CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 45 JULY, 1959 NUMBER 3

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HISTORY OF KELP HARVESTING IN CALIFORNIA[1]

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Long Beach, California

GENERAL INFORMATION

Algae is a general term applied to a large number of primitive freshwater or marine plants. On the West Coast of North America there are several hundred species of salt water algae ranging in size from minute to very large plants. Larger marine algae have been separated into three groups according to color: red, green, and brown, but some botanists recognize a fourth, the green-brown algae. Seaweed is an inclusive name applied to most marine plants other than the minute forms and kelp is usually applied to the larger seaweeds. If we exclude from consideration very small ocean plants and grass-like shallow water plants with functioning true roots (eel grass for example), we may use the three terms: marine algae, seaweed, and kelp almost interchangeably. Of the many species of marine algae in California, only three or four kelps are commercially important and a half dozen smaller seaweeds are sometimes gathered for food or agar-agar.

The giant kelp (*Macrocystis pyrifera*), a perennial brown alga, is the most important species in California and has furnished most of the kelp material harvested during the 49-year period from 1910 to the present. Bull kelp (*Nereocystis lutkeana*) is abundant along the Monterey coast and northward, but has not been harvested in large amounts. The large northern kelp (*Alaria* sp.), plentiful in Alaska, has not been utilized in California.

Some of the marine algae are annuals, a few are biennials, and several are perennials. They do not have roots. Instead, they anchor to the bottom by means of a clasping organ (holdfast) that grows around a rock or attaches to a solid surface to prevent the plant from being washed away. Food is not obtained from the sea bottom, but is taken from the surrounding water by the pigment (chlorophyll) of the plant in the presence of sunlight (photosynthesis). A quantity of carbon dioxide is necessary for such a large plant to grow and only small amounts are dissolved in sea water. Therefore, a constant change of water is required for kelp growth. This limits kelp to exposed positions where waves and currents are present. A rocky bottom with good attachments for holdfasts is another requirement limiting the distribution of kelp beds. Water temperature is the chief factor govern-

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[1] Submitted for publication April, 1959.

EDITOR'S NOTE: The author worked for the Department of Fish and Game for 36 years from 1919 until his retirement in 1955. During this time he was intimately associated with kelp harvesting and all of the attendant ramifications. This paper was prepared after his retirement to fulfill a request by the department to tie together into a permanent record the complex history of kelp harvesting in California—information that previously was only partially available in printed form.

ing the distribution of the different kelp species. During the past 40 years an extensive literature has been published covering the life history, growth habits, and reproduction of west coast kelps, especially of the giant kelp of Southern California.

ALGAE AS HUMAN FOOD

While the territorial area of Alta California was being explored by the Spanish, coastal Indians were recorded as eating marine algae gathered from the shore. One such record mentions the Indians of Fort Ross (1812) gathering seaweed for use as soup stock.

For the past 75 years, at least, small forms of marine algae have been gathered at low tide for drying and shipping to centers of large populations of Chinese and Japanese. Some shipments were made to cities in the eastern United States, but most of this material has gone to China. The species most favored for human food is a small ruffled plant, *Porphyra perforata*. For many years, Chinese buyers maintained small camps scattered from Fort Bragg to Santa Barbara, where seaweed was dried and sacked for shipment (Bonnot, 1931). No records were kept of this harvesting, but the operation was never very large. What was probably a record crop was gathered in 1929, when the California harvest was estimated at 150 tons, dry weight.

During the last two or three decades seaweeds have been prepared in various forms as health foods for human consumption. These usually have been in the form of pills to supplement the diet, but a kelp powder has been marketed for sprinkling over breakfast cereals and other foods to add an attractive salty flavor. Two companies have specialized in these products, but the amounts of kelp required for this trade are very small.

AGAR-AGAR

Certain species of marine algae may be used in producing agar-agar, a gelatinous substance of value chiefly as a culture medium in bacteriological laboratories. Agar-agar is also used for taking dental impressions, sizing cloth, and as a stiffener in candies and jellies. In Southern California, more than a dozen species of seaweed may be so used (Bonnot, 1931). For the past three or four decades, one agar company (American Agar and Chemical Company, San Diego) has processed both imported and local seaweed. One or two Japanese diving teams gathered seaweed on a small scale for many years, but this was such a small "fishery" that no records were kept of their operations. Most of the agar-agar used in the United States was imported from Japan because of higher production costs for California seaweed. When World War II suddenly cut off importation from Japan there was an immediate need for agar production in California. The United States War Production Board issued a freezing order on all agar. In order to encourage agar production, the California Fish and Game Commission directed Paul Bonnot of the Bureau of Marine Fisheries to make a survey of the distribution and abundance of agar weed from Point Conception to the Mexican boundary. This was done by full-suit diving and the results were made public in a mimeographed report by Bonnot (January, 1942). During 1942 and 1943, 8 or 10 agar processing plants sprouted in the greater Los Angeles area, and nearly everyone with "full-suit" commercial abalone diving experience was induced to gather agar weed. This sudden burst of activity was short lived for it was soon discovered that the poorly paid abalone divers of Baja California could gather, dry and ship weed to Los Angeles factories far cheaper than local weed could be prepared. All but two or three of the processing plants closed down and at the end of the war the local agar business folded up.

GERMAN POTASH

Great deposits of salts were discovered in the beds of ancient seas near Stassfurt, Germany (about 1840) and within 25 years these deposits were being mined in such volume that most of the world became dependent upon Germany for potash salts. The United States took about one-fifth of the output of these German mines. The government of Germany maintained strict control over the operation of the mines. A government-controlled agency (Kali Syndikat) determined the amount to be produced and marketed by each mine, the proportion allotted for export, the sale price, and export tax.

In spite of these controls, United States imports increased year by year through 1912, but by 1913 they began to drop off. In the meantime (1910), a dispute between American potash buyers and the German marketing syndicate became so heated, that diplomatic exchanges resulted between the two governments and newspapers gave it wide publicity. This attracted the attention of the American public to our dependency upon Germany for fertilizer, and Congress authorized investigations by federal officials to develop, if possible, a local supply of potash on a commercial scale. This attracted the attention of private enterprise and possible sources of fertilizer were examined by federal and private investigators. Although small deposits of potash were known to exist in several parts of the world, these sources were inadequate for our needs. Agents of the United States Department of Agriculture, Bureau of Soils, were most interested in developing local fertilizer material for American farmers. It was considered necessary that the United States be freed from dependency upon a foreign government and a marketing syndicate, that could at any time reduce our allotment of potash and dictate the price charged and the tax levied. As evidence of the uncertain supply, the German government, in the early months of 1915, did prohibit further export of potash. This followed the mobilization of European troops and the beginning of World War I. After the close of the war (1918), importation of potash from Germany was resumed, but on a reduced scale.

KELP POTASH

In several countries, coastal farmers had long practiced using dried kelp and seaweed ash for fertilizer. In a general way, the potash content of kelps was known. As early as 1902, the chemical composition was determined for our three largest west coast algae. Preliminary laboratory investigations (1910) disclosed that, in addition to potash, our kelps carried a larger number of useful byproducts than any other potash-bearing material. It became evident that the Pacific Coast kelp beds offered the most promising source of fertilizer and it was hoped that recovery of byproducts would help carry the cost of producing potash. The best methods of extraction, cost of harvesting and processing, the extent of the available supply, and the effect of harvesting upon the kelp beds were not known. These unknowns determined the research program adopted by the United States Department of Agriculture, Bureau of Soils, under the authorization of the United States Congress.

The investigations were supervised by personnel from the United States Bureau of Soils. Frank K. Cameron was in charge of the chemical and physical investigations. Dr. R. P. Brandt was placed in charge of part of the work and headquartered at Scripps Institution of Oceanography, La Jolla. He was assisted by several staff members of Scripps Institution of Oceanography, over a period of many years. Prominent among these researchers was W. C. Crandall, collaborator in kelp investigations. Methods of extracting potash and other products from kelp were under the direction of J. W. Turrentine.

Although the early interest in kelp by the United States Bureau of Soils emphasized potash as fertilizer, there were hints that materials for explosives were not being overlooked. The need for acetone for explosives was even more critical than that for potash because it was in such short supply. Large ammunition contracts depended upon developing new sources of acetone and potash. To recover acetone the Dupont Powder Co. had attempted fermentation of plant material in a leased pickle works in Maryland. At a critical time the culture failed and attention then centered upon west coast kelp.

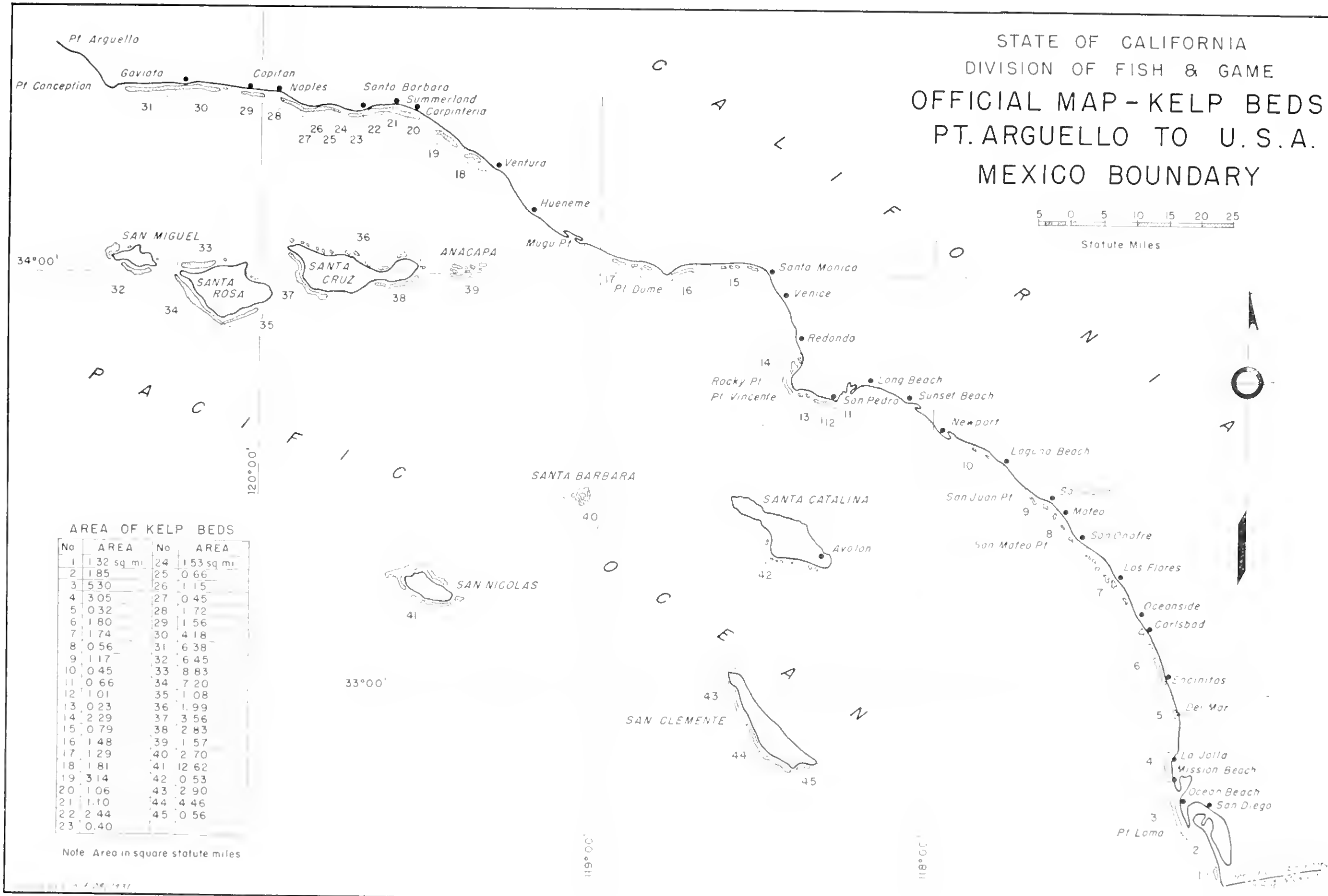
As early as 1914, Dupont was examining the possibility that kelp might yield the necessary acetone and potash. A sample of two wet tons of seaweed taken by a representative of the powder company from in front of the Del Monte Bathhouse (Monterey) led to the first recorded objection to kelp harvesting. Mr. F. E. Booth complained to the San Francisco Office of the State Department of Commercial Fisheries that his fishermen declared kelp cutting would ruin sardine fishing in Monterey Bay.

In 1916, Hercules Powder Co. built the large kelp plant at San Diego to recover acetone as well as potash. The work was successful. The United States Government plant at Summerland (1917) concentrated its efforts on kelp byproducts, chief of which was acetone.

Kelp products made it possible for the United States powder companies to fill huge ammunition contracts with our allies in World War I as well as to supply our own armed forces. Thus seaweed played an important part in winning the war.

EARLY SURVEYS OF KELP BEDS

The program to assure this country of a supply of locally produced potash started in 1910. Preliminary inspections were made of some of the kelp beds. Samples of kelp were gathered and chemical analyses were made in the laboratories of the United States Bureau of Soils. Systematic field work commenced in 1911, with a survey of the individual kelp beds of the Pacific Coast of North America from the Gulf of California to western Alaska. The survey included mapping the location, extent, and ecological characteristics of the beds, plus other



AREA OF KELP BEDS

No	AREA	No	AREA
1	1.32 sq mi	24	1.53 sq mi
2	1.85	25	0.66
3	5.30	26	1.15
4	3.05	27	0.45
5	0.32	28	1.72
6	1.80	29	1.56
7	1.74	30	4.18
8	0.56	31	6.38
9	1.17	32	6.45
10	0.45	33	8.83
11	0.66	34	7.20
12	1.01	35	1.08
13	0.23	36	1.99
14	2.29	37	3.56
15	0.79	38	2.83
16	1.48	39	1.57
17	1.29	40	2.70
18	1.81	41	12.62
19	3.14	42	0.53
20	1.06	43	2.90
21	1.10	44	4.46
22	2.44	45	0.56
23	0.40		

Note Area in square statute miles

FIGURE 1. Kelp bed map based on the United States Department of Agriculture (Bureau of Soils) map of 1911. The beds were numbered in 1931 by the California Division of Fish and Game. There have been changes in the area of some beds and a few have disappeared since 1911.

pertinent information as to transportation, desirable locations for processing factories, labor supply, and especially the possible yield from each bed. The southern surveys were directed by W. C. Crandall in 1911 and 1912, from Cape San Lucas and the Gulf of California to Puget Sound.

Surveys of Puget Sound were conducted by George B. Rigg in 1911 and 1912, and of western Alaska in 1913. T. C. Frye carried out the 1913 surveys of southeast Alaska.

These surveys resulted in U. S. Department of Agriculture Report No. 100 covering most of the phases of "Potash from Kelp" (Cameron, 1915). The maps of individual beds supplementing Report No. 100 were published in a separate portfolio of charts in 1914. These maps are still used in the administration of kelp harvesting in California, although our local beds were numbered later by H. B. Nidever of the California Division of Fish and Game.

It soon became evident that the beds of giant kelp of Southern California (south of Point Conception) offered the best opportunity for heavy cutting. Individual plants lived for several years and the surface leaves, when trimmed off were quickly replaced by new growth. This would allow harvesting as often as three or four times a year. The beds north of Point Conception were composed of annual seaweeds and could be harvested only once a season. The southern beds were larger, and more dense, and were almost pure stands. Northern beds were composed of several species, smaller in area and more scattered, making harvesting more costly. In addition, economic factors favored the southern coast where established population centers offered a labor supply and transportation facilities. Finally, smoother water south of Point Conception would permit a greater number of operational days at sea each year.

EXPLOITATION PERIODS

Harvesting giant kelp in quantity along the California coast can be separated into two distinct periods. The first (1911-1919), a nine-year feverish boom, was induced by the high cost of potash imports from Germany during the years leading up to and throughout World War I. This period chiefly supplied materials for explosives. It produced an overabundance of processing companies, many operating only for a short time on a small scale. Other companies sold stock but harvested no kelp. Transfers of ownership and consolidations were frequent among these smaller companies. As a whole, the industry was unstable, except that three or four well-financed companies operated on a large scale to fill governmental contracts for explosives.

A second period, from the mid-1920's to the present, has been on a smaller scale and characterized by a more normal peacetime development of byproducts. Harvesting over these 30-odd years has been stable, involving only three firms. Two have operated continuously over the three decades.

HARVESTING METHODS

While kelp utilization was being developed in California (1912-1915) almost every possible method of harvesting was tried. The most primitive was to gather the beach litter that washed ashore as a result

FIGURE 2. Kelp spread in open field to sun dry. Roseville near San Diego. April, 1917. Photograph by W. F. Thompson.

FIGURE 3. Burning sun-dried kelp to recover ash. Roseville near San Diego, 1917. Photograph by W. F. Thompson.

of storm breakage and black rot or from summer warm water sloughing of the plants. This litter was spread on the beach to dry in the sun and was then burned and the ash saved for the 8 or 10 percent of potash it contained. At least one firm cut seaweed from a skiff and let it drift ashore where it was dried and burned. Another firm cut kelp from a skiff, tied the fronds to a long rope, and pulled them ashore with a windlass. Most kelp was obtained by pulling the fronds into a skiff or small barge and cutting the stems as deep as possible (6 to 10 feet) by using a knife on a long pole. A very destructive method entailed encircling a portion of a bed with a cable and power pulling the plants into a bundle so that the stems could be cut and the weed towed ashore. This destroyed many holdfasts. In some cases the cut weed was chopped by a machine on the barge and later sent through a revolving dryer in preparation for burning. These methods supplied kelp ash to the companies recovering potash.

When some of the larger firms (about 1916) began using a fermentation process to obtain potash and acetone, it became necessary to deliver fresh seaweed in much greater quantity and the mowing method was developed. It operated similar to and resembled the hay mowing machines used by farmers. A 10- to 20-foot wide horizontal blade with reciprocating knives was mounted on the bow of a barge in such a manner that it could be lowered to about four feet beneath the water surface. Vertical knives, at each end of the horizontal blade, trimmed off floating fronds that extended past either side. An endless chain conveyor carried the cut kelp into the barge. Mowing eliminated injury to the plants—a common shortcoming in earlier harvesting methods.

There remained to be solved, however, the problem of escapement of cut ends. At first, the skipper of a barge would harvest only in the thickest portion of a kelp bed, often zig-zagging to hit these spots. This permitted too much loss at the sides of the cutting blade. Cutting round and round a bed, like mowing a field of hay, was similarly poor. The larger companies sought out and developed better methods. They found that loss could be reduced to a minimum by cutting either "with the grain" (the same direction that air and water currents were causing the surface fronds to drift) or directly against the drift. The better harvesters cut the first swath near the outside of a bed so that subsequent runs picked up most of the escapement. The Hercules Powder Co. (about 1917) ordered two or three of its barges to operate in an oblique formation through a bed so that each swath picked up the escapement of the preceding barge. In modern harvesting, kelp loss can be kept to a minimum if proven methods are followed.

PROCESSING COMPANIES

The interest taken by the U. S. Government in the kelp beds of the Pacific Coast attracted the attention of investment seeking capital. A few kelp organizations were incorporated in 1911, but the Coronado Chemical Co. is credited with being the first to harvest and process giant kelp (Cameron, 1915). This plant was located at Cardiff-by-the-Sea, about 20 miles north of San Diego. Other companies were incorporated and started building factories in 1912 and 1913, so some experimental harvesting was done in 1911 and 1912. The Ocean Products Co. at Port

Townsend (incorporated in 1912) and the Pacific Products Co. at Anacortes, erected plants on Puget Sound in 1913. In 1914, the Western Algin Co. of Seattle built a plant at Port Stanley on Puget Sound. The North Pacific Kelp Potash Co. and the Pacific Coast Kelp Potash Co. were organized in 1913, but they harvested little or no kelp.

The second harvesting firm in California was the Ocean Products Co. with a plant at Half Moon Bay (1913). This company and the Coronado Chemical Co. were absorbed in 1913 by the American Potash Co. and their equipment was moved to a factory in Long Beach. The Pacific Products Co. (not the Seattle firm of the same name) had a plant near Point Fermin, San Pedro in 1913 as did the Pacific Kelp Mulch Co. The latter was absorbed by the Mexican Kelp and Fertilizer Co. of San Diego, an outfit that harvested near Ensenada, Baja California, and shipped dried seaweed to San Diego and Los Angeles Harbor. The Pacific Kelp Co. had an experimental plant at Pillar Point, Half Moon Bay, and in 1913 the Kelp Products Co. built a factory at San Diego.

Plants operating in the Los Angeles area in 1913 included the California Fertilizer Co. at Terminal Island and the American Potash Co. at Long Beach. The Terminal Island plant prepared a fertilizer made up of 75 percent kelp, 15 percent sardine meal, and 10 percent bone phosphate. The American Potash Co. (later the American Products Co.) dried and burned kelp.

At midsummer of 1914 several small plants were experimentally producing potash for fertilizer, but some of these turned into stock selling schemes.

By the end of 1914, the three California plants producing the most potash were American Potash, Pacific Kelp Mulch, and Pacific Products. A number of small firms were experimenting with methods for potash extraction, but their kelp harvesting, accomplished by hand cutting from skiffs, was intermittent and small scale. Throughout the prewar period a few small firms dried and burned kelp and sold the ash to established processing plants. The combined California harvest in 1913 was estimated at 2,500 wet tons. During 1914, cost of foreign fertilizers more than doubled and capital sought out the kelp beds as a source of potash. By September, 1915 the sale price of potash had risen from 38 to 300 dollars per ton. A significant news note in an October, 1914 trade journal mentioned inquiries from E. I. Dupont de Nemours Powder Co. This was an early hint that the potash might be needed more for explosives than fertilizer.

In 1915 only a few firms were added to the growing list of West Coast kelp harvesters. National Potash and Iodine Co. of Bremerton, Washington bought out the Western Algin Co. of Port Stanley, Washington. The Coast Reduction Co. operated a Long Beach plant but it burned soon after it was completed. Late in the year the Hercules Powder Co. hired fishermen at Monterey to gather kelp for hauling to San Francisco by tug. No doubt this was prompted by the German edict in March, 1915 prohibiting further export of potash.

During 1916, several companies were incorporated in Washington and Oregon, but most of them never operated. In California there were so many small operations, some of which cut kelp by hand, that the establishment of additional factories no longer attracted investment capital. However, a trend toward enlarging the operations of a few big plants did receive some financial backing. In order to prevent possible damage to the kelp beds from irresponsible hand cutting and to promote the general welfare of this new kelp industry, the larger firms organized the Pacific Kelp Manufacturing Association of Southern California. The first firms that were represented in the association were the Lorned Manufacturing Co. (formerly American Products Co.), Diamond Match Co. (Los Angeles Harbor), Sea Products Co. (Long Beach), National Kelp Potash Co., Pacific Products Co. (Long Beach), and Oceanic Engineering Corp.

Swift and Co. completed a large plant at San Diego in 1916 and a few small firms were consolidated elsewhere on the coast. The most significant addition to the harvesting picture that year was the construction of a large plant at Chula Vista by Hercules Powder Co. This firm started with two big harvester barges of 250 tons capacity each. The plant later was enlarged to handle 2,000 wet tons daily and soon 1,500 men were employed in a three million dollar factory. At first charred kelp was leached for potash, but this was replaced by a fermentation process developed by the Hercules Co.

