulated, while the majority of the oysters that originated in warmer regions, such as New Jersey or Virginia, either did not spawn at all or discharged by the end of the summer only a portion of the accumulated spawn.

Data were obtained to supplement previously reported observations on temperature requirements for maturation of oyster gonads. The range covered extended between 15.0 and 30.0°C.

The cold waters of Boothbay Harbor, Maine as "cold storage" for oysters, O. virginica, and clams, Venus mercenaria, to prevent their spawning early in the season were successfully used. This method will provide workers with ripe oysters and clams late in the season when the local population is spent.

Experiments showed that types of micro-organisms that can be utilized as food by larvae of O. virginica must be very limited. Although Chlorella sp. was the most satisfactory of a number of micro-organisms tried, it did not give consistently good results when fed to larvae during early stages. However, once larvae reached 125 microns in size they appeared to utilize Chlorella sp. During the summer of 1950 only a small percentage of larvae could be grown to a size of 125 μ; however, when fed Chlorella sp., almost all that did reach this size continued to grow and metamorphosed.

In addition to Chlorella sp., four species of bacteria, Vibrio marinofulvus, Micrococcus maripuniceus, Bacillus imomarinus, and one of the red sulfur bacteria, three species of flagellates, Chlamydomonas sp., Astasia klebsii, and one of the colorless monads, were tried as food for young oyster larvae. In low concentrations, bacteria and flagellates appeared to have no effect on growth rate or survival of young larvae. When fed in excess, they increased mortality. Another small green alga, Stichococcus bacillaris, was utilizable, but, like Chlorella sp., did not give consistently good results.

Detritus from several sources did not appear to be a good food. When dissolved glucose, yeast extract or other organic media were added, no increase in growth rate was noted at low concentrations. At higher concentrations, dense bacterial growth killed the larvae.

A comparative study of the growth and survival rate of oyster larvae in the water of Milford Harbor and in water collected in the Thimble Islands district was made. The latter has heavy and almost never failing sets while the former usually has irregular and light sets. Studies which will continue next year will help determine factors which are different in the two areas, the difference accounting for heavier sets of oysters. Yale University microbiologists are cooperating in this study.

In screening chemical compounds that may be useful in controlling gastropods and some other enemies of oysters and clams, over 800 compounds were tried. American Cyanamid Company, Monsanto Chemical Company, and Hercules Chemical Company supplied these compounds. The screening gave several promising compounds; some attracted and others repelled the enemies. Several compounds were directly toxic to oyster drills or starfish while others acted as relaxants. Specially designed experiments will evaluate promising compounds.

Observations on behavior of European oysters (Ostrea edulis) in the water of Milford and in three different areas of Maine showed that they not only survive the winter but propagate normally. Heavy sets of these oysters were obtained in laboratory jars in winter and outside experimental tanks in summer. The sets showed good growth under local conditions. Additional studies were also made on food requirements, growth rate and mortality of their larvae under laboratory and outside tank conditions. Spat of O. edulis grown at Milford was shipped in May to the fisheries authorities of the State of Washington and arrived there in excellent condition.

SPECIAL SHELLFISH INVESTIGATIONS

Walter A. Chipman, Chief

In growing phytoplankton cultures in the laboratory for use in studies of feeding invertebrates, it has been possible to conduct investigations on their phosphorus utilization. In a series of washing experiments using culture medium containing P^{32}, it has been shown that loss of phosphorus from Nitzschia and Chlamydomonas cells depends on the physiological condition of the cells. There was a greater uptake and a greater loss when cells were grown in media containing high concentration of phosphorus than when grown in one low in phosphorus. Phytoplankton cells grown in the absence of phosphorus grow and divide for a limited period, and there results a condition which may be termed a phosphorus deficiency within the cells. Deficient cells took up phosphorus more readily when again exposed to phosphorus than cells grown in an abundance of phosphorus. From experiments performed comparing phosphorus uptake of cells grown in the dark with those grown in the light, it was observed that phosphorus was not taken into the cells in the dark during the time photosynthesis was not going on. Although cells actively photosynthesizing and growing and dividing in the light take up phosphorus, it had not been demonstrated that such cells had not been exchanging phosphorus and that phosphorus was moving in both directions. By the use of cells made radioactive with P^{32} and the use of non-active cells in media containing P^{32} placed in the dark, it has been demonstrated that no significant exchange of phosphorus takes place. It seems that active metabolism is required in the accomplishment of transfer of phosphorus into marine phytoplankton.