During 1916, 11 kelp processing plants operated in Southern California at San Diego, Wilmington, and Long Beach, and a few small plants were being constructed. The operating firms employed 16 harvesting barges having an average daily capacity of 200 tons each. The four largest firms were Hercules Powder Co., National City; Swift and Co. Kelp Works, San Diego; Diamond Match Co., Wilmington; and American Products Co., Long Beach. The seven remaining plants were National Kelp Potash Co.; Sea Products Co., Long Beach; Pacific Products Co., Long Beach; Lorned Manufacturing Co., Occidental Chemical Co.; San Diego Kelp Ash Co.; and Oceanic Engineering Corp. San Diego plants cut kelp beds from Point Loma to La Jolla and the Los Angeles Harbor area companies harvested from Point Fermin north to Rocky Point.

Kelp harvesting in Mexican waters during 1916 was controlled by M. Kondo through Kondo Fisheries Co., San Diego. Kelp was dried near Ensenada, baled, and shipped by weekly steamer to San Diego where it was sold to extraction plants. Following this World War I harvesting below the border, was a period of about four decades when very little exploitation of Mexican kelp took place. However, in June, 1956, arrangements were made by a California kelp processing company to harvest the beds growing within approximately 100 miles of the border. This was to be for a trial period in which to determine the amounts and quality of kelp that might be available for commercial harvesting. Up to March, 1959, a number of trips were made under this agreement.

The most significant kelp utilization event of 1917 was the construction and operation on a commercial scale of the United States Kelp Experimental Plant at Summerland (Santa Barbara County). This plant not only produced potash by various methods, but concentrated its efforts on developing kelp byproducts. Success was achieved in recovering iodine and acetone. Still another company, El Capitan Products Co., was established during 1917 with an operating plant near Santa Barbara. One of the partners in this enterprise was Captain Walter Engelke who had been skipper of harvester barges for several large kelp firms and probably had more harvesting experience than any other man on the coast. Later he was skipper of patrol boats for the California Division of Fish and Game until his retirement in 1947.

The 1918 peak of our war effort saw a period of heavy kelp harvesting by a few leading firms with emphasis placed on extraction of potash and acetone for explosives. Some of the small companies were consolidated, including the California Chemical Co. of Summerland which was reorganized as the Occidental Chemical Co. of Oakland. Other small firms folded up.

Toward the end of 1918, it was the hope of the potash companies that they might continue in business after World War I. Realizing that potash prices might drop, they tried to develop kelp byproducts to supplement their output. In this respect, large firms had the advantage over small outfits in that they already had been recovering some byproducts, but with the signing of the Armistice in November, 1918, the price of potash and acetone dropped so low that big as well as small plants were forced to close. The three million dollar Hercules Powder Co. plant at Chula Vista, that had been working three shifts of eight hours each, had to discharge practically all its employees. It had operated for 2½ years and is said to have harvested 621,000 wet tons of kelp. Government explosives contracts were cancelled and kelp harvesting practically ceased. However, the U. S. Experimental Plant at Summerland continued harvesting for another 2½ years while experimenting with the recovery of other byproducts. Several materials, such as bleaching carbon, were developed, but these processes could not pay dividends in a competitive market and government appropriations were stopped. The plant closed down in the summer of 1921.

In spite of the general collapse of the kelp industry in the winter of 1918-1919 some harvesting was resumed in 1919 in an effort to market some of the byproducts that had been developed. The sale of these byproducts was sluggish and production costs were relatively high. Mission Chemical Co. was organized at San Diego in the summer of 1919, but met with little success.

Following the 1919 and 1920 cessation of most harvesting in Southern California was a short period (1920-1926) when kelp was utilized very little. Three or four years later a few scattered attempts were made to gather seaweed, especially on Puget Sound. These operations were small scale efforts to recover byproducts from kelp, but sale prices were too low to cover production costs, and they were short-lived. In 1931, the Ocean Products Co. of Anacortes, Washington, was using kelp as a basic ingredient in soap and another firm was producing a shampoo from kelp. In Ojai, California, a Mr. Baker was putting out a kelp bread that sold well for a time. One or two other firms were selling stock.

In 1927 the second or post-World War I era of large-scale kelp harvesting began. Two new companies were organized then and have operated continuously ever since. One, Philip R. Park Inc., San Pedro, began harvesting on a commercial scale in 1928. Kelp meal and other ingredients were blended in this plant for use as stock and poultry food.

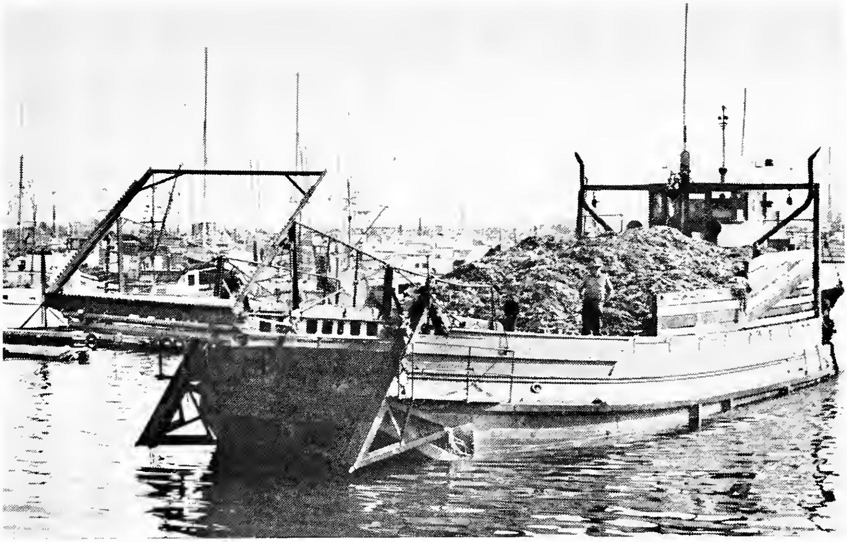


FIGURE 4. Kelp harvesting barge of the early 1940's. Photograph courtesy of Philip R. Park, Inc., San Pedro, California.

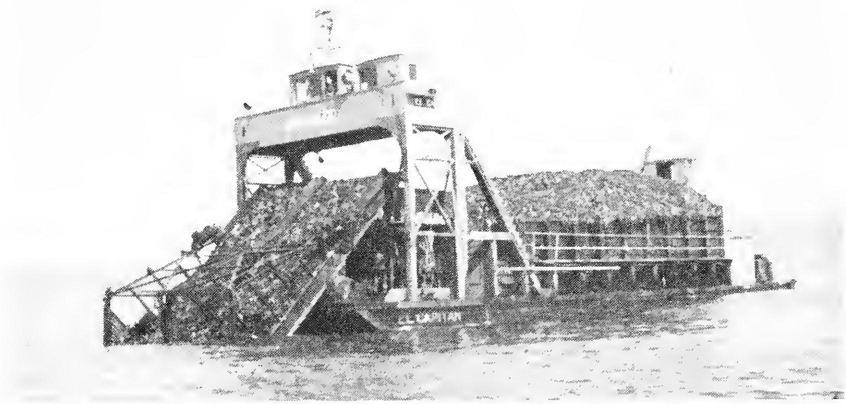


FIGURE 5. Kelp harvesting barge *El Capitan* built in 1941 for Kelco Co., San Diego. Photograph 1952 courtesy of Kelco Co.

The second was started indirectly as a result of research by the American Can Company for a material to control the viscosity of a gasket compound for sealing tin cans. Algin proved the most satisfactory of several materials tried so the company erected a San Diego plant in 1927 for recovering algin from kelp. This factory operated under the name "Thornley & Company" and produced algin according to specifications and processes prescribed by technical personnel of the American Can Company. The name was later changed to "Kelp Products Corporation" and in August, 1929, it was reorganized under the name "Kelco Company." In 1941, the Kelco Company built a plant at Hueneme for producing dried kelp meal as a vegetable-mineral supplement in animal feeds. Shortly after the Pearl Harbor attack in December, 1941, the United States Navy took over the Port of Hueneme, and the Kelco Company plant, as well as the sardine canneries at the port, were dismantled. In the meantime Kelco Company at San Diego has expanded and its research staff has developed new algin products for scores of uses.

Two smaller operations also started up during this second era of kelp harvesting. From 1933 to 1943, the San Diego firm of J. Michael Walsh harvested from 8 to 35 tons of seaweed per year for use in health pills to supplement the human diet.

Then in 1950 Kelp Organic Products Co. established a plant at Hueneme and has produced kelp meal intermittently ever since.

HARVESTING AT MONTEREY

A second era of kelp harvesting at Monterey was started in August, 1930. In this area the dominant species of seaweed is bull kelp, which has a single large float or head from which the leaves stream out over the surface of the water. This large single float has given rise to another common name—great bladder kelp. Incidentally, these floating heads offer ideal concealment for the sea otters that loll on their backs in a kelp bed. Only by use of a strong glass can an observer distinguish between the seaweed floats and otter heads bobbing in the water. The area between Point Pinos (Pacific Grove) and Point Sur about 20 miles to the south was harvested from a 38-foot boat. The seaweed was cut 10 or 15 feet below the water surface with a sickle blade mounted on a long pole, and pulled into the boat by hand. It took a three-man crew about five hours to gather a four-ton boatload. Price to the fisherman was $10 per wet ton. Loads were delivered at the Monterey dock and trucked to a grinding shed, one of which was located at Oak Grove near Monterey. As much water as possible was then squeezed out in a screw press and the resulting slabs of kelp were packed in barrels for shipment to New York. Two companies were involved in selling kelp at Monterey. The Sandoz Chemical Co. sold it for manufacturing dyes and the Sardue Chemical Co. sold it for making a soap for washing textiles. This hand cutting yielded approximately 200 wet tons in 1930 and 500 in 1931. In 1931, an influx of warm water along the California coast was said to have caused a scarcity of kelp at Monterey. However, beds down the coast from Monterey were reported to have been much less extensive even before kelp cutting started in 1930. This earlier decline of the beds was blamed upon Japanese abalone divers cutting the stems of bull kelp. This seems a very unlikely story because deterioration of beds has been reported at other times and in other places where there had been no abalone diving or seaweed gathering.

KELP REGULATIONS

Cutting of Pacific Coast kelp began in 1910, but the first California plant to process kelp was in 1911. In the two or three years following, several firms operated. At first, kelp was gathered in a variety of ways, usually by pulling the plants into a boat by hand and cutting the stems as deep under the water as possible. One or two small operators hand cut the plants and let them drift into the beach to be picked up. These were bad practices and were protested by the established processing firms, by the State Fish and Game Commission, and by some of the coastal inhabitants. In 1916, one or two counties passed ordinances against indiscriminate harvesting. These were of doubtful constitutionality because counties lack jurisdiction over natural resources belonging to the State.

There was no state law governing the collecting of marine algae and it was questionable whether or not the Federal Government had authority to regulate offshore seaweeds so an appeal was made to the United States Department of Agriculture. An opinion of the Solicitor of the Department of Agriculture (dated October 12, 1911) was in effect that the area inside the three-mile limit was under state jurisdiction and outside that limit, neither the State nor the Federal Government had control. The paramount right of the Federal Government to regulate commerce and navigation was an exception to this general ruling. Since practically all kelp beds were within three miles of the coast there was an appeal for the State to assume regulation of kelp cutting. In the meantime, in 1914 the Department of Commercial Fisheries was established under the Fish and Game Commission and it seemed logical that this new department should handle kelp as a "fishery." To eliminate bad cutting methods, regulations and a boat to patrol harvesting areas were needed.

In September, 1916, a meeting of interested parties was called to draft a bill for presentation to the California Legislature. Representatives of the kelp firms, the U. S. Department of Agriculture, Scripps Institution of Oceanography, and the State Fish and Game Commission were present at this meeting. The purpose of the bill was to fix the authority of the Fish and Game Commission to supervise kelp gathering and to patrol the cutting areas. More difficult was the drafting of regulations to govern harvesting. A stumbling block was the fact that the Fish and Game Commission had no discretionary power to make rules and to apportion beds among the several operating companies. At this meeting, it was unanimously agreed that the harvesting firms would be governed by a gentleman's agreement as to the allotment of beds and harvesting methods. The Fish and Game Commission was to monitor the harvesting practices and patrol the areas cut by each company, although legal enforcement authority was lacking. In case of disputes, representatives of Scripps Institution of Oceanography and the Fish and Game Commission were to sit as arbiters. The final lengthy bill presented to the 1917 session of the California Legislature contained essentially the same points as had been in the draft worked out at the 1916 meeting. This bill was passed and became a law, effective July 26, 1917.

The 1917 law provided that aquatic plants in waters of the State were the property of the State. The Board of Fish and Game Commissioners was empowered to carry out the provisions of the act and to make and enforce rules and regulations for harvesting kelp, to issue licenses, and to collect fees. A license was required to take aquatic plants for profit. The license fee was \$10 per year and a $1\frac{1}{2}$-cents-per-wet-ton privilege tax was charged for kelp harvested. Provision was made for weighing the take, keeping records (open to inspection), and reporting monthly the weights and tax due. If any fish resource or kelp bed was injured or the food of game fish impaired, the commission could close the bed to cutting for a period not to exceed one year. If there was a violation of law or regulations the license could be cancelled. There was provision for hearings, witnesses, court orders, subpoenas, etc. After the revocation of a license, the Fish and Game Commission could withhold issuance of a new license for a period not to exceed one year. There was a penalty for harvesting without a license.

A patrol boat was needed in Southern California, both to enforce the new kelp regulations and to curtail the poor harvesting methods employed by some of the small companies. This need was the chief reason for building the Fish and Game patrol boat, ALBACORE I, which was placed in service January 1918, in spite of the difficulties of construction during wartime.

The 1917 law further provided that all fines and license fees and two-thirds of the privilege tax money be paid into the Fish and Game Preservation Fund. One-third of the privilege tax money went to the State University Fund for use by Scripps Institution of Oceanography for biological research. This allotment amounted to one-half cent per ton for continuing kelp studies.

The gentleman's agreement regarding leasing of beds worked smoothly for five years or until 1921 when the State Legislature added a leasing law to the act of 1917. This authorized the Fish and Game Commission to lease the exclusive privilege to harvest designated kelp beds, not exceeding 25 square miles in area, to any one lessee. It was required that a formal application for a lease be made and advertized with a call for bids. The application fee was refunded if the bid was not accepted. Leases were not to exceed two years duration. Notice of the lease was to be filed with the county recorder. The annual fee for the lease was the amount bid in the application. Leasing fees were to be paid into the Fish and Game Preservation Fund.

There was no essential change in the kelp laws until 1931 when the Legislature amended the Leasing Act of 1921. The amended act provided a 3-cent-per-ton tax on kelp from a leased bed and a minimum payment of $40 per square mile leased, this to be a credit to the lessee from which payments of tonnage tax would be deducted. An interesting clause of the 1931 Leasing Law provided that the applicant for a lease should show he "intends actually to harvest kelp" from the bed leased and "that such kelp be put to a beneficial use." Subleasing was prohibited. The lease period was not to exceed 15 years. It was provided that all moneys from leasing should be paid into the Fish and Game Preservation Fund. This meant that Scripps Institution of Oceanography could receive a one-third share of the privilege tax only from open or unleased beds. Because many beds were then under lease, the amount of money credited to Scripps was greatly reduced.

Prior to 1933, fish and game laws were scattered chapters of the Penal Code but beginning in 1933 they were assembled into a separate set of laws known as the Fish and Game Code. Many of the Penal Code sections were amended at this time. Some sections of the kelp laws were reworded and excessive legal phrasing reduced. The acts covering kelp harvesting (1917) and leasing (1921) were combined as Sections 580 through 596 of the Fish and Game Code. The revised kelp laws under the new code became effective on August 21, 1933. The essential provisions of former laws were retained. A further revision of the Fish and Game Code in 1957 resulted in renumbering Sections 580 through 596 to read 6650 through 6706.

By the 1933 revision a harvesting license was required. The Commission was authorized to close beds if it felt they were being impaired and hearings were provided for. Licenses could be revoked for violation of regulations. The privilege tax of $1\frac{1}{2}$ cents per wet ton on kelp from unleased or open beds still applied, but the allotment of one-third of the funds from these beds to Scripps Institution of Oceanography was dropped. Fifteen-year leases were retained as formerly. There was a 3-cent-per-ton tax on kelp from leased beds and $40 per square mile payment for leasing.

In 1941 the Legislature raised the privilege tax on kelp harvested from open beds to 5 cents per wet ton. The 3-cent tax on kelp from leased beds remained unchanged. Section 589.1 of the 1941 Code added the wording: "The Commission may make such rules and regulations as may be necessary to insure the proper harvesting of kelp and other aquatic plants." In 1945, Code Section 587 provided for revoking a license for certain violations of the kelp laws or regulations. The provisions of these last two sections form the legal basis for the rules adopted by the Fish and Game Commission, commonly referred to as "Title 14" of the California Administrative Code.

Title 14 regulations are in addition to specific legislative acts. Section 589.1 of the Fish and Game Code (new Section 6653) gives the Commission authority to make rules and regulations to insure proper harvesting of kelp and other aquatic plants and Section 587 (now 6656) gives the Commission additional authority to revoke licenses. The regulations adopted by the Commission have the legal authority of laws passed by the State Legislature. Title 14 regulations for 1956 governed harvesting to prevent escapement of cut, drift, or loose kelp and to insure complete utilization of all cut seaweed. They provided for efficient harvesting to prevent deterioration of the beds and allow no cutting deeper than four feet under the water surface.

On December 1, 1950, the Fish and Game Commission adopted a formal policy on kelp harvesting and the leasing of beds. Some of this policy had been stated in code sections and in Title 14, but there were several new items. One-third of the kelp beds were to remain unleased (open) "to avoid any form of monopoly." Beds were to be leased "by negotiation rather than competitive bidding to insure harvesting by responsible firms." Further, it was stated that "revenue is not the object of the fees charged." The term of the lease was set at 15 years and no cutting was to be permitted deeper than four feet below the water surface.

At the call of the then Bureau of Marine Fisheries, meetings were held with harvesting firms in the summer of 1950 to explain policy and to work out terms of future leases. The kelp companies proposed that fees charged them be increased to aid administrative costs and research by the Fish and Game Commission. The proposal was accepted and the tax on kelp from leased beds was doubled to 10 cents per wet ton and the annual fee for leasing beds was raised from $40 to $100 per square mile. New 15-year leases were issued on this basis in the early spring of 1951.

The above account of detailed laws might suggest that a series of court battles had been necessary in administrating the kelp regulations. Quite the contrary, there has been very little court action. There has been no necessity to use the several pages of law in the code book. The harvesting firms, because of enlightened self interest, wish to protect and perpetuate the beds. They do more than co-operate, they meet the law enforcement agencies more than half way. This attitude was evident not only in the gentleman's agreement of 1916 and the 1950 offer to increase fees and taxes, but also in formulating protective regulations and in adjusting difficulties, whether large or small.

In addition to the laws enacted by the State Legislature there were, at many legislative sessions, bills introduced to curtail or prohibit the harvesting of kelp in the State. Such bills were never approved by the Legislature, but they have been a recurring threat to the kelp industry and to the utilization of a valuable natural resource of the State. Most of the objections to kelp harvesting rested upon one or more of five assumptions:

1. Harvesting injured or ruined the beds.
2. Sport fishing in or near harvested beds was seriously impaired.
3. Drifting kelp litter (escapement from harvesting) entangled sport fishing gear when casting from the beach.
4. Kelp litter on the beach (due to harvesting) was detrimental to bathing.
5. Beach erosion increased with the cutting of beds.

The assumptions lacked factual backing.

KELP RESEARCH

The kelp beds of Southern California have been under close observation for the past 49 years (starting in 1910). During this time there have been numerous studies conducted by representatives of two state and two federal agencies. In addition, several private investigators have been assigned kelp studies. Few of our resources have been submitted to such close study over such a long period of years. This is remarkable when we realize that these studies have resulted in similar or identical conclusions reached by the many investigators through the years. Most of the phases of the subject have been studied repeatedly. The beds themselves were examined to learn their relationships to their surroundings (ecology), their diseases and enemies. The life history of the plants was studied, including rate of growth and replacement after harvesting. Studies have covered methods of mowing, escapement, beach litter, erosion of beaches, and most important, the relationship of harvesting to fishing.

In addition, there have been almost continuous investigations of the products that might be recovered from kelp. These investigations have been for the purpose of enlarging the market for kelp products. In the early days, the work was promoted by the Federal Government as well as by harvesting companies, but since about 1926 it has been chiefly in the hands of two processing firms. These industrial studies usually are not included in an account of kelp investigations. Also omitted are the botanist's work of determining relationships of the plants and classification of the species.

Two phases of the subject have not been fully covered. It long has been known that there are variations in the abundance of surface kelp at different times of the year. This is largely the result of storms and water temperatures. It was noted as early as 1912, that certain beds diminished for a period of a few years while other beds were not affected. This seemed to have little or no relationship to harvesting. The disappearance of portions of beds has not been explained, except that winter storms may occasionally uproot plants by pulling up holdfasts. In some cases a bacterial disease "black rot" has contributed to the retarding of surface growth, but this is usually for short periods of time. The possible effect of water pollution on density of kelp beds is the other subject not yet fully covered by investigations.

In 1902 Mr. David Balch made determinations of the chemical composition of the more important West Coast kelps, including the giant kelp of Southern California, the bull kelp of central California and the large northern kelp (genus *Alaria*). This knowledge was of great value a few years later when developing a new source of potash became a necessity.

In 1910, under the supervision of the U. S. Bureau of Soils, preliminary examinations of the kelp beds and laboratory chemical analyses were made. During the three years 1911 to 1913 a systematic survey was made of all the beds from the Gulf of California to the coast of Alaska. The beds were mapped by agents of the Bureau of Soils, densities were determined and observations made as to life history, growth habits and relationship of beds to their surroundings. Harvesting methods and processing techniques were included in these surveys.

With the entrance of the Hercules Powder Co. into the field of kelp processing in 1915 there began a period of privately financed research. It was directed chiefly toward the recovery of chemical products and methods of gathering seaweed.

Also during 1915 observations were made of kelp harvesting and its relation to fisheries, by officers of the California Fish and Game Commission and agents of the U. S. Bureau of Fisheries.

At a fisheries conference in San Diego in August, 1916, a committee was appointed to encourage the continuance of kelp studies by the four agencies then active: The California Fish and Game Commission, Scripps Institution of Oceanography, the U. S. Bureau of Fisheries, and the U. S. Bureau of Soils. The following month the four agencies met with representatives of the kelp processing companies to draft legislative proposals for kelp management. It was agreed that until proper legislation could be passed regulation of the industry should be in the hands of the California Fish and Game Commission. The Kelp Act of 1917 that resulted from these meetings provided that one-third of the revenue from privilege taxes on harvested kelp would go to Scripps Institution of Oceanography to finance the continuance of kelp studies already started by that organization. This one-third allotment of funds was in effect for only 16 years, but kelp research at Scripps has been conducted almost continuously since about 1910, a period of almost half a century. Of special interest was a co-operative study in 1917 and 1918 that was carried out at Scripps by the U. S. Bureau of Fisheries and staff members of Scripps Institution to determine whether or not kelp harvesting affected the fisheries of Southern California.

The U. S. Department of Agriculture, Bureau of Soils, built at Summerland a commercial scale kelp processing plant and research laboratory under the direction of Dr. J. W. Turrentine. It operated with congressional appropriations. The chief object was to develop kelp byproducts, in addition to potash. Several products were extracted including iodine, but most important it perfected methods of recovering acetone. The Summerland plant was active from August, 1917 to May, 1921. It was about the only firm that continued operating through 1920. It used two harvesting barges and made valuable contributions to better harvesting practices.