One of the chief concerns of the research work planned of the shellfish laboratory at Beaufort is a study of the food and feeding of oysters and clams. Studies are being made of the percentage of phytoplankton cells present in the feces and in the pseudofeces after feeding a known number of cells. A comparison is being made of different species of dinoflagellates and diatoms as one part of this study. Because it has beer impossible to use radioactive isotopes as a measure of the number of cells, the actual use of food materials can be measured. Although only a start has been made in feeding of various organisms and materials to oysters and clams, it has confirmed earlier findings that great numbers of cells pass through the digestive tract unused. As a matter of fact, certain experiments seem to indicate that some forms are not utilized as food and recovery from the feces is virtually 100 percent.

Studies on the rate of uptake phosphorus by oysters and clams have shown that the rate at which radioactive phosphorus enters the shell and the body of the oyster is rapid. Although the turnover rate of phosphorus in the shells is slow, the large amount of phosphorus present allows for great accumulation of radioactivity in the shells. Fractionation of phosphorus-containing compounds in oyster meats has shown a rapid turnover

rate and a high specific activity in the phosphate esters of the acid soluble material. A slower turnover rate is indicated for the phosphorus of the lipid fraction and the nuclear proteins.

In preliminary experiments oysters and clams were exposed to sea water containing P^{32} in high specific activity. The animals were returned to sea water and loss of activity measured in the tissues. Although the sea water supplied the animals was changed rapidly, loss of activity by the animals was slight and slow. There appeared to be some increase in activity in the meat. It is evident that a supply of available phosphorus was getting to the animal for formation of organic compounds from losses within the shell, which have a slow turnover rate but a high total phosphorus content. Also, algae and other materials of the bottom in close proximity of the animals became radioactive and retained this activity for some time. These sources were making phosphorus available for use by the oyster and clam. Undoubtedly factors such as these must be considered when one is concerned about the biological life of radioisotopes in shellfish on the bottoms of our estuaries.

Because of the interest in the possibility of pollution with radioactive wastes and the fact that shellfish accumulate certain materials within their bodies, experiments are being carried on on the total amount of activity that shellfish will accumulate from exposures to small concentrations of radioisotopes in sea water and how long this radioactivity is retained by shellfish. It is anticipated that the results will give information as to how safe it would be to eat certain marine animals after they have been exposed to radioactive solutions and, if the animals were unsafe for food, how long before they might be considered safe. It is apparent that shellfish accumulate certain elements in very high concentrations and that they are easily contaminated by exposure to only dilute radioactive solutions. Since many of the particularly dangerous fission products are bone seekers and accumulate in structures high in phosphorus and calcium, the importance of the shell of marine forms is apparent.

In connection with studies on the total uptake and biological life, opportunity is afforded to study the metabolic role of certain selected trace metals. The role of manganese and zinc is to be investigated in the first experiments planned when isotopes are received.