The period 1920 through 1925 was almost a blank in the harvesting of kelp and there was a corresponding low ebb in kelp research. After 1926 studies were made by kelp companies to develop sales of their products. One such project, a co-operative study, was carried out at Scripps Institution of Oceanography, supervised by the U. S. Bureau of Fisheries, and financed by the Kelco Co. of San Diego. It started on July 1, 1931 and was directed by Dr. H. P. Morris. Extensive experi-

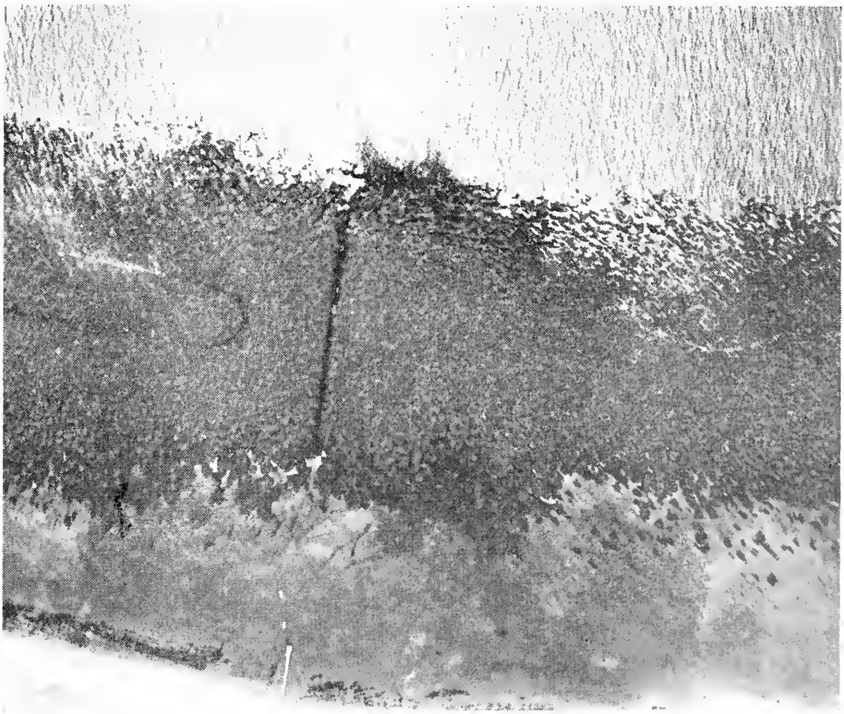


FIGURE 6. Aerial photograph from 7,200-foot elevation of heavy kelp bed off Gaviota pier. The loop (left center of the bed) is the track left by a harvester barge. The dark vertical line is a boat channel through the kelp from the pier. The dark fringe of seaweed close to shore consists of species other than giant kelp. Photograph by Al Reese, May, 1955.

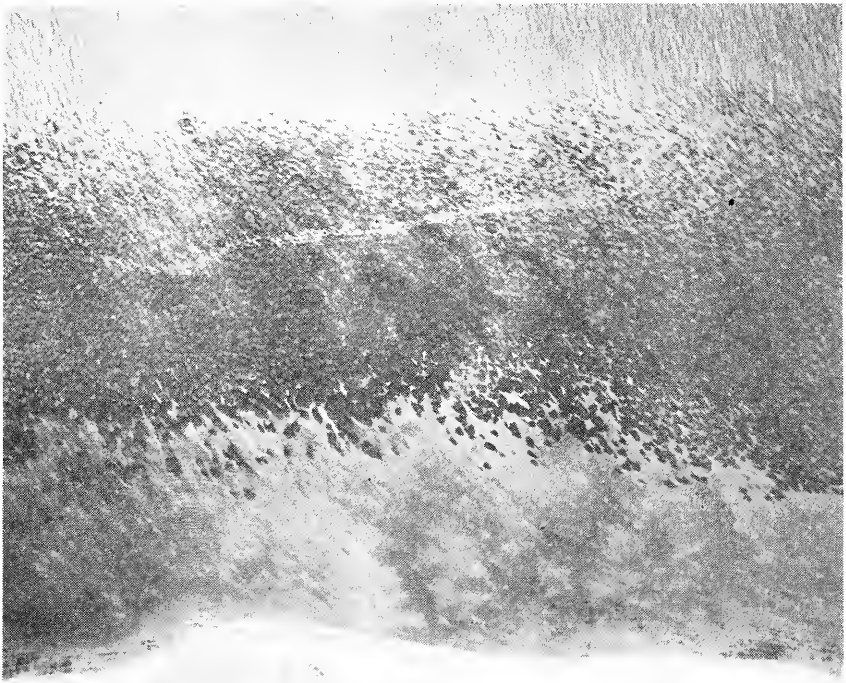


FIGURE 7. Aerial photograph of kelp west of Gaviota pier showing track of a harvester barge through a portion of the bed. Photograph by Al Reese, 1955.

ments in animal feeding were then being conducted by the Philip R. Park Co. at San Pedro.

In October, 1931, the California Fish and Game Commission conducted a survey of several Southern California beds. The patrol boat Bluefin (Captain Walter Engelke) was used for the fieldwork. A similar, but more intensive survey off the Orange County coast was made in August, 1949, by patrol boat under Captain Lars Weseth, assisted by Walter Engelke (retired) and staff members of the State Fisheries Laboratory. This survey had special reference to the sport fisheries of the area.

In the early 1940's Dr. Claude E. Zobell of Scripps Institution carried out kelp observations, contrasting mainland kelp beds with those around the offshore islands. He also made a six-year study of beach litter and shore erosion. In the period 1944 to 1947, Mr. C. K. Tseng worked on kelp problems at Scripps and a half-dozen publications resulted.

The most complete study of the kelp beds was conducted by Mr. Conrad Limbaugh of Scripps Institution of Oceanography from September, 1948 to March, 1954. The results of this five and one-half year study were published in a 158 page report dated September, 1955. It covered life history studies, effects of harvesting, and the fish life of the kelp beds. After the first year, the survey was financed by a fellowship grant to the University of California from the Kelco Co. of San Diego.

Soon after the completion of this study, and mainly because of recurring complaints of the alleged effects of harvesting on fishing, the Fish and Game Commission ordered the appointment of a committee with membership made up of the different factions interested in kelp and fishing. This body would summarize evidence and make recommendations as to whether or not there should be changes in the policy for kelp harvesting. The Kelp Study Committee was organized in 1955 but it was soon evident that additional research would be needed to supply the answers to several questions. In 1956, a service agreement was entered into by the Department of Fish and Game and the University of California (Institute of Marine Resources), which was to conduct the research on the effects of harvesting, the reasons for changes in abundance and ways to improve the kelp beds.

In the meantime, during the summer of 1955 and again in 1956, personnel of the State Department of Fish and Game conducted a survey of the kelp beds by means of aerial photography from Point Arguello to the Mexican boundary.

In late 1957 the State Water Pollution Control Board entered into a service agreement with the University's Institute of Marine Resources for an investigation of the effects of pollution on kelp. This program is co-ordinated closely with a companion investigation for the Department of Fish and Game.

The two investigations by the Institute should solve the remaining questions pertinent to the kelp problem.

USES OF KELP

The uses to which kelp may be put have only a minor place in a history of kelp harvesting, but the question is so frequently asked that a brief note on the subject is added here. In World War I potash, acetone, and iodine were the chief products recovered from kelp. These chemicals from California kelp played little part in World War II. At present, two products are important, kelp meal as stock food and algin. The uses of algin would make a very long list that would bewilder a layman. A few of the more than 100 products of which algins are an important component are pharmaceuticals, dairy products, soda fountain drinks, cosmetics, salad dressings, candies, jellies, natural and synthetic rubber, textiles, paper products, insulator board, paints, sizing for printing on cloth and cardboard, boiler compounds, and adhesives. For those of us who had high school chemistry some years ago, the present day manipulation of colloids is certainly confusing.

REFERENCES

Bauder, C. S.
1920. Agar-agar to be manufactured in Southern California. Calif. Fish and Game, vol. 6, no. 1, pp. 31-32.

Bonnot, Paul
1931. California seaweeds. Calif. Fish and Game, vol. 17, no. 1, pp. 40-44.

Brandt, R. P., and J. W. Turrentine
1923. Potash from kelp: early development and growth of the giant kelp, *Macrocystis pyrifera*. U. S. Dept. Agric., Bull., no. 1191, 40 pp.

Burd, John S.
1915. The economic value of Pacific coast kelps. Univ. Calif., Agric. Exper. Sta., Bull. no. 248, pp. 183-215.

California Fish and Game
1918. Kelp and potash manufacture. Calif. Fish and Game, vol. 4, no. 3, pp. 149-150.
1919. Tide conditions injure fisheries. Calif. Fish and Game, vol. 5, no. 1, pp. 39-40.

Cameron, Frank K.
1915. Potash from kelp. U. S. Dept. Agric., Rept. no. 100, 122 pp., 40 plates.

Chapman, V. J.
1945. The kelp trade. Nature, vol. 155, no. 3944, pp. 673-674.
1950. Seaweeds and their uses. London, Methuen and Co., Ltd., 287 pp.

Collings, Gilbeart H.
1941. Commercial fertilizers, their sources and use. New York, McGraw-Hill. 617 pp.

Crandall, W. C.
1912. The kelps of the Southern California coast. *In* Fertilizer resources of the U. S. U. S. Senate Doc., 190, app. N, pp. 209-213.
1915. The kelp beds from Lower California to Puget Sound. *In* Potash from kelp. U. S. Dept. Agric., Rept. no. 100, pp. 33-49.
1918. A review of the kelp industry. Calif. Fish and Game, vol. 4, no. 3, pp. 105-107.

Johnson, Carl
1948. Kelp cutting. Bullets and Hooks, vol. 4, no. 12, pp. 18-19, Mar.-Apr.

Limbaugh, Conrad
1955. Fish life in the kelp beds and the effect of kelp harvesting. Univ. Calif., Inst. Mar. Res., IMR Ref. 55-9, 158 pp.

Norton, Thomas H.
1915. Potash production in California and potash from kelp. U. S. Dept. Comm., Reprint from Comm. Repts., June 12 and 19, 13 pp.

Pacific Fisherman
1916. Building kelp plants in Southern California. Pac. Fisher., vol. 14, no. 4, p. 14, April.

Phillips, Julius B.
1932. Giant kelp utilized at Monterey. Calif. Fish and Game, vol. 18, no. 1, pp. 43-46.

Porteous, Edward
1918. The growth of kelp. Calif. Fish and Game, vol. 4, no. 3, pp. 108-112.

Rigg, George B.
1942. Plant resources of the sea along the northwest coast and Alaska. Calif. Fish and Game, vol. 28, no. 4, pp. 206-209.

Scofield, N. B.
1916. Kelp. *In* Calif. Fish and Game Comm., Twenty-fourth Biennial Rept. for the years 1914-1916. Sacramento, State Print. Off., pp. 94-96.
Will cutting kelp injure the fisheries? Calif. Fish and Game, vol. 2, no. 3, pp. 129-131.
1918. Kelp. *In* Calif. Fish and Game Comm., Twenty-fifth Biennial Rept. for the years 1916-1918. Sacramento, State Print. Off., p. 59.
1921. Kelp potash industry. *In* Calif. Fish and Game Comm., Twenty-sixth Biennial Rept. for the years 1918-1920. Sacramento, State Print. Off., p. 75.

Scofield, W. L.
1935. The harvesting of kelp in California. Calif. Fish and Game, vol. 21, no. 1, pp. 61-64.

Standard Oil Bulletin
1918. California's kelp industry. Standard Oil Bull., pp. 3-7, 16, December.

Tressler, Donald K., and James McW. Lemon
1951. The brown algae—algin from kelp and fucoids. *In* marine products of commerce. Rev. ed. New York. Reinhold Pub. Corp., pp. 94-106.

Tseng, Cheng Kwei
1944. Utilization of seaweeds. Scripps Inst. Oceanog., Contrib., n. s., no. 229, 10 pp. (Reprinted from Sci. Mon., vol. 59, pp. 37-46, July.)
1945. Colloids from kelp. *Ibid* no. 256, 4 pp. (Reprinted from Chem. and Metal Eng., June.)
1946a. Seaweed colloids in the textile industries. *Ibid* no. 273, 4 pp. (Reprinted from Textile Age, June.)
1946b. Seaweed products and their uses in America. *Ibid* no. 276, 39 pp. (Reprinted from N. Y. Bot. Gard., Jour., vol. 47, nos. 553-554, Jan. and Feb.)
1947a. Algin. *Ibid* no. 351, 11 pp. (Reprinted from Encyclopedia Chem. Eng., vol. 1, pp. 343-353.)
1947b. Seaweed resources of North America and their utilization. *Ibid* no. 311, 29 pp. (Reprinted from Econ. Bot., vol. 1, no. 1, pp. 69-97, Jan.-Mar.)

Turrentine, J. W.
1915. Utilization of Pacific kelp. Pac. Fisher., vol. 13, no. 6, pp. 13-14, June.
1919. Potash from kelp: the experimental plant of the United States Department of Agriculture. Preliminary paper. Jour. Ind. Eng. Chem., vol. 11, no. 9, pp. 864-874.
1926. Potash, a review, estimate and forecast. New York, John Wiley and Sons, Inc., 188 pp.

Wohnus, J. Frederick
1942a. The development of the sporophyte of *Macrocystis pyrifera*. Scripps Inst. Oceanog., Contrib., n. s., no. 177, 3 pp. (Reprinted from Turtox News, vol. 20, no. 10, Oct.)
1942b. The kelp resources of Southern California. Calif. Fish and Game, vol. 28, no. 4, pp. 199-205.

Zobell, Claude E.
1941. Kelp cutting. Calif. Conserv., vol. 6, no. 7, pp. 2-4.

A REVISED CHECK LIST OF THE FRESHWATER AND ANADROMOUS FISHES OF CALIFORNIA[1]

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INTRODUCTION

The California freshwater and anadromous fish fauna is not a stable entity. Since the appearance of the first edition of this list (Shapovalov and Dill, 1950), the nomenclatural status of certain of the fishes has been drastically revised. Many of the revisions are minor and relatively insignificant, while others are comprehensive and have contributed to a better understanding of the relationships among the various taxonomic categories.

Revised lists frequently follow reversals of major trends in fish taxonomy. In this connection, Legendre (1954) says, "For the interest of the systematics-minded, some remarks on the classification of our fishes have perhaps a place here; for legitimate surprise may be aroused by some changes of nomenclature. We may mention immediately that the present trend is towards condensation, simplification and uniformization of group names, this being the opposite of the tendency to ever greater diversification which prevailed in the first quarter of this century."

New additions to the list include several forage and game species imported by the California Department of Fish and Game as one phase of its research-management program, plus additional euryhaline species collected in fresh waters. The bait minnow industry along the lower Colorado River is the source of many species listed in the supplementary list as of "uncertain occurrence".

The total revisions, spanning nine years, were of sufficient importance and number to invalidate the original list and require this new edition. Continued introductions, collections, and taxonomic studies may require further revisions every 5 to 10 years.

ACKNOWLEDGMENTS

Semifinal drafts of the manuscript were sent to Reeve M. Bailey, W. I. Follett, Carl L. Hubbs, Robert R. Miller, and Boyd W. Walker. In addition, Shapovalov discussed a number of the controversial points with Drs. Bailey and Follett. We are most appreciative of the criticisms of all these men and have incorporated many of their suggestions in the final list. However, we have not been able to reconcile all differences

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[1] Submitted for publication April, 1959.
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of opinion, so it should not be considered that they are in full agreement with all names listed.

PURPOSE

The major objective in publishing this list remains identical with that stated for the original: To present an accurate list of the known fishes as the first step in the compilation of a detailed handbook of the freshwater and anadromous fishes of California. As predicted by the authors at the time, the compilation of this work has not been an easy task. Much information has accumulated in recent years on the life histories of important game fishes; a key to species level has been completed in preliminary form (Kimsey and Fisk, 1958); a series of excellent black-and-white photographs of the more common species has been taken. However, there has been no opportunity to put forth the concerted effort necessary to bring together and integrate the material. It is hoped that renewed effort and progess will be stimulated and promoted through publication of this up-to-date list.

A second purpose, perhaps equally important, is the promotion of stability and uniformity in the common and scientific names of freshwater fishes. A recent and accurate list should be available for use by both professional workers and laymen to prevent the appearance of obsolete and incorrect names in the literature, records, and correspondence. The only major list of California freshwater fishes published prior to the first edition of this list was by Evermann and Clark (1931), and it has long been obsolete.

Authors proposing to publish local, state, or nation-wide lists can materially advance stability in fish nomenclature by attempting to resolve differences through consultation with the various experts in the field who have authored existing lists. We have consistently done this, have invariably met with co-operation, and thereby have resolved most problems.

SCIENTIFIC NAMES

In scientific naming, stability is largely dependent upon the thoroughness and care of the taxonomist. Any proposed revisions must be carefully evaluated. For example, Schultz (1957, pp. 48-49) has stated:

"The evaluation of generic characters and recognition of genera is possible only when a comprehensive study is made of a family on a world-wide basis and when there is established the nature of the similarities and differences among groups of species. . . .

"The problem of how far to progress nomenclatorially in recognizing generic categories must be resolved in a practical manner so that biologists are not presented with a confusion of ill-defined genera. Usually this confusion and lack of agreement among ichthyologists and fishery biologists results from inadequate studies of a family. Obviously, no dependable solution is possible on how many genera and subgenera to recognize in a family until the zoological relationships of all its species have been adequately compared morphologically, physiologically, and as to habits. No doubt, after this work has been done, a middle of the road or even a conservative attitude on the number of phyletic lines to name would meet with general acceptance. Too often in ichthyology there is a tendency either to unite genera without adequate study or to establish new genera without any attempt to review the family. The least confusion results if the present status of each genus in a family is retained until such time as it is thoroughly studied.''

We are in accord with this opinion but believe that the ideas expressed are applicable to species and subspecies as well. Subspecies in particular are subject to much lumping and partitioning, at times without secure evidence. Some ichthyologists have seriously questioned the existence of certain forms on our list while, on the other hand, they have proposed hitherto unknown forms for inclusion. In every case, we have let the decision hinge on the appearance of substantiating data in the literature. The publication of new scientific names and elimination of familiar ones without sufficient supporting evidence accomplishes little and furthers confusion in fish nomenclature.

Bailey (1956, pp. 328-329) has given considerable thought to the problem of subspecies: ''. . . . the common taxonomic practice of dividing geographically variable species into named races, or subspecies, has been subjected to critical scrutiny. It has been noted that the pattern of geographic variation in some species takes the form of a rather gradual and progressive gradient, termed a cline. It is now agreed by many taxonomists that despite the high biological significance of this type of variation, it is undesirable to assign subspecific names on the basis of clinal gradients. . . .

''Commonly the differences between geographic subspecies are slight and are best expressed as average conditions applying to a considerable fraction of individuals, but not to all. It is my revised opinion that acceptable subspecies should evidence high uniformity over the respective ranges and should differ one from another with high constancy. Zones of intergradation should be rather narrow. If they are wide the variation merges insensibly into a clinal gradient. . . .

''The ichthyologist, in studying material, often perceives differences among populations from various parts of the geographic range of a species. Such discoveries may presage the definition of validly recognizable subspecies. The premature use of such information without publication of the full data is disconcerting to other workers, who are unable to evaluate the basis for the action. The different stocks sometimes turn out to be fully distinct species. . . .''

Another excellent discussion of the subject which supplements the above statements was presented by Bailey, Winn, and Smith (1954, pp. 148-150). The following excerpt seems particularly pertinent:

''Many clinal variations in the morphology of fishes may be caused partly or wholly by gradients of environmental factors, especially temperature. The assumption that all taxonomic characters, such as meristic counts, are governed solely by genetic factors is no longer tenable. . . . Whether the gradient is caused by heredity or the environment, we reject the practice of establishing subspecies on characters that show clinal variation. Furthermore, the insistence that a cline be a perfectly smooth gradient, we regard only as an academic problem. Minor irregularities are to be anticipated because of local genetic emphasis, sampling errors, environmental variations that impose structural change, and other vagaries.''

We concur in the statements above and in keeping with them have employed binomials instead of trinomials wherever sufficient published evidence exists to show that a cline truly exists. This has been done for *Notemigonus crysoleucas* (Bailey, Winn, and Smith, 1954, pp. 123-124, 149; Hart, 1952, pp. 33-38, 77); and *Ictalurus punctatus* (Bailey, Winn, and Smith, 1954, p. 130, 1954). Subspecific partitioning of many species in the main list is probably of questionable validity; however, we retain the status quo and await the publication of evidence showing whether or not the trinomials are justified.

Space does not permit a description of each change in scientific names used in bringing this list up to date. Most of the major changes are discussed in appropriate text sections that follow. Recourse to the references will provide further details. Several of the minor revisions follow decisions made by the International Commission on Zoological Nomenclature. Some of the more important references include Bailey (1956), Bailey, Winn, and Smith (1954), Hart (1952), La Rivers and Trelease (1952), Legendre (1954), Lindsey (1956b), Miller (1950a), Robins and Miller (1957), Schultz (1957), Taylor (1954), and Walters (1955).

COMMON NAMES

Stability in common naming can best be achieved by adhering as closely as possible to a workable set of criteria, as outlined below.

The selection of common names for California freshwater fishes is complicated by two somewhat paradoxical factors: the multiplicity of names which have already been applied to certain species, and—in the case of certain other forms—the dearth of common names. Thus, members of the genus *Cyprinodon* have been called by such varied names as desert minnow, desert killifish, pursy minnow, pygmy fish, and pupfish. Conversely, a large number of native cyprinids are so similar and indistinctive in appearance that the layman has never recognized their specific differences nor called them by any name other than the rather general chub or shiner. This list attempts to reconcile such difficulties by assigning one official common name to each species and subspecies.

The basic rules or criteria for the selection of common names remain identical with those presented in the original list. The principles again have proven of practical value in the objective establishment of the revised common names. Such guides are necessary to prevent arbitrary selection based on personal preference. Insofar as possible, we have adhered to them, as follows:

(1) Names should agree with those in actual common use; or—when there is no common or vernacular use—with those in published literature. Strictly "book names" should be avoided.

(2) Names should agree with those on other authoritative lists, especially those of the American Fisheries Society (1948), the Outdoor Writers Association of America (1958), and Roedel (1953b).

(3) Names should indicate relationship and not confuse it.

(4) Names should be descriptive.

(5) Preference should be given to names which are short, distinctive, interesting, catchy, romantic, or euphonious.

Each of these qualifications has exceptions which makes it useless by itself. Therefore, each principle listed above should be read as though it were prefaced by the words, "Other considerations being equal

* * *" For example, the name Sacramento perch does not meet either Rule 3 or 4 above, since this species (*Archoplites interruptus*) is not a true perch. However, since it is so commonly used (Rule 1) and since it agrees fully with the name used in the two primary references cited in Rule 2, it would be foolish to select another name.

Aside from such considerations, in this revision we have attempted continued advancement of the twin ideals of stability for individual names and the designation of relationships through the selection of common names according to a definite plan. Such aims have long been recognized by ornithologists and are well exemplified by the names listed in "The Distribution of the Birds of California" (Grinnell and Miller, 1944). Thus, wherever possible the same basic common name has been given to all members of a single genus, with prefixes added to that common name for each full species of that genus. In the case of subspecies, additional prefixes have been added to the specific name. For example, all members of the genus *Siphateles* have been termed chub; members of the *Siphateles bicolor* group have been termed tui chub; and each subspecies of the group is further designated by an additional term such as Sacramento for *S. b. formosus*, the Sacramento tui chub.

It should be noted that this method will permit the retention of at least part of the common name even if the species or subspecies undergoes a revision which will change the scientific name. For example, based on studies by Miller (1950a), the San Gorgonio rainbow trout (*Salmo gairdnerii evermanni*) was transferred to the cutthroat trout series to become the San Gorgonio cutthroat trout (*Salmo clarkii evermanni*). This, in part, answers the criticism of the Committe on Names of Fishes of the American Fisheries Society (Bailey, 1955), "The practice of applying one name to each genus, a modifying name for each species, and still another modifier for each subspecies, while appealing in its simplicity, has the defect of inflexibility." Further, "If a fish is transferred from genus to genus, or shifted from species to subspecies or vice versa, the common name should nevertheless remain unaffected. It is not a primary function of common names to indicate relationship."

We contend that to reveal, rather than confuse, relationships should be an important and vital function of common names. Some of the most deeply-rooted vernaculars are completely misleading—little can be done now to establish meaningful names. When a name is entered in an official list it should not be changed unless there are important reasons for it. However, changing the name to maintain the proper relationship of a form known to professional fisheries people but unfamiliar to laymen does not present a serious problem and to us is justifiable. In any event, preparation of this present revision showed that the system was workable and had meaning, with no major difficulties encountered.

The authors are inclined to share the opinion of Bailey (*op. cit.*) and Alden H. Miller (Grinnell and Miller, 1944) that only full species deserve common names. Nevertheless, we have listed common names for each subspecies, with full recognition that a number of them may not endure. One reason prompting this decision is that certain subspecies have been distinguished as entities almost from the beginning, and it would seem unfortunate to obscure (through omission) such names as kokanee and Piute.

It should also be noted that a number of systematists have disagreed with certain of our groupings; e.g., that for the native trouts, in which assignment to specific or subspecific status is, in some instances, original with the authors. However, a firm nomenclature has never been developed for some of these plastic groups. And—as we have stated before—even after some decided changes in scientific nomenclature, most of our common names can still be retained with enough recognizable parts to promote stability.

In accordance with the criteria for the selection of common names promulgated by the Committee on Names of Fishes (Bailey, *op. cit.*) we have deleted capitalization of common names in text use except for those elements that are proper nouns.

SCOPE

The main list covers both native and successfully established exotic species. The supplementary list includes exotic species unsuccessfully introduced or of uncertain occurrence.

We have attempted to include all native forms whose occurrence has been reported in the literature or verified through the examination of collections. The existence of some of these as valid species or subspecies (*Catostomus occidentalis lacusanserinus,* for example) has been questioned by some workers. Our criterion for inclusion of such forms is very simple: We have tried to include all forms whose taxonomic identity has not yet been disproved in *published* literature.

Possibly certain other records of occurrence (such as that for *Rhinichthys osculus carringtonii*) are based on misidentification. Possibly some of the native species are no longer a part of our fauna. Native forms which are now either extinct or extremely rare include *Salmo clarkii evermanni*, *Salmo gairdnerii regalis*, *Catostomus latipinnis*, *Ptychocheilus lucius*, *Gila crassicauda*, and *Plagopterus argentissimus*. The inclusion of *Plagopterus*, for example, rests upon a single collection made in 1890. However, it is practically impossible to prove or disprove such suppositions. Hence, in the case of the native species it has been thought best to err on the side of inclusiveness rather than on the side of exclusion. On the other hand, only those exotic or introduced species of which breeding populations are known to have survived are included in our main list.

Fishes recorded only from outside California have not been included even if the stream in question flows into or out of this State, e.g., the Klamath and Truckee rivers. However, in the case of the Colorado River, which is a boundary stream, fishes recorded from the Arizona side of the stream, and even from the mouth of its tributary, the Gila River, have been included.

Hybrids have also been omitted. Both interspecific and intergeneric hybrids of a number of the species listed have been recorded from the natural waters of California (e.g., Hubbs and Miller, 1943). One hybrid game fish has been introduced on an experimental scale to determine its potential in high lake management. This is the splake, an eastern brook trout x lake trout hybrid (*Salvelinus fontinalis* x *Salvelinus namaycush*). It has been planted in waters of the Lakes Basin Recreational Area, Sierra County, as part of the Trout Management Study, Dingell-Johnson Project F-8-R. The first plant was made in the summer of 1955. Additional plants have been made but a final evaluation of the hybrid's success and role in the trout program has not been completed.

Fishes Successfully Introduced Into the Salton Sea

Most of the fishes in the check list are strictly freshwater or anadromous. For the sake of completeness we have also listed those marine and brackish water species which are known to penetrate into fresh water. However, strictly marine species from the Gulf of California which have been introduced into and have successfully spawned in the Salton Sea, an inland body of water with salinity approaching that of ocean water, are omitted from the main list. They are included below, since they have established breeding populations in an inland body of water. Information about them was supplied by Dr. Boyd W. Walker (letter of February 8, 1957), former director of the University of California Salton Sea research program financed with Wildlife Conservation Board funds. Further information is contained in an article which traces the history of the introductions (Anon., 1958).

Three species presented in the main list are also firmly established in the sea—*Cyprinodon macularius*, *Gambusia affinis affinis*, and *Gillichthys mirabilis*. *Dorosoma petenense* is present in the sea in large numbers but there is no indication of successful spawning. *Mugil cephalus* was formerly present in large numbers, but is now scarce and is disappearing due to lack of recruitment. The fish used to reach the sea through irrigation laterals but can no longer do so because of new dams and headgates.

HAEMULIDAE—grunt family

Anisotremus davidsonii (Steindachner)—sargo

Introduced in 1951. The first sargo known to have been spawned in the sea, a juvenile young-of-the-year, was taken in October, 1956. The first verified catch of an adult was made on September 17, 1958. Since then sargo up to 12 inches in length have been taken by sport fishermen in considerable numbers.

SCIAENIDAE—croaker family

Bairdiella icistius (Jordan and Gilbert)—gulf croaker

First introduced in October, 1950. The population of gulf croakers is now very large. They are firmly established and should remain until the salinity of the sea becomes too high to support fish life.

Cynoscion parvipinnis (Ayres)—shortfin corvina

First introduced in October, 1950. Shortfin corvina are now present in small numbers, but are definitely reproducing in the sea. They may be swamped out by *C. xanthulus*.

Cynoscion xanthulus (Jordan and Gilbert)—orangemouth corvina

First introduced in October, 1950. They are now present in large and increasing numbers.

Fishes New to the Main List Since 1950

A total of 11 species[3] and seven subspecies not listed in the 1950 check list has been added to this revised edition. They are repeated here with a brief explanation and documentation as evidence for their inclusion.

Although the California freshwater fish fauna has been studied for many years, some undiscovered species may remain. Coastal fresh waters are the most likely source, where collecting should uncover additional euryhaline forms penetrating into fresh water. There is a good possibility that boundary waters contain forms hitherto unknown to this State. Another possible source of additions to its fish fauna is the bait minnow industry along the lower Colorado River in Arizona, Nevada, and California. Numerous exotic bait minnows are trucked to this area from diverse regions. The establishment of *Notropis lutrensis* in the Colorado River (Hubbs, 1954) is probably due to escapements from minnow farms. Miller (1952) presents a list of the various bait fishes used by the industry in the California portion of the river. These are included in the supplementary list, since there is a possibility that they may become established.

The introduction of exotic game and forage fishes by the California Department of Fish and Game may be expected to provide a continuing source of new species. The fish management programs of the Inland Fisheries Branch, its warmwater phase in particular, includes as part of its long-range planning an evaluation of the various aquatic habitats and what might constitute the most suitable game and/or forage species, either native or exotic. Each potential import is thoroughly studied and screened to insure against detriment to existing fisheries.

Dorosoma petenense (Günther)—threadfin shad

Kimsey (1954) described the original introduction of threadfin shad into California. In a progress report, Kimsey et al. (1957) summarized the history of the project:

"As part of the tri-state program on the Colorado River, Arizona, California, and Nevada agreed in 1953 to introduce the threadfin shad * * * into the Colorado River in an effort to improve a poor forage-fish situation.

"In November, 1953, a broodstock of threadfin shad obtained from the Tennessee River at Watts Bar, Tennessee, was flown to California. These fish were successfully propagated in San Diego County, California, brood ponds in 1954.

"On November 16, 1954, 520 threadfin shad about two inches long were planted in Lake Havasu at Havasu Boat Landing. On March 3, 1955, another plant of 500 fish was made at the same place. These were the only fish planted by the California Department of Fish and Game in the Colorado River."

In a striking example of population eruption, the threadfin shad at the end of 1955 appeared to be in every habitable part of the Colorado River from Davis Dam to the Mexican border and in adjacent irrigation ditches, canals, settling basins, and the Salton Sea.

[3] In addition, one form listed as a subspecies in the 1950 list (*Cottus bairdii beldingii*) has been elevated to full species status as *Cottus beldingii*. The reason for this change is discussed in the section on Forms Removed From the Main List Since 1950.

Salmo gairdnerii kamloops (Jordan)—Kamloops rainbow trout

According to Wales (1950), "The first known introduction of the Kamloops rainbow trout * * * into California waters was made on June 17, 1950. At that time 1,000 fish was liberated in certain tributaries to Shasta Lake, Shasta County * * *" Shasta Lake has received additional plants, as have Castle Lake, Siskiyou County, and other mountain lakes. The large numbers involved, the long-term stocking program, and the widespread distribution justify inclusion of this form in the revised main list.

Deltistes luxatus (Cope)—Lost River sucker

Chasmistes brevirostris Cope—shortnose sucker

Both species were collected recently in Copco Lake, a reservoir on the main stem of the Klamath River in Siskiyou County, by Millard Coots of the California Department of Fish and Game. Known from adjacent waters in Oregon, these two relict catostomids had been suspected of existing in adjoining waters in Siskiyou and Modoc counties, but verified collections had hitherto been lacking. Gilbert (1898) reported *D. luxatus* as apparently resident in the deeper waters of Tule Lake, Siskiyou County.

Notropis lutrensis (Baird and Girard)—red shiner

Hubbs (1954) described the establishment of the red shiner in the Colorado River and connected waters of Arizona, Baja California Norte, and California. He attributes the establishment of this species to escapements from the Arizona Fish Farms near Blythe, and believes the stock came from near Lake Buchanan, Texas. It was first collected from the Colorado River in 1953, and is now well established there.

A brood stock of 368 adults was brought to Central Valleys Hatchery at Elk Grove, Sacramento County, in April, 1954. Some of these reproduced successfully, and 600 were stocked in two private ponds near Lower Lake, Lake County, in 1957.

The extent of the red shiner's establishment outside the Colorado River drainage is not known.

Pimephales promelas Rafinesque—fathead minnow

The first record of the fathead minnow in California is from a bait tank near the Colorado River in 1950.

In 1953, Mr. Frank Butler, a domestic fish breeder of Turlock, imported 40,000 under permit. The Department of Fish and Game purchased 1,000 of these for propagation at Central Valleys Hatchery at Elk Grove, Sacramento County. Propagation was successful, and the resulting fish were distributed to a number of waters, to serve as forage for game species. Insofar as we know, no trout waters have been stocked. Breeding populations are now established in many waters.

Mollienesia latipinna LeSueur—Sailfin molly

In recent years this species has become established in canals and ditches tributary to the Salton Sea, in the vicinity of the Riverside-Imperial County line.

Platichthys stellatus rugosus Girard—southern starry flounder

This subspecies was overlooked in compiling the original check list. Dr. Carl L. Hubbs brought this oversight to our attention.

Percina caprodes (Rafinesque)—log perch

The presence of the log perch in California was first brought to the attention of the California Department of Fish and Game by Mr. Al Musseldine of the U. S. Fish and Wildlife Service, who took several specimens from artificial lakes at Beale Air Force Base early in March, 1958. They were brought into California inadvertently by the U. S. Fish and Wildlife Service with a shipment of largemouth bass, bluegill, and possibly black bullhead sometime in 1953. Three lakes were planted: Miller, Blackwelder, and Polk. All are located in Yuba County on Hutchinson Creek, tributary to Dry Creek and thence the Yuba River.

On March 27, 1958, J. B. Kimsey, George McCammon, and J. B. Richard of the California Department of Fish and Game seined about a dozen log perch from Miller and Blackwelder lakes. They found breeding populations to be present. The creek was not seined, but since both lakes overflow regularly it is quite possible that the species now occurs in other parts of the drainage.

Lepomis microlophus (Günther)—red-ear sunfish

Breeding populations of the red-ear sunfish are now established in many waters scattered over the State. Its establishment in the lower Colorado River was described by Beland (1953).

In 1954, 3,960 fingerlings were imported into southern California from the U. S. Fish and Wildlife Service hatchery at Dexter, New Mexico, by the California Department of Fish and Game. These fish were distributed to many private ponds in southern California.

In the fall of 1956, 66 adults were brought to Central Valleys Hatchery from southern California. A number of private ponds in the San Joaquin Valley were stocked at the same time. The fish spawned successfully at Central Valleys Hatchery, and the progeny were planted in a number of waters. We know of no instance in which an introduction has failed.

Atherinops affinis (Ayres)—topsmelt

As an occasional invader of fresh water, the topsmelt belongs in the main list. Gunter (1942, 1956), Roedel (1953a), and Carpelan (1955) state that the topsmelt enters brackish and even fresh water. Dr. Carl L. Hubbs has collected (May 25, 1916) specimens in fresh running water of San Luis Creek near Avila, San Luis Obispo County, about one mile above the mouth.

Clinocottus acuticeps (Gilbert)—sharpnose sculpin

As an euryhaline species which occasionally enters fresh water, this form deserves a place in the list. It was collected by Dr. Carl L. Hubbs in fresh water rills on the beach at Crescent City, Del Norte County (letter from Hubbs to Shapovalov, August 1, 1950).

Leptocottus armatus armatus Girard—northern staghorn sculpin

Leptocottus armatus australis Hubbs—southern staghorn sculpin

Both subspecies of *L. armatus* have been added here on the recommendation of Dr. Carl L. Hubbs. He collected (May 31, 1923) *L. a. armatus* from fresh water near the mouth of Elk Creek, Del Norte County. He recorded *L. a. australis* from fresh tidewater of Morro and Chorro creeks. San Luis Obispo County (Hubbs, 1921). The two subspecies were separated in this publication on the basis of variational analysis.

Gasterosteus aculeatus aculeatus Linnaeus—northern threespine stickleback

Gasterosteus aculeatus microcephalus Girard—west coast threespine stickleback

Gasterosteus aculeatus williamsoni Girard—unarmored threespine stickleback

The addition of the above subspecies is based on the recommendation of Dr. Carl L. Hubbs.

Eleotris picta Kner and Steindachner—spotted sleeper

This is another euryhaline species which occasionally penetrates into fresh water. The first specimen of this species to be described from California was caught by a fisherman at the canal spillway between Winterhaven and the Colorado River in Imperial County (Hubbs, 1953).

Forms Removed From the Main List Since 1950

The three species and three subspecies listed below are no longer included in the main list. Recent taxonomic studies, mentioned in the annotations, have shown that they are synonymous with other forms. In addition, *Salmo clarkii pleuriticus* has been moved from the main list to the Revised Supplementary List, for reasons explained in that section.

Salmo gairdnerii rosei Jordan and McGregor—Lake Culver rainbow trout

The taxonomic identity of this subspecies has been disproved in the literature by Dill and Shapovalov (1954). Apparently this lake was originally barren of fish life. In addition, Drs. Carl L. Hubbs and W. I. Follett examined all the type material of *S. gilberti* and *S. rosei* in the Stanford University collections and found no differences between the two forms. With this information, Dill and Shapovalov concluded, "In view of the combined evidence presented, we can only conclude that *Salmo rosei* is a synonym of *Salmo gilberti*, now known as *Salmo gairdnerii gilberti* Jordan."

Catostomus arenarius (Snyder)—sandbar sucker

Hubbs and Miller (1951) have established that *C. arenarius* is a large-scaled variant of *C. tahoensis*, with no other distinctions.

Notemigonus crysoleucas auratus (Rafinesque)—western golden shiner

Considerable evidence shows that the golden shiner exhibits strong clinal characteristics throughout its geographic range (Bailey, 1956; Hart, 1952). For further details on the problem of subspecies and clines see the previous section on Scientific Names.

Ictalurus punctatus punctatus (Rafinesque)—southern channel catfish

Deletion of this subspecies is in accord with our policy of not recognizing trinomials for forms exhibiting pronounced clinal variations. Bailey, Winn, and Smith (1954, p. 130) conclude, "The geographic variation within *I. punctatus* consists chiefly of a weak cline in anal fin-ray count amounting to a mean difference of about two rays at the extremities of the range . . . We do not believe that subspecific segregation is justified."

Cottus macrops Rutter—bigeye sculpin

A comparison of type material of *C. klamathensis* and *C. macrops* by Robins and Miller (1957) and of fresh collections failed to reveal differences judged to be of specific value. They decided to synonymize *C. macrops* with *C. klamathensis*, but noted that study of additional features may show them worthy of subspecific rank.

Cottus bairdii Girard—mottled sculpin

Robins and Miller (1957) have made a detailed study of both new material and type specimens of sculpins of the genus *Cottus* in an attempt to clarify the taxonomy of what is considered one of the most perplexing groups of North American freshwater fishes. In reference to the mottled sculpin, they comment, "For the present, we feel that the only western forms of *Cottus* that should be aligned specifically with *bairdii* are *C. b. semiscaber* and *C. b. punctulatus* of the upper Columbia and Colorado rivers, respectively." In following the recommendations of Robins and Miller we have revised our former treatment of the *C. bairdii* complex by synonymizing *C. bairdii beldingii* with *C. beldingii* and *C. bairdii shasta* with *C. gulosus*.

REVISED MAIN LIST

Native Species and Established Exotic Species

This revised list consists of 110 full species, which may be subdivided as follows: 64 native freshwater and anadromous species, 14 native marine or euryhaline species which occasionally penetrate into fresh water, and 32 introduced species. The 110 species comprise 23 families and 63 genera.

Species which have been introduced into California waters are denoted by an asterisk (*), and marine fishes which occur only occasionally in freshwater by an "O".

PETROMYZONTIDAE—lamprey family

1. *Entosphenus tridentatus* (Richardson)—Pacific lamprey
2. *Lampetra ayresii* (Günther)—river lamprey
3. *Lampetra planeri* (Bloch)—brook lamprey

ACIPENSERIDAE—sturgeon family

4. *Acipenser transmontanus* Richardson—white sturgeon
5. *Acipenser medirostris* Ayres—green sturgeon

ELOPIDAE—ladyfish family

6. *Elops affinis* Regan—machete O

CLUPEIDAE—herring family

7. *Clupea pallasii* Valenciennes—Pacific herring O
8. *Alosa sapidissima* (Wilson)—American shad *
9. *Dorosoma petenense* (Günther)—threadfin shad *

OSMERIDAE—smelt family

10. *Thaleichthys pacificus* (Richardson)—eulachon
11. *Spirinchus thaleichthys* (Ayres)—Sacramento smelt O
12. *Hypomesus pretiosus* (Girard)—surf smelt O
13. *Hypomesus olidus* (Pallas)—Pond smelt O

COREGONIDAE—whitefish family

14. *Coregonus williamsoni* Girard—mountain whitefish

SALMONIDAE—salmon and trout family

15. *Oncorhynchus gorbuscha* (Walbaum)—pink salmon
16. *Oncorhynchus keta* (Walbaum)—chum salmon
17. *Oncorhynchus kisutch* (Walbaum)—silver salmon
18. *Oncorhynchus tshawytscha* (Walbaum)—king salmon
19. *Oncorhynchus nerka* (Walbaum)—sockeye salmon (anadromous form); kokanee salmon (freshwater form *)
20. *Salmo trutta* Linnaeus—brown trout *
21. *Salmo clarkii* Richardson—cutthroat trout
    21a. *Salmo clarkii clarkii* Richardson—coast cutthroat trout
    21b. *Salmo clarkii henshawi* Gill and Jordan—Lahontan cutthroat trout
    21c. *Salmo clarkii evermanni* Jordan and Grinnell—San Gorgonio cuttthroat trout
    21d. *Salmo clarkii seleniris* Snyder—Piute cutthroat trout
22. *Salmo gairdnerii* Richardson—rainbow trout
    22a. *Salmo gairdnerii gairdnerii* Richardson—steelhead rainbow trout
    22b. *Salmo gairdnerii kamloops* (Jordan)—Kamloops rainbow trout *
    22c. *Salmo gairdnerii stonei* Jordan—Shasta rainbow trout
    22d. *Salmo gairdnerii gilberti* Jordan—Kern River rainbow trout
    22e. *Salmo gairdnerii aquilarum* Snyder—Eagle Lake rainbow trout
    22f. *Salmo gairdnerii regalis* Snyder—royal silver rainbow trout
23. *Salmo aguabonita* Jordan—golden trout
    23a. *Salmo aguabonita aguabonita* Jordan—South Fork of Kern golden trout
    23b. *Salmo aguabonita whitei* Evermann—Little Kern golden trout
24. *Salvelinus fontinalis* (Mitchill)—eastern brook trout *
25. *Salvelinus malma* (Walbaum)—Dolly Varden trout
26. *Salvelinus namaycush* (Walbaum)—lake trout *
    26a. *Salvelinus namaycush namaycush* (Walbaum)—common lake trout *

CATOSTOMIDAE—sucker family

27. *Ictiobus cyprinella* (Valenciennes)—bigmouth buffalo *
28. *Catostomus occidentalis* Ayres—western sucker
    28a. *Catostomus occidentalis occidentalis* Ayres—Sacramento western sucker
    28b. *Catostomus occidentalis lacusanserinus* Fowler—Goose Lake western sucker
29. *Catostomus mniotiltus* Snyder—Monterey sucker
30. *Catostomus microps* Rutter—Modoc sucker
31. *Catostomus tahoensis* Gill and Jordan—Tahoe sucker
32. *Catostomus latipinnis* Baird and Girard—flannelmouth sucker
33. *Catostomus rimiculus* Gilbert and Snyder—Klamath smallscale sucker
34. *Catostomus snyderi* Gilbert—Klamath largescale sucker
35. *Catostomus humboldtianus* Snyder—Humboldt sucker
36. *Pantosteus santaanae* Snyder—Santa Ana mountain-sucker
37. *Pantosteus lahontan* Rutter—Lahontan mountain-sucker
38. *Deltistes luxatus* (Cope)—Lost River sucker
39. *Chasmistes brevirostris* Cope—shortnose sucker
40. *Xyrauchen texanus* (Abbott)—humpback sucker

CYPRINIDAE—carp or minnow family

41. *Cyprinus carpio* Linnaeus—carp *
42. *Carassius auratus* (Linnaeus)—goldfish *

43. *Tinca tinca* (Linnaeus)—tench *
44. *Notemigonus crysoleucas* (Mitchill)—golden shiner *
45. *Orthodon microlepidotus* (Ayres)—Sacramento blackfish
46. *Mylopharodon conocephalus* (Baird and Girard)—hardhead
47. *Lavinia exilicauda* Baird and Girard—hitch
    47a. *Lavinia exilicauda exilicauda* Baird and Girard—Sacramento hitch
    47b. *Lavinia exilicauda harengus* Girard—Monterey hitch
48. *Ptychocheilus grandis* (Ayres)—Sacramento squawfish
49. *Ptychocheilus lucius* Girard—Colorado River squawfish
50. *Gila robusta* Baird and Girard—bonytail chub
    50a. *Gila robusta elegans* Baird and Girard—Colorado River bonytail chub
51. *Gila orcuttii* (Eigenmann and Eigenmann)—arroyo chub
52. *Gila bicolor* (Girard)—Klamath chub
53. *Gila crassicauda* (Baird and Girard)—thicktail chub
54. *Pogonichthys macrolepidotus* (Ayres)—splittail
55. *Richardsonius egregius* (Girard)—Lahontan redside
56. *Hesperoleucus symmetricus* (Baird and Girard)—western roach
    56a. *Hesperoleucus symmetricus symmetricus* (Baird and Girard)—Sacramento western roach
    56b. *Hesperoleucus symmetricus subditis* Snyder—Monterey western roach
57. *Hesperoleucus navarroensis* Snyder—Navarro roach
58. *Hesperoleucus parvipinnis* Snyder—Gualala roach
59. *Hesperoleucus venustus* Snyder—Venus roach
60. *Hesperoleucus mitrulus* Snyder—northern roach
61. *Siphateles bicolor* (Girard)—tui chub
    61a. *Siphateles bicolor bicolor* (Girard)—Klamath tui chub
    61b. *Siphateles bicolor obesus* (Girard)—coarseraker tui chub
    61c. *Siphateles bicolor pectinifer* (Snyder)—fineraker tui chub
    61d. *Siphateles bicolor formosus* (Girard)—Sacramento tui chub
62. *Siphateles mohavensis* Snyder—Mohave chub
63. *Rhinichthys osculus* (Girard)—speckled dace
    63a. *Rhinichthys osculus robustus* (Rutter)—Lahontan speckled dace
    63b. *Rhinichthys osculus carringtonii* (Cope)—Pacific speckled dace
    63c. *Rhinichthys osculus klamathensis* (Evermann and Meek)—Klamath speckled dace
    63d. *Rhinichthys osculus nevadensis* Gilbert—Nevada speckled dace
64. *Notropis lutrensis* (Baird and Girard)—red shiner *
65. *Pimephales promelas* Rafinesque—fathead minnow *
    65a. *Pimephales promelas confertus* (Girard)—southwestern fathead minnow *
66. *Plagopterus argentissimus* Cope—woundfin