WOODS HOLE, MASSACHUSETTS, SHELLFISH INVESTIGATIONS

Paul S. Galtsoff, in Charge

In connection with preparation of a book on the biology and cultivation of American oysters, a review was made of the present status of our knowledge of the reproduction of the eastern oyster (Crassostrea virginica) and physiology of its adductor muscle. This work was supplemented by new observations and laboratory experiments. It is a well-known fact that

temperature exerts a stimulating effect on shedding of eggs and sperm by ripe oysters. This observation led to development of a concept of "critical temperature" which implies that as the water warms up to a definite level the temperature exerts a triggerlike effect on the discharge of sex products. Field studies conducted by various investigators in various parts of the country have demonstrated, however, that temperatures at which spawning takes place vary from about 17°C. to 28°C. These observations led to the hypothesis that population of Crassostrea virginica consists of several "physiological races" or "subspecies" which are characterized by their ability to spawn at different temperatures. Laboratory experiments which were repeated this year at Woods Hole confirmed the earlier conclusion that the concept of "critical temperature" is not valid because spawning in ripe oysters may be induced by a combination of chemical and thermic stimulations. Depending on the degree of physiological ripeness of the organism, the response of individuals taken from one locality and presumably belonging to the same "race" may take place at different temperatures varying from about 17°C. to 32°C. These observations show that as development of gonads progresses, oysters reach a "critical" stage during which spawning may be induced by temperature, by chemical stimuli, or by a combination of these factors. These date show the concept of "critical temperature" is not in accord with facts and leads to erroneous assumptions. Understanding conditions which determine success or failure of oysters to spawn is of considerable practical importance, for such knowledge should givern the oyster farmer in his attempt to repopulate his grounds by transplanting oysters from different parts of the coast.

Oysters taken from water may remain alive for several days and even weeks because they are able to close their shells and retain sea water entrapped between their valves. Oyster farmers learned by experience that oysters periodically exposed at low tide withstand shipment better than those kept under water all the time. In order to take advantage of this ability of oysters to protect themselves against loss of water and desiccation, some oyster growers let their stock remain on tidal flats for several days before shipment.

Closing of the oyster shell is accomplished by a contraction of the adductor muscle of the oyster and by the ability of one portion of this muscle to remain in a contracted stage without using energy. Opening of the shell is due to a springlike action of a hinge when the muscle is relaxed. By means of a simple device designed and constructed in the laboratory it was possible to determine the force exerted by the muscle in hermetically closing the shells. It was found that in various oysters tested in the laboratory the total force needed to close the shell of a marketable oyster varied from 51 grams to 663 grams. Expressed in terms of pressure per unit of area, observed values ranged from 33 to 532 grams per square centimeter. Oysters from Peconic Bay (Fireplace), Apalachicola, and from grounds in Pensacola Bay which are overrun by strong tidal currents have stronger hinges that oysters from Narragansett, Bay, upper part of Chesapeake Bay, East Bay, Florida, and intertidal zone of Pensacola Bay. The mean force needed to close shells of oysters of the first group varied from 148 to 179 grams per

square centimeter, while in the second group this force varied from 92 to 99 grams per square centimeter.

The force needed to overcome resistance of the adductor muscle in opening the shell was found to be many times greater than the force exerted by the animal in keeping its valves tightly closed. Experiments were conducted with oysters kept in air and in sea water. It was found that the relationship between the pulling force applied to the muscle and time of its complete fatigue can be expressed by a hyperbolic curve. Critical pulling force under which the adductor stretches almost immediately is about 10 kilograms (22 lbs.). Under a continuous pull of 1 kilogram (2.2 lbs.) oysters became completely fatigued in about 20 days.

Despite the fact that excellent oyster setting grounds are found in upper Buzzards Bay and that good maturing grounds are available on both sides of the Cape, the local oyster industry has been reduced during the last 10 years to a very low level of production. A few of the oyster growers still operating in Massachusetts confine their efforts to bringing adult oysters about 3 inches long from Long Island Sound for planting in Cape waters. The oysters are usually sold the following year. A 1:1 return is considered a success and frequently only 3/4 of a bushel can be harvested for a bushel of oysters planted. Some of the more progressive oyster farmers desiring to revive the industry asked for information regarding establishment of seed areas in tidal marshes along the shore line of the Cape. Two of these projects, one in the Taunton River and one in Chatham, are being established according to recommendations supplied by the laboratory. If these trials are successful, the method of utilizing tidal marshes as seed-producing ponds may become instrumental in reviving the vanishing oyster industry of Cape Cod.

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