ICTALURIDAE—catfish family

67. *Ictalurus punctatus* (Rafinesque)—channel catfish *
68. *Ictalurus catus* (Linnaeus)—white catfish *
69. *Ictalurus nebulosus* (LeSueur)—brown bullhead *
    69a. *Ictalurus nebulosus nebulosus* (LeSueur)—northern brown bullhead *
70. *Ictalurus melas* (Rafinesque)—black bullhead *
    70a. *Ictalurus melas melas* (Rafinesque)—northern black bullhead *
71. *Ictalurus natalis* (LeSueur)—yellow bullhead *
    71a. *Ictalurus natalis natalis* (LeSueur)—northern yellow bullhead *

CYPRINODONTIDAE—killifish family

72. *Fundulus parvipinnis* Girard—California killifish
    72a. *Fundulus parvipinnis parvipinnis* Girard—southern California killifish
73. *Cyprinodon macularius* Baird and Girard—desert pupfish
74. *Cyprinodon nevadensis* Eigenmann and Eigenmann—Nevada pupfish
    74a. *Cyprinodon nevadensis nevadensis* Eigenmann and Eigenmann—Saratoga Nevada pupfish
    74b. *Cyprinodon nevadensis amargosae* Miller—Amargosa Nevada pupfish
    74c. *Cyprinodon nevadensis calidae* Miller—Tecopa Nevada pupfish
    74d. *Cyprinodon nevadensis shoshone* Miller—Shoshone Nevada pupfish
75. *Cyprinodon salinus* Miller—Salt Creek pupfish
76. *Cyprinodon radiosus* Miller—Owens Valley pupfish

POECILIIDAE—topminnow family

77. *Gambusia affinis* (Baird and Girard)—mosquitofish *
    77a. *Gambusia affinis affinis* (Baird and Girard) — western mosquitofish *
78. *Mollienesia latipinna* LeSueur—sailfin molly *

PLEURONECTIDAE—righteyed flounder family

79. *Platichthys stellatus* (Pallas)—starry flounder O
    79a. *Platichthys stellatus rugosus* Girard—southern starry flounder O

SERRANIDAE—bass family

80. *Roccus saxatilis* (Walbaum)—striped bass *

PERCIDAE—perch family

81. *Perca flavescens* (Mitchill)—yellow perch *
82. *Percina caprodes* (Rafinesque)—log perch *

CENTRARCHIDAE—sunfish family

83. *Micropterus dolomieui* Lacépède—smallmouth bass *
    83a. *Micropterus dolomieui dolomieui* Lacépède—northern smallmouth bass *
84. *Micropterus punctulatus* (Rafinesque)—spotted bass *
    84a. *Micropterus punctulatus punctulatus* (Rafinesque)—northern spotted bass *
85. *Micropterus salmoides* (Lacépède)—largemouth bass *
86. *Chaenobryttus gulosus* (Cuvier)—warmouth *
87. *Lepomis cyanellus* Rafinesque—green sunfish *
88. *Lepomis gibbosus* (Linnaeus)—pumpkinseed *
89. *Lepomis microlophus* (Günther)—red-ear sunfish *
90. *Lepomis macrochirus* Rafinesque—bluegill *
    90a. *Lepomis macrochirus macrochirus* Rafinesque—common bluegill *
91. *Archoplites interruptus* (Girard)—Sacramento perch
92. *Pomoxis annularis* Rafinesque—white crappie *
93. *Pomoxis nigromaculatus* (LeSueur)—black crappie *

ATHERINIDAE—silverside family

94. *Atherinops affinis* (Ayres)—topsmelt O

MUGILIDAE—mullet family

95. *Mugil cephalus* Linnaeus—striped mullet O

EMBIOTOCIDAE—viviparaus perch family

96. *Cymatogaster aggregata Gibbons*—shinner perch O
97. *Hysterocarpus traskii* Gibbons—tule perch

COTTIDAE—sculpin family

98. *Clinocottus acuticeps* (Gilbert)—sharpnose sculpin O
99. *Cottus gulosus* (Girard)—riffle sculpin
100. *Cottus asperrimus* Rutter—rough sculpin
101. *Cottus klamathensis* Gilbert—Klamath sculpin
102. *Cottus asper* Richardson—prickly sculpin
103. *Cottus beldingii* Eigenmann and Eigenmann—Piute sculpin
104. *Cottus aleuticus* Gilbert—Aleutian sculpin
105. *Leptocottus armatus* Girard—staghorn sculpin O
    105a. *Leptocottus armatus armatus* Girard—northern staghorn sculpin O
    105b. *Leptocottus armatus australis* Hubbs—southern staghorn sculpin O

GASTEROSTEIDAE—stickleback family

106. *Gasterosteus aculeatus* Linnaeus—threespine stickleback
    106a. *Gasterosteus aculeatus aculeatus* Linnaeus—northern threespine stickleback
    106b. *Gasterosteus aculeatus microcephalus* Girard—West Coast threespine stickleback
    106c. *Gasterosteus aculeatus williamsoni* Girard—unarmored threespine stickleback

ELEOTRIDAE—sleeper family

107. *Eleotris picta* Kner and Steindachner—spotted sleeper O

GOBIIDAE—goby family

108. *Eucyclogobius newberryi* (Girard)—tidewater goby
109. *Gillichthys mirabilis* Cooper—longjaw mudsucker O
110. *Clevelandia ios* (Jordan and Gilbert)—arrow goby O

REVISED SUPPLEMENTARY LIST

Exotic Species—Unsuccessfully Introduced or of Uncertain Occurrence

The exotic fishes listed below fall into several groups:

(1) Fishes known to have been introduced but which have not survived; e.g., No. 33.
(2) Fishes reported—possibly erroneously—to have been introduced, but which have not survived; e.g., No. 7.
(3) Fishes which have been reported from this State but whose identification is questioned by the authors; e.g., No. 26.
(4) Fishes which have not been recorded from the State for many years; e.g., No. 25a.
(5) Fishes reported by Miller (1952) as comprising the species of bait minnows that are being (or have been) utilized along the Colorado River, from Lake Mead to Yuma. There is no positive evidence at present that any of the forms here listed has become established. They are denoted below by a double dagger (‡).

As will be seen by our annotations, we know of no demonstrable evidence that any of them are successfully established in the fresh waters of California today.

The general sources for the history and lack of success of most of these introductions are fairly well known. Therefore, there is little point in listing all the references concerning the status of these fishes. We have alluded to specific literature only when our opinion differs from that of the authors cited, or when such inclusion serves to clarify the exact status of the species.

The original supplementary list (Shapovalov and Dill, 1950) contained *Salmo gairdnerii kamloops*, *Pimephales promelas confertus*, and *Gillichthys detrusus*. The first two have been placed in the main list. The third, the gulf mudsucker, has been deleted entirely on the basis of study by Miller (1952) who concludes ". . . . there is no basis at this time for the inclusion of *detrusus* in the Californian fauna".

CHANIDAE—milkfish family

1. *Chanos chanos* (Forskål)—milkfish

Milkfish from the Hawaiian Islands were planted in a stream in Solano County in 1877. There are no records of their survival there. The species is an ocean fish which occasionally enters fresh water.

COREGONIDAE—whitefish family

2. *Coregonus clupeaformis* (Mitchill)—lake whitefish

2a. *Coregonus clupeaformis clupeaformis* (Mitchill)—Great Lakes whitefish

All plants were made during the last century. Even the few old reports of recapture (*circa* 1880) are considered highly dubious.

THYMALLIDAE—grayling family

3. *Thymallus arcticus* (Pallas)—Arctic grayling
   3a. *Thymallus arcticus signifer* (Richardson)—saillin Arctic grayling
   Several attempts have been made to introduce this form, and it apparently met with a brief success in Yosemite National Park following plants made during the 1929-1933 period. The last authentic report of its survival there (in Grayling Lake) appears to have been in 1934. Its present occurrence is highly doubtful.

SALMONIDAE—salmon and trout family

4. *Salmo salar* Linnaeus—Atlantic salmon (anadromous form); landlocked Atlantic salmon (freshwater form)
   Both forms have been planted several times. The old records of their survival may be dubious; there are no authentic recent records.
5. *Salmo clarkii* Richardson—cutthroat trout
   5a. *Salmo clarkii lewisi* (Girard)—Yellowstone cutthroat trout
   Several shipments of cutthroat trout eggs have been brought in from other states, and plants made in California waters. It is probable that most of these were *S. c. lewisi*.
   5b. *Salmo clarkii pleuriticus* Cope—Colorado River cutthroat trout
   This subspecies is being dropped from the main list. Dill (1944, p. 149) summarized the published reports of its occurrence in the Salton Sea region, noting that these records "are rather old and some may be dubious". The reported specimens may have been misidentified; in any case, they almost certainly consisted of individuals washed into the basin from tributaries of the Colorado River many years ago. No specimens are known to exist in any collections.

ESOCIDAE—pike family

6. *Esox masquinongy* Mitchill—muskellunge
   6a. *Esox masquinongy ohioensis* Kirtland—Ohio muskellunge
   Introduced into Lake Merced, San Francisco County, in 1893. None survived.
7. *Esox lucius* Linnaeus—northern pike
8. *Esox americanus* Gmelin—redfin pickerel
   8a. *Esox americanus vermiculatus* LeSueur—grass pickerel
   E. lucius was supposedly introduced in 1891, but one of the fish resulting from this shipment was identified in 1896 as *E. vermiculatus* (now *E. a. vermiculatus*). Possibly both species were included. There are no records of capture of either species after 1896.

CHARACIDAE—characid family

9. *Astyanax fasciatus* (Cuvier)—banded tetra ‡
   9a. *Astyanax fasciatus mexicanus* (Filippi)—Mexican banded tetra ‡

CATOSTOMIDAE—sucker family

10. *Catostomus commersonnii* (Lacépède)—white sucker ‡
    10a. *Catostomus commersonnii sucklegi* Girard—western white sucker ‡
11. *Catostomus ardens* Jordan and Gilbert—Utah sucker ‡
12. *Pantosteus delphinus* (Cope)—bluehead mountain-sucker ‡
    12a. *Pantosteus delphinus delphinus* (Cope) ‡
    12b. *Pantosteus delphinus utahensis* (Tanner) ‡
13. *Pantosteus platyrhynchus* (Cope)—Bonneville mountain-sucker ‡
14. *Pantosteus plebeius* (Baird and Girard)—Rio Grande mountain-sucker ‡
15. *Pantosteus* sp.—dusky mountain-sucker ‡

CYPRINIDAE—carp or minnow family

16. *Gila atraria* (Girard)—Utah chub ‡
17. *Gila nigrescens* (Girard)—Rio Grande chub ‡
18. *Snyderichthys aliciae* (Jouy)—leatherside chub ‡
19. *Richardsonius balteatus* (Richardson)—northern redside ‡
    19a. *Richardsonius balteatus hydrophlox* (Cope)—Bonneville redside ‡
20. *Agosia chrysogaster* Girard—longfin dace ‡
21. *Lepidomeda* sp.—Virgin River spinedace ‡
22. *Lepidomeda* sp.—White River spinedace ‡

ICTALURIDAE—catfish family

23. *Ictalurus furcatus* (LeSueur)—blue catfish
24. *Ictalurus platycephalus* Girard—flat bullhead

On the basis of a survey made in 1925, Coleman (1930) records "The Great Blue, or Forked-Tail Cat—*Ictalurus furcatus*, Cuv. and Vincen.," and "The Brown-Spotted Cat—Ameirus (*sic.*) *platycephalus*, Girard," from Clear Lake, Lake County. Neither has been recorded from the lake since that time, despite extensive collecting. Hence, Coleman's paper is the sole evidence for the existence of these species in California. We believe that he confused *Ictalurus catus* (which *is* found in Clear Lake and which is often called "forked-tail catfish" or "blue cat") with his "*furcatus*." We suspect that his record of *I. platycephalus* is based upon his erroneous interpretation of fishermen's reports.

25. *Ictalurus melas* (Rafinesque)—black bullhead
    25a. *Ictalurus melas catulus* (Girard)—southern black bullhead
    A collection from the Colorado River at the mouth of the Gila River in 1904 included this subspecies, according to Robert R. Miller. We know of no later records from California.

ANGUILLIDAE—freshwater eel family

26. *Anguilla rostrata* (LeSueur)—American eel

Introduced in 1874, 1879, and 1882. There are no authentic records of survival.

CYPRINODONTIDAE—killifish family

27. *Oryzias latipes* (Temminck and Schlegel)—medaka

The statement by Snyder (1935), "It has been found in San Francisquito Creek," and Coates (1942, p. 185), ". . . . this fish has been turned loose in . . . . parts of California, where it is reported to be thriving," are the sole bases for its admission to this list. In a conversation with Snyder on March 21, 1943, he told us (W. A. D.) that some of his students had collected this form in San Francisquito Creek, Santa Clara County. He did not recall the date or other circumstances.

28. *Fundulus zebrinus* Jordan and Gilbert—southwestern plains killifish ‡

PERCIDAE—perch family

29. *Stizostedion vitreum* (Mitchill)—walleye
    29a. *Stizostedion vitreum vitreum* (Mitchill)—yellow walleye
    Introduced in 1874. No records of continued survival.

CENTRARCHIDAE—sunfish family [4]

30. *Micropterus coosae* Hubbs and Bailey—redeye bass

Kimsey (1954) recorded the importation of 40 specimens into California for use as brood stock by the Californa Department of Fish and Game. They were taken to Central Valleys Hatchery, Elk Grove, California. Kimsey (1957) reviewed the history of this introduction and its status. He concluded, "No redeye bass were planted in the open waters of the State and none are now present in California."

31. *Lepomis macrochirus* Rafinesque—bluegill
    31a. *Lepomis macrochirus speciosus* (Baird and Girard)—southwestern bluegill.
    According to Miller (1952), "The southwestern bluegill . . . is also now evidently established in the Colorado River through introduction . . . (*fide* C. L. Hubbs in letter of May 10, 1951, to R. D. Beland, and letter from Beland of August 23, 1951, to W. A. Dill)."

32. *Enneacanthus gloriosus* (Holbrook)—bluespot sunfish

This species is listed in the accession list for Steinhart Aquarium as having been collected in March, 1931, in the vicinity of Willows, California. The identification was made by Alvin Seale, but the specimens were not saved. We believe this to be a misidentification.

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[4] "*Lepomis euryorus* McKay." Seale (1930) lists "Sunfish. *Eupomotis euryoris*" in an article entitled, "List of twenty fresh water fishes found in California that may be used in small aquariums or garden pools." The Steinhart Aquarium accession list for 1931 records "*Apomotis euryorus*" as collected near Willows, California. The identification was made by Alvin Seale; the specimens were not saved. Hubbs and Hubbs (1932) have proved that the nominal species "*Lepomis euryorus*" is a hybrid between *Lepomis cyanellus* and *Lepomis gibbosus*. Both of these species are known to be present in California but *L. gibbosus* has not yet been recorded from near Willows, nor do we have any records of its presence in the State as early as 1930 or 1931.

33. *Ambloplites rupestris* (Rafinesque)—rock bass

33a. *Ambloplites rupestris rupestris* (Rafinesque)—northern rock bass

It is recorded in literature as having been introduced in 1874 and again in 1891, and another record of a plant of "Rock bass" in 1917 was furnished by E. H. Glidden. Brief statements by Neale (1931, p. 12) and Anon. (1934) as to its limited success in California, and its occasional listing in State fish rescue records up to 1939, are the only bases for belief that this fish ever endured. The terminology used in these rescue records (published in the Biennial Reports of the California Division of Fish and Game) has often been inexact. We have been unable to find a single verifiable record of the occurrence of the rock bass in California.

REFERENCES

American Fisheries Society

1948. A list of common and scientific names of the better known fishes of the United States and Canada. Amer. Fish. Soc., Spec. Publ. no. 1, 45 pp.

Anon.

1934. The rock bass (*Ambloplites rupestris*). Aquarium Jour., vol. 7, no. 10, p. 192.

1958. The Salton Sea story. Outdoor California, vol. 19, no. 12, pp. 4-7, 13.

Bailey, Reeve M.

1951. A check list of the fishes of Iowa with keys for identification. *In:* Iowa Fish and Fishing. Iowa St. Cons. Comm., pp. 185-238.

1952. Report of standing committee on names of fishes. Amer. Fish. Soc., Trans., vol. 81 (1951), pp. 324-326.

1953. Report of standing committee on names of fishes. Amer. Fish. Soc., Trans., vol. 82 (1952), pp. 326-328.

1955. Report of standing committee on names of fishes. Amer. Fish. Soc., Trans., vol. 84 (1954), pp. 368-371.

1956. A revised list of the fishes of Iowa with keys for identification. *In:* Iowa Fish and Fishing. Third Edition. Iowa St. Cons. Comm., pp. 327-377.

Bailey, Reeve M., and William A. Gosline

1955. Variation and systematic significance of vertebral counts in the American fishes of the family Percidae. Univ. Mich., Misc. Publ. Mus. Zool., no. 93, 44 pp.

Bailey, Reeve M., Howard Elliott Winn, and C. Lavett Smith

1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. Acad. Nat. Sci. Phila., Proc., vol. 106, pp. 109-164.

Beland, R. D.

1953. The occurrence of two additional centrarchids in the lower Colorado River. Calif. Fish and Game, vol. 39, no. 1, pp. 149-151.

Carpelan, Lars H.

1955. Tolerance of the San Francisco topsmelt, *Atherinops affinis affinis*, to conditions in salt-producing ponds bordering San Francisco Bay. Calif. Fish and Game, vol. 41, no. 4, pp. 279-284.

Coates, Christopher W.

1942. Tropical fishes for a private aquarium. Cleveland and New York. The World Publ. Co., xi + 226 pp.

Coleman, George A.

1930. A biological survey of Clear Lake, Lake County. Calif. Fish and Game, vol. 16, no. 3, pp. 221-227.

Dill, William A.

1944. The fishery of the lower Colorado River. Calif. Fish and Game, vol. 30, no. 3, pp. 109-211.

Dill, William A., and Leo Shapovalov

1954. *Salmo rosei*, not a valid species. Calif. Fish and Game, vol. 40, no. 3, pp. 337-338.

Douglas, P. A.

1953. Survival of some fishes recently introduced into the Salton Sea, California. Calif. Fish and Game, vol. 39, no. 2, pp. 264-265.

Eddy, Samuel
1957. How to know the freshwater fishes. Dubuque, Iowa, Wm. C. Brown Co., vi + 253 pp.

Eschmeyer, Paul H., and Reeve M. Bailey
1955. The pygmy whitefish, *Coregonus coulteri*, in Lake Superior. Amer. Fish. Soc., Trans., vol. 84 (1954), pp. 161-199.

Evans, Willis A., and Philip A. Douglas
1950. Notes on fishes recently introduced into southern California. Calif. Fish and Game, vol. 36, no. 4, pp. 435-436.

Evermann, Barton Warren, and Howard Walton Clark
1931. A distributional list of the species of freshwater fishes known to occur in California. Calif. Div. Fish and Game, Fish Bull. 35, 67 pp.

Foerster, R. E.
1947. Experiment to devolop sea-run from land-locked sockeye salmon (*Oncorhynchus nerka kennerlyi*). Fish. Res. Bd. Canada, Jour., vol. 7, no. 2, pp. 88-93.

Gerking, Shelby D.
1955. Key to the fishes of Indiana. Invest. Ind. Lakes and Streams, vol. 4, no. 2, pp. 49-86.

Gilbert, Charles H.
1898. The fishes of the Klamath Basin. U. S. Fish Comm., Bull., vol. 16 (1897), pp. 1-13.

Grinnell, Joseph, and Alden H. Miller
1944. The distribution of the birds of California. Cooper Ornith. Club, Pac. Coast Avifauna, no. 27, 608 pp.

Gunter, Gordon
1942. A list of the fishes of the mainland of North and Middle America recorded from both fresh water and sea water. Amer. Midl. Nat., vol. 28, no. 2, pp. 305-326.
1956. A revised list of euryhalin fishes of North and Middle America. Amer. Midl. Nat., vol. 56, no. 2, pp. 345-354.

Hart, J. S.
1952. Geographic variations of some physiological and morphological characters in certain freshwater fish. Univ. Toronto Pr., Univ. Toronto. Biol. Ser. no. 60, Publ. Ontario Fish. Res. Lab., no. 72, iv + 79 pp.

Hourston, A. S.
1955. A study of variations in the maskinonge from the regions in Canada. Royal Ontario Mus. Zool. and Palaeo., Contrib., no. 40, 13 pp.

Hubbs, Carl L.
1921. The latitudinal variation in the number of vertical fin-rays in *Leptocottus armatus*. Univ. Mich., Occ. Pap., Mus. Zool., no. 94, 7 pp.
1953. *Eleotris picta* added to the fish fauna of California. Calif. Fish and Game, vol. 39, no. 1, pp. 69-76.
1954. Establishment of a forage fish, the red shiner (*Notropis lutrensis*), in the lower Colorado River system. Calif. Fish and Game, vol. 40, no. 3, pp. 287-294.

Hubbs, Carl L., and W. I. Follett
1953. Manuscript list of the fishes of California. Unpublished manuscript, 65 pp.

Hubbs, Carl L., and Laura C. Hubbs
1932. Experimental verification of natural hybridization between distinct genera of sunfishes. Mich. Acad. Sci., Arts and Let., Pap., vol. 15, 1931, pp. 427-437.

Hubbs, Carl L., and Karl F. Lagler
1958. Fishes of the Great Lakes region. Cranbrook Inst. Sci., Bull. 26. Revised edition, 227 pp.

Hubbs, Carl L., and Robert Rush Miller
1943. Mass hybridization between two genera of cyprinid fishes in the Mohave Desert, California. Mich. Acad. Sci., Arts and Let., Pap., vol. 28, 1942, pp. 343-378.

1951. *Catostomus arenarius*, a Great Basin fish, synonymized with *C. tahoensis*. Copeia, no. 4, pp. 299-300.

Hubbs, Carl L., and Orthello L. Wallis
1948. The native fish fauna of Yosemite National Park and its preservation. Yosemite Nature Notes, vol. 27, no. 12, pp. 133-144.

Illick, Helen J.
1956. A comparative study of the cephalic lateral-line system of North American Cyprinidae. Amer. Midl. Nat., vol. 56, no. 1, pp. 204-223.

Kimsey, J. B.
1954. The introduction of the redeye black bass and the threadfin shad into California. Calif. Fish and Game, vol. 40, no. 2, pp. 203-204.
1957. The status of the redeye bass in California. Calif. Fish and Game, vol. 43, no. 1, pp. 99-100.

Kimsey, J. B., and Leonard Fisk
1958. Keys to the freshwater and anadromous fishes of California. Calif. Dept. Fish and Game, Inland Fisheries Branch, Informational Leaflet no. 21, 31 pp. (Mimeo.)

Kimsey, J. B., Robert H. Hagy, and George W. McCammon
1957. Progress report on the Mississippi threadfin shad, *Dorosoma petenensis atchafaylae*, in the Colorado River for 1956. Calif. Dept. Fish and Game, Inland Fisheries Branch, Admin. Rept. no. 57-23, 48 pp. (Mimeo.)

Lagler, Karl F.
1952. Freshwater fishery biology. Dubuque, Iowa, Wm. C. Brown Co., x + 360 pp.

La Rivers, Ira, and T. J. Trelease
1952. An annotated check list of the fishes of Nevada. Calif. Fish and Game, vol. 38, no. 1, pp. 113-123.

Legendre, V.
1954. The freshwater fishes. Key to game and commercial fishes of the Province of Quebec. Vol. 1, First English Edition, 180 pp.

Lindsey, C. C.
1956a. Recommended common and scientific names of British Columbia freshwater fishes. Brit. Columbia Game Comm., Fish Mangt. Div., 26 pp.
1956b. Distribution and taxonomy of fishes in the Mackensie drainage of British Columbia. Fish. Res. Bd. Canada, Jour., vol. 13, no. 6, pp. 759-789.

Miller, Robert Rush
1950a. Notes on the cutthroat and rainbow trout with the description of a new species from the Gila River, New Mexico. Univ. Mich., Occ. Pap. Mus. Zool., no. 529, 42 pp.
1950b. A review of the American clupeid fishes of the genus *Dorosoma*. U. S. Nat. Mus., Proc., vol. 100, pp. 387-410.
1952. Bait fishes of the lower Colorado River from Lake Mead, Nevada, to Yuma, Arizona, with a key for their identification. Calif. Fish and Game, vol. 38, no. 1, pp. 7-42.

Morton, Wm. Markham, and Robert Rush Miller
1954. Systematic position of the lake trout, *Salvelinus namaycush*. Copeia, no. 2, pp. 116-124.

Neale, George
1931. The spiny-rayed game fishes of the California inland waters. Calif. Fish and Game, vol. 17, no. 1, pp. 1-17.

Outdoor Writers Association of America
1958. Standard check list of common names for principal American sport fishes. Fourth printing, 27 pp.

Robins, C. Richard, and Robert Rush Miller
1957. Classification, variation, and distribution of the sculpins, genus *Cottus*, inhabiting Pacific slope waters in California and southern Oregon, with a key to the species. Calif. Fish and Game, vol. 43, no. 3, pp. 213-233.

Roedel, Phil M.
1953a. Common ocean fishes of the California coast. Calif. Dept. Fish and Game, Fish Bull. 91, 184 pp.

1953b. Official common names of certain marine fishes of California. Calif. Fish and Game, vol. 39, no. 2, pp. 251-262.

Schultz, Leonard P.
1957. The frogfishes of the family Antennariidae, U. S. Nat. Mus., Proc., vol. 107, no. 3383, pp. 47-105.

Scott, W. B.
1958. A checklist of the freshwater fishes of Canada and Alaska. Royal Ontario Mus., Div. Zoology and Palaeontology, 30 pp.

Seale, Alvin
1930. List of twenty fresh water fishes found in California that may be used in small aquariums or garden pools. Aquarium Jour., vol. 3, no. 7, pp. 38-39.

Shapovalov, Leo, and William A. Dill
1950. A check list of the fresh-water and anadromous fishes of California. Calif. Fish and Game, vol. 36, no. 4, pp. 382-391.

Snyder, J. O.
1935. California fresh water fish. Aquarium Jour., vol. 8, no. 9, p. 146.

Speirs, J. Murray
1952. Nomenclature of the channel catfish and the burbot of North America. Copeia, no. 2, pp. 99-103.

Stenton, J. E.
1950. Artificial hybridization of eastern brook trout and lake trout. Canadian Fish Cult., no. 6, pp. 20-22.
1952. Additional information on eastern brook trout × lake trout hybrids. Canadian Fish Cult., no. 13, pp. 15-21.

Tarp, Fred Harold
1952. A revision of the family Embiotocidae (the surfperches). Calif. Dept. Fish and Game, Fish Bull. 88, 99 pp.

Taylor, W. R.
1954. Records of fishes in the John N. Lowe collection from the upper peninsula of Michigan. Univ. Mich., Misc. Publ. Mus. Zool., no. 87, 50 pp.

Trautman, Milton B.
1957. The fishes of Ohio. Columbus, Ohio, Ohio State Univ. Press, xviii + 683 pp.

Vladykov, Vadim D., and W. I. Follett
1958. Redescription of *Lampetra ayresii* (Günther) of western North America, a species of lamprey (Petromyzontidae) distinct from *Lampetra fluviatilis* (Linnaeus) of Europe. Fish. Res. Bd. Canada, Jour., vol. 15, no. 1, pp. 47-77.

Wales, J. H.
1950. Introduction of Kamloops rainbow trout into California. Calif. Fish and Game, vol. 36, no. 4, p. 437.
1957. Trout of California. Calif. Dept. Fish and Game, Pamphlet, May, 56 pp.

Walford, Lionel A.
1931. Handbook of common commercial and game fishes of California. Calif. Div. Fish and Game, Fish Bull. 28, 181 pp.

Walters, Vladimir
1955. Fishes of western Arctic America and eastern Arctic Siberia. Amer. Mus. Nat. Hist., Bull., vol. 106, art. 5, pp. 255-368.

Winn, Howard Elliott, and Robert Rush Miller
1954. Native postlarval fishes of the lower Colorado River basin, with a key to their identification. Calif. Fish and Game, vol. 40, no. 3, pp. 273-285.

CHANGES IN A RIVER'S PHYSICAL CHARACTERISTICS UNDER SUBSTANTIAL REDUCTIONS IN FLOW DUE TO HYDROELECTRIC DIVERSION[1]

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INTRODUCTION

The changes which take place in a river's depth, water velocity, and area of submerged bottom, as the quantity of water flowing in the channel changes are the subject of this paper.

The investigation of these factors was carried out as part of a program undertaken by the Pacific Gas and Electric Company of San Francisco. This company operates hydroelectric plants throughout Northern California. At many of these, water is diverted by a dam from a river into a conduit which leads to a powerhouse downstream. Between the diversion dam and the powerhouse the river is greatly reduced in flow. The question of how much water should be maintained for preservation of aquatic life in these sections of reduced flow is one which has troubled both the company and the State of California's Department of Fish and Game for many years.

In late 1952 the company, on its own initiative, proposed to undertake a program aimed at providing factual data to aid in solving this problem. The State Department of Fish and Game took an active part in portions of the program, but played only a consultative role in the work which is the subject of this paper. As far as is known, data of the kind presented here have never been obtained before. Such work can only be carried on by an organization with large resources in men and equipment, with sufficient interest in the problem to devote them to the task, and above all with the ability to control the volume of flow in the stream channel.

The rivers investigated were the Pit and the Feather in Northern California, on both of which the company planned new power plants. A sport fishery for rainbow trout (*Salmo gairdnerii*) was involved in both.

METHODS

One of the basic factors in fish life is food supply. An important producer of trout food is the stream bottom. In the production of bottom food a primary factor is obviously the amount of bottom area;

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the habitat of the organisms. The area of channel bottom covered by water varies as the volume of flow varies; a basic approach therefore would be to determine accurately this area at each stage of flow under consideration.

The method used was to survey a sufficient number of cross sections of the channel to provide a sample from which a valid average could be derived for the part of the river under study. To assure a true random sample, the interval between stations was arbitrarily chosen in advance, based upon the total number needed and the distance to be covered. Experienced survey crews measured the distances exactly, and were instructed that each station must be set up faithfully at the point reached and not shifted in one direction or the other to obtain a more easily surveyed section.

PIT RIVER STUDY

The most thorough of these studies was made in 1955 on the Pit River, one of the principal tributaries of the Sacramento River. The Pit has its source in lava formations which absorb the heavy winter rainfall and release it gradually throughout the year. Therefore it does not have the extreme fluctuations of many California streams. Mean annual flow at a point in the stream section under study was 2,636 c.f.s. (cubic feet per second) over a 42-year period, with a maximum flood of 30,200 c.f.s. in 1937, a year of extraordinarily heavy winter rains. Minimum natural flow in summer in normal years probably would be on the order of magnitude of 2,000 c.f.s., but summer volume most of the time ranges from 3,000 to 3,500 c.f.s.

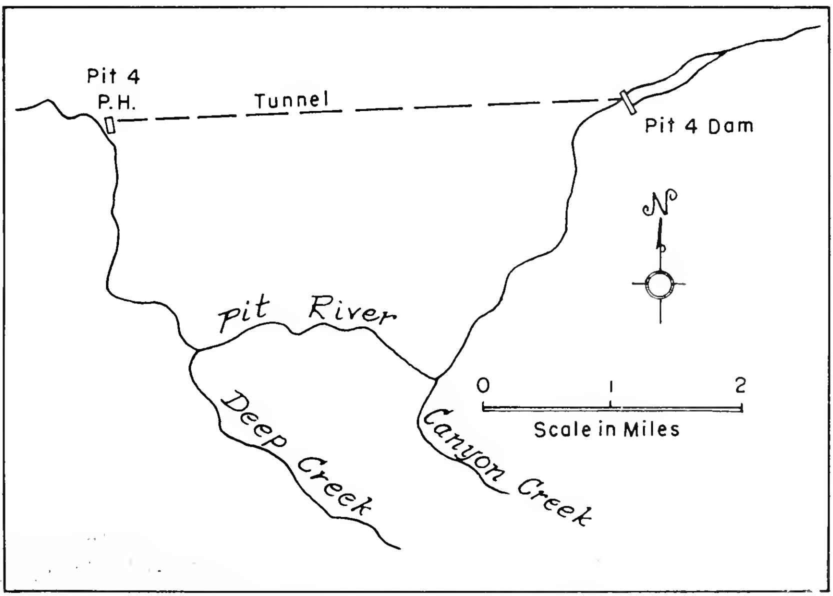

FIGURE 1. Pit River study area from Pit 4 Dam to Pit 4 Powerhouse.

FIGURE 2. Pit River 1,500 below Pit 4 Dam. Release of water at dam 75 c.f.s. Photograph by W. O. Cheney, August, 1955.

The new Pit 4 Powerhouse is at elevation 2,080 feet, the diversion dam at 2,400; distance between them along the channel is about $7\frac{1}{2}$ miles; gradient 8 feet per thousand. Most of the water is diverted out of the river into a 4-mile tunnel leading to the powerhouse. The study described here was undertaken to provide data which might be helpful in solving the problem of how much water should be released into the natural channel between dam and powerhouse for maintenance of fish life.

It was considered probable by those concerned that the required amount of water would not be over 250 c.f.s. Therefore this figure was set as the upper limit for the study, and surveys were made at releases of 50, 100, 150, 200, and 250 c.f.s. Volume was measured by a recording gauge below the dam, and water release was kept constant by automatically operated gates in the dam. The entire river bed from dam to powerhouse was surveyed by a transit traverse, and stations were laid out at 1,000-foot intervals as measured along the center line of the channel. At each station the cross section of the river bottom was carefully profiled with surveyor's level, and the elevation of the water surface in relation thereto measured for each rate of flow. The 40 cross sections thus obtained were plotted to a large scale on paper. The maximum depth, the wetted perimeter (the distance measured along the bottom, including the irregularities, from the water surface on one side to the water surface on the other), and the area of the cross section were scaled from the drawing for each volume of release. The average water velocity through each cross section was calculated from the area so measured and the known volume of flow.

The mean values of the 40 survey sections are shown in Table 1. For those interested in the details the values for each section are contained in Table 2.

TABLE 1

Mean Values of 40 Survey Cross Sections at 1,000-foot Intervals, Pit 4 Dam to Pit 4 Powerhouse

Volume of release at Pit 4 Dam (c.f.s.)	Measurements at various flows				Values at various flows in percent of values at 250 c.f.s.			
	Wetted perimeter (feet)	Maximum depth (feet)	Area in square feet	Water velocity in feet per second	Wetted perimeter	Maximum depth	Area	Water velocity
250	120.2	6.16	340.6	0.982	100	100	100	100
200	114.9	5.90	317.7	0.868	96	96	93	88
150	109.7	5.64	294.8	0.738	91	91	87	75
100	104.6	5.38	272.0	0.567	87	87	80	58
50	95.4	5.10	247.8	0.346	79	83	73	35

As a matter of interest, certain mean values which it was possible to obtain from the 40 cross sections for a volume of 3,500 c.f.s. are shown below:

Volume	3,500 c.f.s.
Width	160.1 ft.
Maximum depth	10.2 ft.
Area	876.0 sq. ft.
Water velocity	4.23 ft. per sec.

It will be noted that the tables do not give directly the values which were the prime objective of the study, that is, the total area of bottom covered by water at each rate of flow. However, the mean wetted perimeter is a direct function of this area. Multiply the value of the mean wetted perimeter at any rate of flow by the total length under study—in this case 40,000 feet, Station O being at the dam—and you have the total submerged area; e.g., 120.2 × 40,000 = 4,808,000 square feet of bottom covered by water at a rate of flow of 250 c.f.s. However, it is the relationships at various volumes of flow that are of interest rather than the absolute values, and since the wetted perimeter is an exact index of these relationships, this linear measure is used throughout as being easier to handle and to visualize than the large values in square feet.

Changes in Wetted Perimeter, Depth, Area, and Velocity

The first important information to be derived from Table 1 is the fact that the wetted perimeter decreases much less rapidly than the volume of flow. Volume at 50 c.f.s. is 20 percent of volume at 250; but wetted perimeter at 50 c.f.s. is 79 percent of what it was at 250 c.f.s. (Table 1). Or to take another example, when volume of 200 c.f.s. is reduced by 50 percent to 100 c.f.s., wetted perimeter is reduced by only 9 percentage points. This means that the total submerged area at 100 c.f.s. is over 90 percent of what it was at 200 c.f.s.; that the total habitat

TABLE 2

Data Obtained at Different Flows From Cross Sections of 40 Stations at 1,000-foot Intervals from Pit 4 Dam to Pit 4 Powerhouse

Station	Wetted perimeter (feet)					Area of cross section (sq. feet)					Velocity (feet per sec.)					Maximum depth (feet)				
	Stream flow (c.f.s) 50	100	150	200	250	Stream flow (c.f.s) 50	100	150	200	250	Stream flow (c.f.s) 50	100	150	200	250	Stream flow (c.f.s) 50	100	150	200	250
Y-1	32.5	35.0	37.5	40.0	42.5	77.0	89.3	101.5	113.7	126.0	0.65	1.12	1.48	1.76	1.98	3.40	3.85	4.25	4.60	4.95
Y-2	70.0	75.5	81.0	86.5	92.0	46.0	76.8	107.6	138.3	169.0	1.09	1.30	1.39	1.45	1.48	1.92	2.37	2.59	2.89	3.18
Y-3	108.0	112.5	116.1	119.5	122.4	205.0	238.8	272.6	306.3	340.0	0.24	0.42	0.55	0.65	0.74	3.10	3.55	3.88	4.20	4.50
Y-4	107.0	113.0	119.0	124.0	129.0	341.0	373.0	405.0	437.0	464.0	0.15	0.27	0.37	0.46	0.51	5.65	5.95	6.23	6.50	6.85
Y-5	83.0	88.0	93.0	97.0	101.0	130.0	158.8	187.6	216.4	245.0	0.38	0.63	0.80	0.92	1.02	3.70	4.07	4.37	4.66	4.95
Y-6	75.0	80.0	85.0	90.0	95.0	120.0	143.8	167.6	191.4	215.0	0.42	0.70	0.89	1.04	1.16	2.65	3.0	3.29	3.57	3.85
Y-7	73.0	76.5	80.0	86.0	90.0	153.0	169.3	185.6	202.0	218.0	0.33	0.59	0.81	0.99	1.14	3.10	3.40	3.60	3.80	4.00
Y-8	90.0	92.0	95.0	98.0	100.0	325.0	341.8	358.6	375.4	392.0	0.15	0.29	0.42	0.53	0.64	6.15	6.34	6.53	6.72	6.90
Y-9	57.0	58.7	60.4	62.2	64.0	312.0	326.3	341.6	356.1	371.0	0.16	0.31	0.44	0.56	0.67	10.10	10.42	10.73	11.04	11.35
Y-10	103.0	109.0	115.0	122.0	138.0	291.0	318.0	345.0	372.0	399.0	0.17	0.31	0.43	0.54	0.81	10.20	10.45	10.70	10.95	11.20
Y-11	160.0	163.0	166.0	169.0	172.0	482.0	504.8	527.6	550.5	573.0	0.10	0.20	0.28	0.36	0.44	4.40	4.65	4.85	4.90	5.05
Y-12	127.5	128.75	130.0	131.75	132.5	597.0	603.3	609.6	615.8	622.0	0.08	0.16	0.25	0.32	0.40	10.35	10.55	10.72	10.89	11.05
Y-13	107.0	109.0	111.0	113.0	115.0	547.0	576.0	604.0	632.0	660.0	0.09	0.15	0.23	0.30	0.38	8.40	8.69	8.92	9.14	9.35
Y-14	82.0	102.0	112.0	122.0	132.0	106.4	126.6	146.8	167.0	187.2	0.47	0.79	1.02	1.20	1.34	2.80	3.09	3.34	3.57	3.80
Y-15	102.0	104.0	106.0	108.0	110.0	478.5	503.7	528.4	551.1	587.3	0.10	0.20	0.28	0.36	0.43	12.95	12.42	12.73	13.03	13.35
Y-16	83.0	93.0	98.0	103.0	107.0	174.0	197.8	221.6	245.4	269.0	0.29	0.51	0.68	0.81	0.93	3.60	3.80	4.00	4.20	4.40
Y-17	157.0	163.0	167.0	171.0	175.0	243.8	276.6	309.1	342.2	374.8	0.24	0.36	0.48	0.58	0.67	4.10	4.36	4.59	4.82	5.05
Y-18	108.0	123.0	132.0	141.0	150.0	114.1	152.8	190.4	228.0	265.6	0.44	0.65	0.79	0.88	0.94	4.25	4.62	4.93	5.24	5.55
Y-19	96.0	88.0	90.0	92.0	94.0	550.0	574.3	598.5	622.7	646.9	0.09	0.17	0.25	0.32	0.39	12.60	13.00	13.30	13.60	13.90
Y-20	82.0	85.25	88.5	91.75	95.0	93.8	113.0	132.0	151.0	170.0	0.53	0.88	1.11	1.32	1.47	2.70	3.00	3.29	3.57	3.85
Y-21	93.0	95.25	97.5	99.75	102.0	338.2	363.0	389.0	414.6	440.2	0.15	0.28	0.39	0.48	0.57	7.04	7.33	7.62	7.94	8.20
Y-22	88.5	89.86	91.24	92.62	94.0	312.0	327.0	342.0	357.0	372.0	0.16	0.34	0.44	0.56	0.67	5.80	6.15	6.50	6.90	7.30
Y-23	152.0	157.0	162.0	167.0	172.0	697.0	727.0	752.0	778.0	804.0	0.07	0.11	0.20	0.27	0.31	14.6	15.6	16.6	17.6	18.6
Y-24	116.0	126.0	137.0	149.0	161.0	159.0	174.0	192.0	210.0	228.0	0.34	0.57	0.78	0.95	1.09	2.4	2.6	2.8	3.0	3.2
Y-25	45.0	51.0	57.0	64.0	72.5	39.8	53.3	66.8	80.3	93.8	1.26	1.88	2.25	2.19	2.68	2.15	2.30	2.55	2.8	3.15
Y-26	105.5	106.0	106.5	106.9	107.5	918.5	936.0	953.5	971.0	988.6	0.05	0.11	0.16	0.21	0.25	14.0	14.23	14.43	14.64	14.85
Y-27	121.5	129.1	137.1	144.8	152.5	233.0	243.0	252.0	261.0	270.0	0.24	0.41	0.60	0.77	0.93	3.5	3.73	3.96	4.18	4.4
Y-28	132.0	142.0	151.0	159.5	168.0	141.0	188.0	235.0	282.0	332.0	0.35	0.53	0.61	0.71	0.75	4.0	4.19	4.36	4.53	4.7
Y-29	90.0	98.0	105.5	113.0	120.0	77.0	94.0	110.0	125.0	140.0	0.65	1.06	1.36	1.60	1.79	3.6	3.97	4.32	4.66	5.0
Y-30	63.0	110.0	122.0	134.0	145.0	80.0	100.0	120.0	140.0	160.0	0.63	1.00	1.25	1.43	1.56	1.54	1.78	2.02	2.26	2.50
Y-31	129.0	133.0	137.0	141.0	145.0	240.0	275.0	309.0	343.0	377.0	0.24	0.36	0.49	0.58	0.66	4.40	4.64	4.86	5.08	5.30
Y-32	122.0	127.5	133.0	139.5	145.0	107.0	122.0	137.0	152.0	166.0	0.47	0.82	1.09	1.32	1.51	2.10	2.25	2.40	2.55	2.70
Y-33	80.0	87.5	95.0	102.5	110.0	98.0	120.0	142.0	164.0	186.0	0.51	0.83	1.06	1.22	1.34	2.80	3.08	3.33	3.57	3.80
Y-34	132.0	143.0	154.0	165.5	177.0	111.0	135.0	159.0	183.0	207.0	0.45	0.71	0.94	1.09	1.21	2.10	2.31	2.19	2.67	2.85
Y-35	88.0	89.5	91.0	92.5	94.0	199.0	225.0	250.0	276.6	302.4	0.25	0.44	0.60	0.72	0.83	3.50	3.65	3.94	4.22	4.50
Y-36	88.0	95.0	102.0	112.0	118.0	56.3	78.0	99.6	121.2	142.8	0.89	1.28	1.51	1.65	1.75	1.60	1.81	1.98	2.14	2.30
Y-37	71.0	73.0	75.0	77.0	79.0	157.0	171.2	191.1	208.4	226.0	0.32	0.57	0.78	0.96	1.11	3.90	4.10	4.30	4.50	4.70
Y-38	107.5	111.9	116.2	120.6	125.0	271.0	302.2	333.4	364.6	396.0	0.18	0.33	0.45	0.55	0.63	4.65	4.94	5.20	5.45	5.70
Y-39	138.0	148.0	156.0	162.0	168.0	157.0	170.5	181.0	197.0	211.0	0.32	0.59	0.82	1.02	1.18	2.35	2.53	2.66	2.78	2.90
Y-40	66.0	72.5	80.0	87.5	95.0	180.0	207.0	234.0	261.0	288.0	0.28	0.48	0.72	0.77	0.87	2.10	2.31	2.52	2.69	2.85
Mean values	95.4	104.6	109.7	114.9	120.2	217.8	272.0	291.8	317.7	340.6	0.35	0.57	0.73	0.87	0.98	5.10	5.38	5.64	5.90	6.16

accessible to bottom organisms is over 90 percent of what it was; and that, other things being equal, the total bottom population at 100 c.f.s. would still be over 90 percent of what it was at 200 c.f.s.

However, other things are not equal. Depth, which may be considered an index of shelter for fish, closely parallels wetted perimeter in its percentage reduction; and area of cross section, an index of the total amount of space available for aquatic life, is probably not a limiting factor as volume varies over the range considered here. But mean velocity of the water (Table 1) shows a very much greater percentage reduction; it is in this factor that really striking and significant changes occur. Studies have been made on the relationship between bottom-dwelling organisms and water velocity (Needham and Usinger, 1956), but a great deal is still unknown. Moreover, the figures we have here give at best only the average velocity through each cross section. What actually happens is that the water velocity changes over every single point of the channel bottom. About all we can say with certainty is that these changes undoubtedly affect the population of bottom-dwellers, not only quantitatively but qualitatively, and thus indirectly affect the fish populations. Also, in a mixed fish population such as we have here, including suckers (*Catostomus occidentalis*), hardheads (*Mylopharodon conocephalus*, a large cyprinid), carp (*Cyprinus carpio*), and other rough fish in addition to the rainbow trout, changes in velocity may affect the various species differently. Some species may be benefited, others may be injured—thus bringing about a redistribution of species, both in locality and in proportional numbers.

Temperature

Change in water velocity also had an effect on water temperature, and thus indirectly on fish. The effect of water temperature was not a part of this particular study, but did form an important part of the overall program. When this channel carries 3,500 c.f.s. the water traverses the distance from dam to powerhouse in about three hours. With volume at 250 c.f.s., and mean velocity at approximately 1 foot per second (Table 1), it takes 11 hours for the water to cover this distance, meaning that it is exposed to the sun during the full high-temperature period of each day—and this in a location where peak summer air temperatures reach 100 degrees F. in the shade. The heating potential of the sun thus exerts a much greater effect at 250 c.f.s. than at 3,500 c.f.s.

Accretion

At this point we must mention a factor which, while it does not affect the overall situation as shown in the tables, must not be left out of the picture. This is the accretion, or inflow of water, into the channel between dam and powerhouse. This, by stream ganging, was found to be approximately 50 c.f.s. at the time of the study. The largest single increment was Deep Creek near Station Y-29 with six c.f.s. Since accretion remained constant at all volumes studied, its proportional effect differed at different volumes.

Theoretically, it would have been possible to adjust the volume of release so that the flow would have been the same at each station at time of measurement, but practically this was not possible and, in fact, was not desirable. This accretion is normal in this river, and the objective of the surveys was to show the normal changes in this river below the dam as the volumes of water released at the dam change.

Effect of the accretion on water temperature, while again not a direct part of this study, is so important that it deserves mention. Maximum water temperatures at the dam are close to 68 degrees F. Maximum temperatures of the tributary water were much below this: Deep Creek 55 degrees F., and the springs and underground seepages which contributed much of the inflow probably less. Accretion water therefore had a cooling influence. And this cooling influence increased as the volume of flow decreased. At 200 c.f.s. release at dam, the cool inflowing water only added 25 percent to the volume, whereas at 50 c.f.s. the cool inflowing water added 100 percent. And where a much greater increase in water temperature on its way down the channel at 50 c.f.s. as contrasted to 200 c.f.s. might have been expected, the influence of the inflowing cool water was such that there was no significant difference in temperature at the different rates of flow. Maximum water temperature between dam and powerhouse at 200 c.f.s. was 71 degrees F., at 100 c.f.s. 70 degrees F., at 50 c.f.s. 70½ degrees F.

FEATHER RIVER STUDY

Similar surveys were carried out on the North Fork of the Feather River, a smaller, faster stream (gradient 12 feet per 1,000 in the survey section). Twenty-five survey stations were established at 500-foot intervals, and measurements made at controlled flows of 140, 200, 300, and 800 c.f.s. The figures for the means are shown in Table 3.

TABLE 3

Mean Values of 25 Survey Cross Sections at 500-foot Intervals, North Fork Feather River, Gansner Bar to Queen Lily Camp Ground

	Measurements at various flows					Values at various flows in percent of values at 300 c.f.s.				
Volume of flow (c.f.s.)	Wetted perimeter (feet)	Width (feet)	Maximum depth (feet)	Area in square feet	Water velocity in feet per second	Wetted perimeter	Width	Maximum depth	Area	Water velocity
800	86.7	83.6	4.6	210.0	4.08					
300	75.1	72.4	3.6	138.0	2.34	100	100	100	100	100
200	71.4	68.6	3.2	118.0	1.86	95	95	89	85	79
140	67.5	65.5	2.8	96.0	1.60	90	91	78	70	68

The flow of 800 c.f.s. was included in the survey because it is not far from the estimated normal uncontrolled summer flow. Since it is outside of the range used on the Pit it is not of value for comparison with that river, and is therefore omitted from the percentage figures, which have been calculated for 300, 200, and 140 c.f.s. Comparing these with Table 1, a striking similarity is seen between the percentage figures at proportional rates of flow, and it is probable that the picture would be much the same for many fast-flowing mountain streams. It would, of course, be very different in flat, slow-moving rivers.

SUMMARY

This study was part of an investigation carried out by the Pacific Gas and Electric Company in Northern California aimed at providing data as an aid in determining the amount of water to be released at hydroelectric diversion dams for maintenance of aquatic life in the channel below the dam. In the Pit River, surveys were made at 40 stations at 1,000-foot intervals between Pit 4 Dam (elevation 2,400 feet) and Pit 4 Powerhouse (elevation 2,080 feet). At each of these stations a cross section of the river bottom was carefully profiled by instruments, and the elevation of the water surface in relation thereto measured for each rate of flow. The 40 cross sections thus obtained were then plotted to a large scale on paper; the maximum depth, the wetted perimeter (the distance measured along the bottom, including the irregularities, from the water surface on one side to the water surface on the other), and the areas of the cross section were scaled from the drawing for each volume of release; and average water velocity through each cross section was calculated from the area so measured and the known volume of flow. From these figures the mean values of the 40 survey sections were computed.

It was considered probable by those concerned that the required amount of water would be not over 250 cubic feet per second. Surveys were therefore made at 50, 100, 150, 200, and 250 c.f.s.

It was found that wetted perimeter decreases much less rapidly than volume of flow. Changes in maximum depth and area of cross section closely parallel wetted perimeter in percentage reduction, but mean velocity of water shows a very much greater percentage reduction.

On the Feather River, a smaller stream with a steeper gradient, surveys of this kind gave very similar results.

REFERENCE

Needham, Paul R., and Robert L. Usinger
1956. Variability in the macrofauna of a single riffle in Prosser Creek, California, as indicated by the Surber sampler. Hilgardia, vol. 24, no. 14, pp. 383-409.

MOVEMENT OF THE RING-NECKED PHEASANT IN THE SUTTER BASIN OF CALIFORNIA[1]

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INTRODUCTION

California wildlife workers have gathered life history and other information since 1946 on the ring-necked pheasant (*Phasianus colchicus*) so as to make sound recommendations for the management of this bird. This study covered the influence of intensive agricultural practices along with man's other activities on pheasants. One of the results was a determination of pheasant movement during the periods of summer to the fall hunting season and from summer to summer.

Most of the work accomplished in the Midwest by Leopold, Lee and Anderson (1938), Grondahl (1953), and Weston (1950) provides information on winter and spring dispersal where severe winter conditions may exist. In California, where this study was conducted, winter conditions are mild and without snow, and should have a minimum influence on the movement of pheasants.

Band returns from pen-reared pheasants taken during the hunting season were used to determine their movements until wild trapping began in 1949 (Harper et al. 1951). Returns from pen-reared birds were almost entirely from hunters' kill. This does not present a complete picture of the movement of game farm birds and would not be representative of wild pheasants.

The movement of pheasants under study was placed into four groups: (1) movement of retrapped wild birds; (2) movement of banded wild birds taken during the hunting season; (3) movement of retrapped game farm birds; (4) movement of game farm birds taken during the hunting season.

Movement information presented in this report was gathered from 1952 through 1958. During this seven-year period, a total of 20,286 pheasants was captured one or more times in the Sutter Basin. All were examined for bands, classified as to sex and age, bands placed on unbanded birds, and all birds were released in the same field of capture. A total of 2,674 returns either from retrapping or hunting season checks was analyzed for movement. Of these, 1,982 were wild pheasants and 692 were game farm birds.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Department of Fish and Game personnel who aided Project 22-R in gathering the

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information presented in this study. Special thanks are given to Project 30-R personnel who assisted in gathering hunting season information during the past seven years; to project leader H. T. Harper who was in charge of the study in 1949-50 and from 1958 to date, and to C. M. Hart, former project leader (1951-1957).

Study Area

This work was done in the Sutter Basin. It is approximately 68,000 acres of reclaimed marsh land located in the southwest portion of Sutter County in the center of the Sacramento Valley (Figure 1).

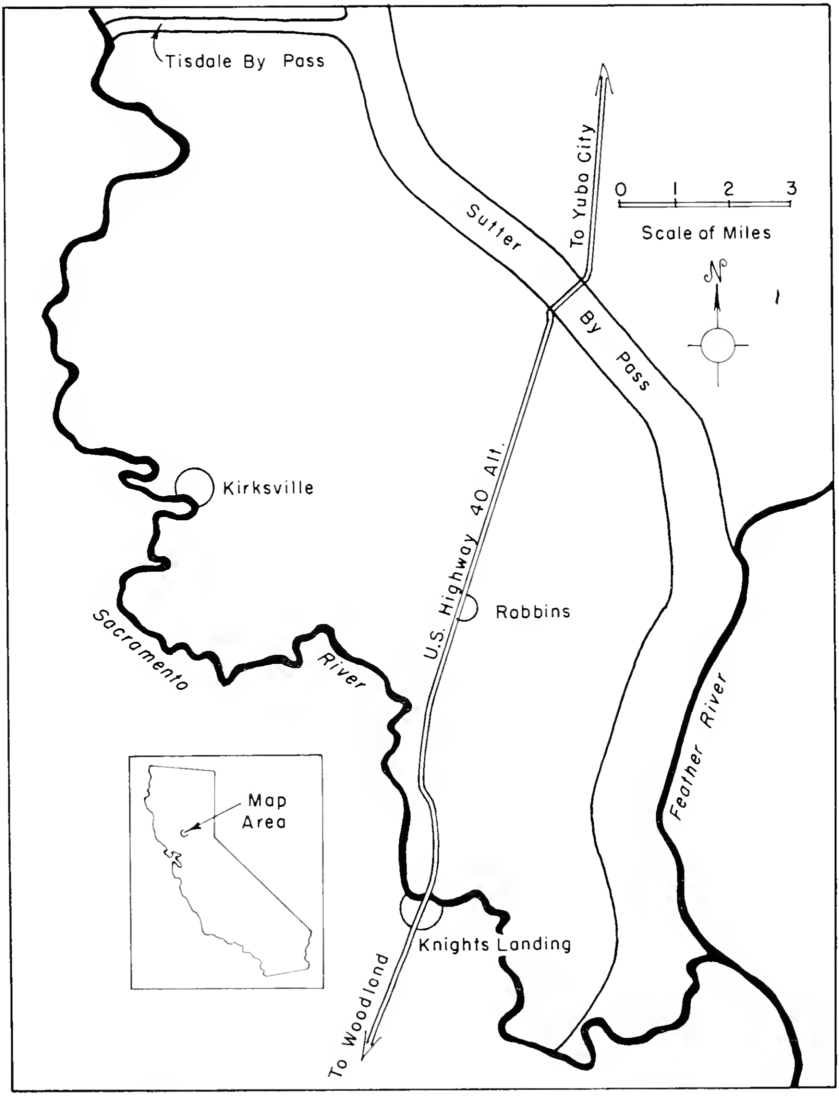

FIGURE 1. Sutter Basin pheasant study area. Drawn by Cliffa Corson.

The area is typical pheasant habitat in the rice-growing region of California. The major agriculture crops are rice, wheat, barley, milo, safflower, beans, and alfalfa. Based on population indices, it was calculated that the Sutter Basin supported 30,000 to 40,000 pheasants during the late summer.

Hunting Regulations and Hunting Pressure

During this study, hunting regulations have had major changes in bag limits, sexes allowed, and length of season. During 1952-54, the regular season was 10 days and allowed two cocks per day and 10 per season. In 1955, one hen was allowed in the season bag of 10; the season was lengthened to 16 days, and the daily bag remained the same as before. During 1956-57 the one hen allowed and length of season remained the same, but the daily bag limit of cocks was raised to four after the first two days. In 1958, the same regulations were in effect except the one hen allowed in the bag was terminated.

Licensed pheasant clubs located in the study area had a season and bag limit different from the general statewide regulations. These clubs were allowed a 75-day season and a daily bag of six pheasants of either sex by virtue of stocking prescribed numbers of pen-reared birds.

Hunting pressure varied in the study area from no hunting on certain farms to light to moderate on licensed pheasant clubs and to a heavy concentration of one hunter per 10 acres on an intensively hunted state co-operative hunting area. The co-operative hunting area was terminated in 1954. Hunter pressure in the Sutter Basin was representative of that which occurs in other parts of the Sacramento Valley.

METHODS

Movement data were obtained from 1952 to 1958 by two methods: (1) trapping and retrapping wild and pen-reared birds by the spotlight method (Harper et al, 1951) during the summer and fall months; (2) band returns of wild and pen-reared birds obtained from hunting season bag checks.

Movement of retrapped birds was recorded to the nearest 0.5 mile between the center of the field of original capture to the center of the field in which the bird was again caught or killed. A movement was measured to the nearest 0.5 mile to reduce the recording that would be necessary if a smaller distance was used. Also, the workers experienced difficulty in keeping oriented at night, making more exact recording virtually impossible.

The pattern in which the fields were sampled was influenced by farming conditions which limited the operation of the spotlighting truck and equipment.

RESULTS

Retrapped Wild Pheasants [2]

From 1952 to 1958 inclusive, 19,240 wild birds were trapped, banded, and released in the field of capture in the Sutter Basin. A total of 1,505 (7.8 percent) were recaptured the same or subsequent years following the initial banding. Of the recaptures, 1,422 (94 percent) were re-

[2] A bird retrapped once was caught twice, retrapped twice caught three times, etc.

trapped once; 79 (5.3 percent) were retrapped twice; three, three times; and one, four times.

Pheasants Retrapped Once

Average movement of the sex and age classes was placed into five groups of similar monthly and yearly periods occurring between the original banding and recapture date, as shown in Table 1.

The average movement of pheasants in the monthly time periods is very limited. Adult males remained constant in their movement of approximately 0.3 to 0.5 mile during the summer. Juvenile males show movement up to 0.9 mile for the three monthly periods. Adult females traveled up to 0.9 mile during this time and juvenile females moved up to 1.2 miles. Overall the juveniles traveled up to one mile whereas adults moved up to 0.8 mile (Table 1).

Birds retrapped the following summer, or approximately one year after the initial capture, showed an average distance traveled of 1.3 miles. The birds that were banded as adults moved 0.7 mile in comparison to 1.8 miles for those banded as juveniles.[3] Cocks and hens of separate age classes also showed different distances traveled (Table 1).

The maximum distance traveled during the period for any individual bird was 13 miles. This was a juvenile female banded in 1954 and recaptured in 1955. Only 24 birds (1.7 percent) of 1,355 were recaptured more than five miles from the original banding site during this study.

Pheasants Retrapped Two or More Times

During the study, some pheasants were retrapped as many as four times. Movement of these was measured from the point of original capture to points of subsequent retrapping.

Twenty-five birds were recaptured twice the same summer over a two-month period. Of the 25 pheasants, 16 were first retrapped in the original field of banding and again eight of the 16 were taken for the third time in the same field. This shows that even with repeated handling during trapping the birds do not leave the immediate area.

Twenty-two birds retrapped twice after an elapsed period of one year from the first banding had an average movement of 1.3 miles in radius.

Eleven birds were retrapped twice after being in the field two and three years from the time of original capture. These showed an average of 1.7 miles movement in radius from the original banding site.

Sixteen birds were recaptured the same year banded and averaged 0.5 mile from the banding site. These same birds were retrapped one to three years later and an additional movement averaging 1.6 miles was recorded.

An average movement of 0.7 mile was recorded for five pheasants recaught one year later and these were again recaptured in two to three years and moved an additional 2.0 miles.

Three birds, all hens, were retrapped three times during the study and averaged 0.7 mile from the field of original banding.

Only one bird banded as an adult hen was recaptured four times. This bird was recaptured twice the same year; twice the following year; and was two miles from the original banding site on final capture.

[3] Juveniles have become adults by their second summer and will be referred to as juveniles throughout the text and tables to avoid needless complication.

TABLE 1

Average Miles Traveled of Retrapped Wild Pheasants in Sutter Basin, 1952-1958

Age when banded	Sex	Elapsed time between banding and recapture													
		0-1 month		1-2 months		2-3 months		Same year*		One year		2-5 years		Total	
		Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles
Adults	Males	36	0.3	10	0.5	3	0.3	49	0.3	17	0.7	4	1.4	70	0.5
Juveniles	Males	250	0.3	65	0.9	18	0.8	333	0.5	84	1.5	3	2.2	420	0.7
Adults	Females	101	0.5	41	0.9	9	0.6	151	0.6	153	0.7	97	0.9	401	0.7
Juveniles	Females	214	0.4	69	1.2	9	1.0	292	0.6	157	1.9	82	1.8	531	1.2
Adults	Males and females	137	0.5	51	0.8	12	0.5	200	0.6	170	0.7	101	0.9	471	0.7
Juveniles	Males and females	464	0.4	134	1.0	27	0.9	625	0.5	241	1.8	85	1.8	951	1.0
All sexes and ages		601	0.4	185	1.0	39	0.8	825	0.5	411	1.3	186	1.3	1,422	0.9

* Combined totals of the first three elapsed time periods.

TABLE 2

Comparison of Wild Banded Pheasant Movement During Two Periods of the Hunting Season, 1953-1958

Age when banded	Sex	Killed the same year banded						Killed 1-4 years after banding					
		First weekend of season		Balance of season		Total		First weekend of season		Balance of season		Total	
		Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles
Adults	Males	30	1.1	22	1.1	52	1.1	5	1.4	6	0.6	11	1.0
Juveniles	Males	171	1.3	124	1.4	295	1.3	21	1.7	20	2.2	41	1.9
Adults	Females	5	3.1	10	0.6	15	1.4	9	0.9	9	1.3	18	1.1
Juveniles	Females	23	1.9	8	1.1	31	1.7	9	1.7	5	1.7	14	1.7
Adults	Males and females	35	1.4	32	0.9	67	1.1	14	1.1	15	1.0	29	1.1
Juveniles	Males and females	194	1.3	132	1.3	326	1.3	30	1.7	25	2.1	55	1.9
All sexes and ages		229	1.3	164	1.3	393	1.3	44	1.5	40	1.7	84	1.6

Movement of Wild Pheasants Obtained From Band Returns

Movement of wild pheasants taken during the hunting season was computed for the first weekend of the season and for the remaining 8 or 14 days (depending on the length of season), to determine if hunting pressure had an effect on movement. No difference was noted in the movement of birds killed the same year banded. On the first weekend of the season 229 returns from birds showed an average movement of 1.3 miles; returns from 164 birds in the remainder of the season showed an average of 1.3 miles (Table 2).

From returns of birds that were in the field one to four years after banding, 44 killed during the first weekend of the season showed an average movement of 1.5 miles from the original banding area, and 40 pheasants killed during the balance of the season moved an average of 1.7 miles (Table 2).

A minor difference was recorded for movement of pheasants banded one month to one year before being bagged. An overall average of 1.4 miles of movement was recorded for birds banded one to three months before the hunting season as compared to 0.9 mile for a similar period for retraps (Tables 3 and 1).

During the Sartain-McManus study a resident juvenile wild cock banded 3½ months before the hunting season was taken 15 miles away; all other returns from 344 band returns from wild birds were from six miles or less from the point of banding (Harper et al, 1951).

An average movement of 1.3 miles was recorded for adults and juveniles banded one to six months before the hunting season and taken during the season. This compares with 0.5 mile for birds retrapped after being in the field for a similar period of time. Birds banded one to five years before being shot averaged 1.6 miles distance from the banding site; and for a similar period of time, those taken by retrapping averaged 1.3 miles.

Movement of Game Farm Pheasants Determined From Trapping

Of several thousand pen-reared pheasants released on licensed pheasant clubs, 474 were trapped during the Sutter Basin study, and they afforded the opportunity to check the dispersal of birds raised artificially. The exact field of liberation was not obtainable for these releases, but since the clubs are small (500 to 1,500 acres) the movement was measured from the boundary of the club to the center of the field of recapture.

An average of 0.4 mile movement for birds recaptured the same year as released indicated that they remained in the immediate vicinity of the club (Table 4). Birds trapped the year following liberation indicated a movement similar to the wild bird population. The average distance traveled for all ages and sexes in the field one year was 1.1 miles. Twenty-seven birds were retrapped after being in the field two to four years. These showed an average movement of 1.1 miles. The maximum distance recorded for birds in this group was 8.5 miles.

Pen-reared birds, captured the same year liberated, showed about the same movement that wild birds showed when retrapped the same year they were initially banded (Tables 1 and 4). Game farm birds recaptured after one or more years in the field showed a movement of

TABLE 3

Movement of Wild Banded Pheasants Obtained by Hunting Season Band Returns, 1953-1958

Age when banded	Sex	Elapsed time between banding and when killed												Total	
		1-3 months		3-4 months		4-6 months		Same year*		One year		2-4 years			
		Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles
Adults	Males	21	1.6	27	0.7	4	0.6	52	1.1	10	0.7	1	3.5	63	1.0
Juveniles	Males	141	1.3	119	1.3	35	1.3	295	1.3	31	2.0	10	1.9	336	1.4
Adults	Females	7	2.2	7	0.8	1	0.0	15	1.4	11	1.2	7	1.0	33	1.2
Juveniles	Females	12	1.7	11	1.6	8	1.9	31	1.7	9	1.6	5	1.9	45	1.7
Adults	Males and females	28	1.7	34	0.8	5	0.5	67	1.1	21	1.0	8	1.3	96	1.1
Juveniles	Males and females	153	1.3	130	1.4	43	1.4	326	1.3	40	1.9	15	1.9	381	1.4
All sexes and ages		181	1.4	164	1.2	48	1.3	393	1.3	61	1.5	23	1.7	477	1.4

* Combined totals of the first three elapsed time periods.

TABLE 4

Average Miles Traveled by Retrapping Game Farm Birds,* 1952-1958

Age when banded	Sex	Elapsed time between liberation and recapture												Total	
		0-1 month		1-2 months		2-3 months		Same year**		One year		2-4 years			
		Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles
Adults	Males	1	0.5	1	0.0	2	0.3	4	0.3	8	0.9	1	0.0	13	0.6
Juveniles	Males	69	0.2	56	0.2	11	0.1	136	0.2	23	1.0	0	0.0	159	0.3
Adults	Females	7	0.6	31	0.6	10	0.4	48	0.6	20	0.9	10	1.3	78	0.7
Juveniles	Females	41	0.3	74	0.5	7	0.5	122	0.4	86	1.2	16	1.1	224	0.8
Adults	Males and females	8	0.6	32	0.6	12	0.4	52	0.5	28	0.9	11	1.2	91	0.7
Juveniles	Males and females	110	0.3	130	0.4	18	0.2	258	0.3	109	1.2	16	1.1	383	0.6
All sexes and ages		118	0.3	162	0.4	30	0.3	310	0.4	137	1.1	27	1.1	474	0.6

* Pen-reared birds released on licensed pheasant clubs.
** Combined totals of the first three lapsed time periods.

1.1 miles from where they were liberated; wild birds traveled 1.3 miles (Tables 1 and 4).

Movement of Game Farm Birds Obtained From Band Returns

Movement of 218 game farm pheasants that were released on licensed pheasant clubs and killed on adjacent areas during the regular hunting season indicated the dispersal was not greater than that of banded wild pheasants. The maximum distance of a return was 12 miles from the point of liberation: however, the average distance was between one and two miles. Table 5 presents movement of game farm birds that were taken on areas adjacent to licensed pheasant clubs. Since bag checks to obtain movement data were not conducted on these clubs, game farm birds killed there are not included in the table.

DISCUSSION

Unsuitable field conditions for spotlighting, and limited time, prohibited retrapping in some of the same fields year after year. Of the birds captured two or more times, 556 (41 percent) were taken from fields that were not reworked after the original banding; consequently, these birds had to show a movement or they never would have been retrapped. However, 866 (59 percent) birds were retrapped that had a chance to show no movement because the fields were re-entered after the original banding. As a result, if a field had been re-entered a higher percentage of the birds showing no movement would be retrapped than those moving, because all fields could not be entered. Therefore, the average movement falls somewhere between the group retrapped in fields other than those not reworked and the group retrapped in fields worked two or more times. The overall movement of birds where the fields of original trapping were re-entered averaged 0.5 mile, whereas movement of birds where the fields of original capture were not re-entered averaged 1.5 miles (Table 6).

It is conceivable that a bird could move one-half mile within a quarter section field, and trapping records would show no movement. Also, it is possible a bird moving across the road into a neighboring field would show one-half mile traveled. However, for all practicable purposes the errors thus introduced are somewhat compensating and because of this are believed to be of minor importance.

Calculations showed that the percentage of juveniles retrapped in the same field banded for the one-year elapsed time period was about one-third less than that of adults. This again shows juveniles move greater distances, probably seeking a home range.

A greater movement of adult hens and juveniles over adult cocks during the summer months probably is caused by the brooding and caring for the young. During the search for food and adequate cover the hen is disturbed by farming practices that overnight can change the habitat from one of adequate food and cover to one of a plowed or burned field.

Movement of pheasants in the Sutter Basin is probably influenced more by farming practices than any one other factor. In this area crop rotation and double cropping are practiced, which disturbs the

TABLE 5

Movement of Game Farm Pheasants * Obtained by Hunting Season Band Returns, 1953-1958

Age when banded	Sex	Elapsed time between banding and return															
		0-1 month		1-2 months		2-3 months		3-4 months		4-5 months		Same year**		One year		Total	
		Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles
Juveniles	Males	97	1.1	13	1.4	34	1.2	22	2.5	2	2.3	168	1.4	9	2.2	177	1.4
Juveniles	Females	14	0.7	3	0.7	3	3.2	16	2.2	2	1.8	38	1.6	3	1.2	41	1.5
	Totals	111	1.1	16	1.3	37	1.4	38	2.3	4	2.0	206	1.1	12	1.9	218	1.4

* Pen-reared birds released on licensed pheasant clubs.
** Combined totals of the first five lapsed time periods.

TABLE 6

Comparison of Miles Traveled by Retrapped Wild Pheasants

Age when banded	Sex	Movement where the fields of original capture were re-entered												Movement where the fields of original capture were not re-entered							
		Time elapsed between banding and recapture									Total			Time elapsed between banding and recapture							
		Same year			One year			2-5 years						Same year		One year		2-5 years		Total	
		Sample size	Avg. miles	% w/o movm't*	Sample size	Avg. miles	% w/o movm't	Sample size	Avg. miles	% w/o movm't	Sample size	Avg. miles	% w/o movm't	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles	Sample size	Avg. miles
Adults	Males	44	0.3	64	3	0.0	100	1	0.0	100	48	0.3	67	5	0.5	14	0.9	3	1.5	22	0.9
Juveniles	Males	263	0.3	63	27	0.7	41	3	2.2	33	293	0.4	60	70	0.9	57	1.9	0	0.0	127	1.4
Adults	Females	122	0.5	52	68	0.4	57	42	0.5	50	232	0.5	53	29	1.2	85	1.0	55	1.2	169	1.1
Juveniles	Females	224	0.5	54	46	1.0	33	23	1.0	35	293	0.6	49	68	1.0	111	2.3	59	2.2	238	1.9
Adults	Males and females	166	0.4	55	71	0.3	59	43	0.5	51	280	0.4	55	34	1.1	99	1.0	58	1.3	191	1.1
Juveniles	Males and females	487	0.4	59	73	0.9	36	26	1.1	35	586	0.5	55	138	1.0	168	2.2	59	2.2	365	1.7
All sexes and ages		653	0.4	58	144	0.6	47	69	0.7	45	866	0.5	55	172	1.0	267	1.7	117	1.7	556	1.5

* Percent of sample size without movement or recaptured in the field where first caught.

cover present during the time pheasants are hatched up to late summer and which may cause a shift in the population.

Weather factors probably have little influence on movement since winters are mild and without snow. No population shifts were recorded or observed during the study which could be attributed to weather, indicating pheasants were not harassed by this natural factor.

Game farm pheasants liberated on this study area, and surviving until trapped or killed, remained within 1.4 miles of the release site during their first year in the field. Therefore, pen-reared pheasants do not add much to the hunter's bag on areas except where they are liberated. A very limited number survive until the second year when some dispersal was noted.

Although wild pheasants are disturbed during the hunting season, their movements apparently are rather restricted in trying to elude the hunters. Though harassed during this period, most surviving pheasants apparently return daily or remain in their home range.

SUMMARY

The Sutter Basin, Sutter County, consisting of approximately 68,000 acres of agricultural land typical of the Sacramento Valley pheasant range was used as a study area from 1952-1958.

Movements of 2,674 pheasants, of which 1,982 were wild birds and 692 were pen-reared, were analyzed during this period. Two methods used to check the movements were, retrapping banded wild and game farm pheasants and hunting season band returns.

Movement was placed into four categories: (1) retrapped wild birds during the summer, and from summer to summer; (2) wild birds obtained from hunting season returns; (3) retrapped game farm birds; (4) game farm pheasants obtained from hunting season returns.

Distances were measured to the nearest 0.5 mile. Adult males traveled 0.3 to 0.5 mile during the summer period of trapping. Juvenile males moved up to 0.9 mile during the same summer of trapping. Adult females moved up to 0.9 mile and juvenile females 1.2 miles.

Birds banded as juveniles and retrapped the following year as adults moved an average of 1.8 miles, whereas adults retrapped the following year were 0.7 mile away.

The maximum distance that any one bird moved this study was a wild juvenile female retrapped 13 miles from the original banding site.

Only 1.7 percent of all wild birds sampled were five miles or more from point of capture.

Of the birds retrapped two to five years later, 45 percent were caught in the same field in which they were banded, which is compared to 47 percent for retraps one year later.

An overall average of 1.3 miles was recorded for birds killed the same year banded. This increased to 1.6 miles for birds killed one to four years after banding. Approximately 10 percent were bagged in the same field in which they were banded.

Retrapped game farm pheasants were comparable to retrapped wild pheasants, in that neither group disperses to any extent. Therefore,

planted birds provide little hunting on areas other than where they are released.

No differential movement was caused by hunting pressures between the opening weekend and the remainder of the season.

The movement of pheasants in the Sacramento Valley is probably influenced more by agricultural practices than by any other factor.

LITERATURE CITED

Grondahl, C. R.
1953. Winter behavior of the ring-necked pheasant, *Phasianus colchicus*, as related to winter cover in Winnebago Co., Iowa. Iowa State College Journal of Science, vol. 27, no. 4, pp. 447-465.

Harper, Harold T., C. M. Hart and D. E. Shaffer
1951. Effects of hunting pressure and game farm stocking on pheasant populations in the Sacramento Valley, California, 1946-49. Calif. Fish and Game, vol. 37, no. 2, pp. 141-176.

Leopold, A., O. S. Lee and H. G. Anderson
1938. Wisconsin pheasant movement study, 1936-1937. Jour. Wildlife Mgt., vol. 2, no. 1, pp. 3-12.

Weston, H. G.
1950. Winter behavior and spring dispersal of the ring-necked pheasant, *Phasianus colchicus*, in Emmett Co., Iowa. Unpublished Ph.D. Thesis, Iowa State College Library, Ames, Iowa.

A FIELD STUDY OF THE RELATIVE VISIBILITY OF VARIOUS COLORS[1]

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PREFACE

This article represents a departure from our regular procedure of reporting the results of research relating to the management of game fish and mammals.

Wildlife management agencies for years took the position that such matters as the promotion of hunter safety did not fall within the purview of their responsibilities. As the number of hunters increased a widespread reversal in the traditional attitude took place. Youth training programs were developed and numerous laws were passed in a concerted effort to make hunting a safer recreation.

Some states have for years required by law that red outergarments be worn when hunting, especially while pursuing deer and other big game.

Laboratory findings by the California Optometric Association and others indicated that the traditionally recommended red garments might not be the most easily identifiable color that it commonly was believed to be.

The following report details the results of research into the values of the several colors as they relate to identification of objects in the hunting field and thusly to hunter safety.—*Seth Gordon, Former Director, California Department of Fish and Game.*

INTRODUCTION

There are two points of view relative to hunting apparel that is safest to wear in the field: first, that a person should wear camouflage, on the theory that "If they can't see you, they can't shoot you"; second, that the hunter should wear the most readily identifiable costume so that he can easily be seen.

The test directors believe that the first point of view is fallacious. Since movement is always involved in hunting, and since movement

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cannot be camouflaged, any hunter is always in danger of being mistaken for game when so garbed. An exception to this would be when hunting waterfowl, for here camouflage is of paramount importance, and no movement is involved. For most hunting situations, however, the authors believe that, since the hunter cannot become invisible while moving, he should wear the most readily identifiable costume.

In September, 1955, a meeting was arranged by the California Optometric Association with representatives of the National Rifle Association and the California Department of Fish and Game in order to discuss color as a factor in hunter safety.

The fact that eight percent of the male population is color "blind" indicated that the widely recommended use of red as a protective color for hunters should be investigated. In California approximately 50,000 hunters are color blind and nationally about 1,360,000. Further, hunter casualty reports have indicated that red had not served the public well as a protective color.

Dr. Gordon Walls of the School of Optometry, University of California, explained that red might appear brown, olive drab or even black to a red-blind person. He also pointed out that the confusion of colors would be equally great for the green-blind person. Since only one person out of 13,000 is blue-blind, this type of color blindness was not considered important to the problem involved.

He further stated that in poor light, fog, early morning or late evening light, the color blind are more likely to make mistakes in color identification than under bright illumination.

Dr. Walls verified the claim of the California Optometric Association that the only color the color blind can readily identify is a golden yellow. This verification was based on laboratory experiments which he had conducted over a number of years.

Mr. Lahr brought to the attention of the group the fact that occasionally persons are mistaken for black bears or other animals, and are shot while hunting.

A further discussion of the way the color red is seen revealed that red is the only color with no achromatic interval. That is, red appears either as red or black to those with normal color vision, depending on the amount of light. Also, red is the first color to disappear with fading light and the last color to become visible as the light increases.

Further discussion among the authors about the properties of color and its use as a protective device, revealed that there was a definite need for field studies to test laboratory theories.

In a search of historical references, no research data or other reason was found as to why red has been used as a warning color for centuries.

Colonel Sloan contacted the U. S. Bureau of Standards in Washington, D. C., in March, 1956. Mr. Dean B. Judd of the bureau provided much additional information on color deficient vision and provided samples of color swatches showing how both red and green blind persons see various colors.

Mr. Judd also reported that the use of yellow life rafts came about quite by accident. The contractor called the Navy Department to inquire what color should be used on some life rafts. The person answering the call inquired, "What colors do you have?" The manufacturer mentioned yellow among others and the party at Navy headquarters ordered, "Make them yellow."

Later it was noted that those pilots forced down at sea, and who had a yellow life raft were more often rescued than those using the old blue or gray life rafts. Investigating this further, the Navy anchored a number of colored buoys offshore and directed its pilots to fly at certain altitudes and to spot as many buoys as they could. The only buoys spotted were the yellow ones, although because of the altitudes involved they were seen as white.

Because of the distances involved in this research, however, it was not felt that the results were directly applicable to visibility under hunting conditions. Also, at sea there is no such thing as light and shade, as prevails under hunting conditions.

It was felt necessary to arrange a series of field tests to determine:

1. Whether color could be a factor in the identification of man in the field.
2. What color, if any, is best for warning, identification, or accident prevention use?
3. Is the same color effective under all conditions of vegetation, topography and/or weather? If not, what colors should be used where?

It was decided that the most practical application of the results of such tests would be:

1. To provide factual information with which to support proper legislation in regard to the wearing of color while hunting.
2. To acquaint the public generally with the value of various colors as a means of identification and promoting safety.

PROCEDURE

Colors and Panels

Colors for the test were selected to cover the complete spectral range, red, orange, yellow, green and blue. In addition, fluorescent yellow, fluorescent red and fluorescent orange made by Day Glo were used in all tests. Plaid, a combination of the basic colors, was used also.

It should be noted here that the colors white and fluorescent green were used in preliminary tests but eliminated from later tests because observation showed them to be completely unreliable. The first was eliminated because it was too easily confused with such things as rocks and patches of overcast sky as seen through tree branches; the second because it seemed to merely blend into whatever background it was placed against.

To know exactly what colors were being used, an evaluation of their spectrophotometric coefficients was made at the University of California under supervision of Dr. Gordon Walls of the School of Optometry. See Appendix I.

Design of Test Panels

The original design of the test panels was a rectangle 18 inches wide by 20 inches long—roughly the size of a man's torso—the area that would be covered by a shirt or jacket. The panels were made of tempered masonite one-eighth inch thick.

After cutting to size, the panels were drilled with two $\frac{5}{16}$ inch holes for mounting on the supporting posts. The panels were then painted with a flat white paint on the smooth side. After the flat coat had dried, two coats of the colored paint were applied.

The fluorescent paints presented more of a problem. These panels were coated with flat white and a layer of cheesecloth stretched over the face of the panel. The fluorescent paint was then applied with a "squeegee" type window cleaner.

Tests were made with and without the cheesecloth covering. It was found that the panels were more visible with the cheesecloth covering left on until the paint dried; they were used in this manner throughout the tests.

Paints used were Sherwin-Williams Company products and are listed by name and number in Appendix I.

The supporting posts were $1\frac{1}{2}$-inch square pine, five feet long, drilled with two $\frac{5}{16}$-inch holes to take the $\frac{1}{4}$ by 2-inch bolts; butterfly nuts were used to facilitate ease in mounting and dismounting the panels. The posts originally extended four inches above the panels so that the lower sharpened end could be driven into the ground without damaging the panels.

The section above the panel proved to be the key by which color deficient test members in the first tests located the panels—the natural color of the wood was readily visible to the color blind soldiers. This element promptly was removed by sawing the posts off to within $\frac{1}{2}$ inch of the top of the panels and staining the posts with redwood stain, so that this was no longer an extraneous factor in the later tests.

The square shape of the panels provided another clue to their location because nothing in nature is so regular in shape. All panels then were altered to eliminate straight lines so that color would be the only factor in their discovery and recognition.

Test Locales

Yellow Grass, Scrub Oak. The tests were conducted in typical California Coast deer terrain. The location was on the military base at Fort Ord, California. The tests were conducted in both overcast and sunny weather.

Evergreen or Rain Forest. The tests were conducted at Fort Lewis, Washington. The weather varied from heavy rain through mist to sunny skies. The trees were bright green, the grass brown, and the shade deep.

Snow. The tests were conducted in the Skokomish Valley of the Olympic Peninsula, Washington. The green of the evergreens was camouflaged by snow; the leafless limbs of deciduous brush and dark patches from stumps and felled logs contrasted with the snow. The sun was bright at the time of the tests.

Yellow or Autumn Forest. The preliminary tests were conducted at Fort Lewis in the Atkins Hill area. The main testing was conducted in the area of Stevens Pass near Merritt about 40 miles west of Wenatchee, Washington. The weather varied from sunny to overcast. The cover was typical of the autumn. The background color was predominantly yellow with splashes of red, green and orange.

Test Personnel

There were two teams of 10 men at each test location. One team was made up of men with normal color vision. The other team had men with color deficient vision (4 Protans and 1 Deutan—Strong; 1 Protan and 2 Deutan—Medium; and 1 Protan and 1 Deutan—Mild) as rated by the optometric section of the Army using the American Optical Company's H-R-R Color Test with Standard Light.

The color deficient team was selected so that the degree of color deficiency represented the proportions found in the general population that is color deficient.

Captain Beason of the Fort Lewis army optometric section was in charge of the color testing, except at Ford Ord where it was handled by the local optometric section.

Methods of Testing

Before each test all participants were briefed as to background information, methods to be used, and purposes of the test.

There were three basic types of tests: (1) Time Test, in which the determining factor was the length of time it took to find a colored panel; the safest color was considered the one which was found in the shortest time. (2) Precedence Test in which the determining factor was the order of preference given different colors when viewed simultaneously. Four panels were exposed at a time. The safest color was the one which was chosen over the others most often. (3) Field Hunting Test in which the determining factor was the ability to find and correctly identify the color of panels placed along a marked trail. The safest color was the one which was found most often and most consistently named correctly.

The first two tests were repeated at distances of 50, 100, 150 and 200 yards. In the last test, the colored panels were never placed more than 25 yards off the marked trail. Therefore, all results are applicable to distances usually involved in hunting.

In both the Time Test and the Precedence Test the targets were presented in the following manner: The men were called to attention with their backs to the target area. Upon command "Attention" they also closed their eyes. They were then given the command, "About Face." They then were given the command, "Open." In the Time Test they would open their eyes and start stop watches simultaneously.

In both tests they were cautioned to preview the entire field of view quickly.

In the Time Test when they found a panel they stopped their watch and recorded the time it took them to find it. If it took 15 seconds or more, they recorded 15 seconds.

In the Precedence Test they recorded the sequence in which they found the first three of the four panels. Observers were on hand to aid the subjects in finding all four panels so that the panels could be identified not only by color (which was often misnamed, especially by those who were color deficient) but also by number counting from left to right.

All tests were made as standard as possible within the limitations of a field test. For example, in the interest of standardization it would have been desirable to put each target in the same spot. In trying to simulate a hunting situation the targets were always placed in different positions.

Movement of targets during testing was eliminated in order to make color the primary determinant. Once, when a red panel was not observed by the members of the color deficient team, it fell to the ground. They immediately observed it.

The nature of the field tests did not make for a study of the findings conducive to statistical analysis. However, results of the Time Test were given a very complete statistical analysis. The results of this analysis were esentially the same as those arrived at by the directors. Observation by competent observers was a significant part of each test. This was done after a person had tried for over a minute to point out a red target 50 yards away—in plain view—to a person with color deficient vision and failed; any further testing, therefore, was academic. Each of the observers had this experience.

The third test simulated a hunting condition and was designated Field Hunting Test. It was set up along a trail some one-half mile long.

The trail was divided into sections identified by 10-inch square white cardboard on which was painted, in black, a letter of the alphabet. It was necessary to use a system providing a positive key, as half of the test subjects were afflicted with color deficient vision and many of the normal color vision group could be expected to name the colors incorrectly.

The test subjects had only to record the letter designating the area wherein the color was seen. If the subject recognized or thought he recognized the color seen, a check was made in the proper column.

Methods of Scoring

Time Test. The normal and color blind groups were scored separately. An arithmetical average of the times taken to find each color at each distance was found. These two averages were then weighted to find the final result. Ninety-two percent of the results were taken from the group with normal color vision and eight percent of the results were taken from the color deficient. Each color was then given a rating, the highest being the color which took the least amount of time to find.

Precedence Test. In each presentation of four panels a determination was made as to which color was seen over which other color in each pair. For example, of a subject rated the colors seen in the order yellow, orange fluorescent, red, blue, they would be scored as follows: Yellow would score over orange fluorescent, red and blue. In this example, yellow would have a score of three, orange fluorescent a score of two, red a score of one, and blue a score of zero. Each presentation of the panels at all distances was scored in this way and the cumulative total found for each color. A weighted rating was found in which the easiest color seen was the one with the highest score.

Field Hunting Tests. Every time a colored panel was identified, the color was given one point toward its final score. The color having the greatest number of points, or the one found most often, was given the highest rating.

The results from each location were summarized by giving a rating for each of the three basic tests and combining these ratings to get the final rating.

RESULTS

The outstanding result of the tests was the demonstration that golden yellow was the most easily visible color for both normal and color deficient groups under all testing conditions, Table 1.

TABLE 1

Visibility Rating of Colors at the Four Testing Locations

Fort Ord	Fort Lewis	Olympic Peninsula	Stevens Pass
1. Golden yellow	Golden yellow	Golden yellow	Golden yellow
2. Yellow fluorescent	Yellow fluorescent	Yellow fluorescent	Orange fluorescent
3. Orange fluorescent	Plaid	Orange	Red
4. Orange	Orange	Orange fluorescent	Red fluorescent
5. Plaid	Orange fluorescent	Red fluorescent	Yellow fluorescent
6. Green	Red fluorescent	Green	Blue
7. Red	Blue	Red	Orange
8. Red fluorescent	Red	Blue	Plaid
9. Blue	Green	Plaid	Green

TABLE 2

Combined Color Visibility Ratings for All Test Areas Scaled From 0 to 100

Color	*Rating*	*Color*	*Rating*
1. Golden yellow	95	6. Red	35
2. Yellow fluorescent	73	7. Plaid	32
3. Orange fluorescent	69	8. Blue	26
4. Orange	54	9. Green	24
5. Red fluoreseent	51		

The color ratings given in Table 1 do not report how much better one color was than another, only that one particular color was better or worse than the others. Colors in the midrange often closely outranked each other. Therefore their ratings can be considered unstable and greatly dependent upon the background. Fluorescent colors were unstable primarily because of changes in the amount of light hitting their surfaces. They were very good, especially orange fluorescent, in direct sunlight, but failed to perform well in shade or at a dawn and dusk. Yellow fluorescent rated high primarily because of the response of the color deficient group. There was less difference between the color ratings at the Stevens Pass area than at the other test locales because of the varied autumn colors present in the background.

A combined color rating for all test areas is given in Table 2. It will be noted from an examination of the total that golden yellow stands alone as the most easily visible color. A rough grouping places yellow fluorescent, orange fluorescent, orange and red fluorescent as next best. Red, plaid, blue and green stand together as poor colors from a visibility standpoint.

A photographic demonstration of the effectiveness of yellow over red is shown in Figure 1.

LIST OF ILLUSTRATIONS

A FIELD STUDY OF THE RELATIVE VISIBILITY OF VARIOUS COLORS

LAHR, HEINSEN, ANDERSON and SLOAN

50 feet

50 yards

100 yards

200 yards

300 yards

FIGURE 1. A photographic portrayal of the relative visibility of yellow versus red. Pictures taken with Kodachrome film, 1/50th second at f8 at noon on October 12, 1957, near Merrit, Washington. The foliage appeared more yellow than the photographs indicate. The distances involved were: (a) 50 feet, (b) 50 yards, (c) 100 yards, (d) 200 yards, and (e) 300 yards.

APPLICATIONS OF THESE FINDINGS

These findings have been applied in a number of different ways and there remain many other possibilities as yet untried.

The following changes in use of color have been noted since the start of field color tests: Washington State Department of Highway Maintenance has changed the color of warning lights on snow removal equipment from blue to yellow and reports fewer accidents.

Racing strips have changed the color of the side flags used to yellow. Drivers report that the yellow flags are easier to see at high speeds.

The Boeing Stratoliner 707 (Jet) has its tail assembly group painted yellow. It was found easier to identify at high altitudes than red and looms up against the clouds. Boeing officials painted the test models after learning the results of the Fort Lewis color tests.

Airline terminals have changed to yellow colored paddles used in directing taxiing aircraft to the proper gate. Airline equipment at terminals has been painted yellow, since it was found to be easier and quicker for pilots to see. Landing arrows on many airstrips have been painted yellow. Yellow lights mixed with red lights are now used for night identification.

Utility companies in the West now have their workers' helmets painted yellow. Better identification has resulted. Firemen have yellow helmets and yellow strips as well as yellow shoulder straps. They are much easier to see in smoke and at night.

The highway toll roads though Indiana and Ohio have changed the color of the dividing strip on exits from white to yellow. Operators report that less "run overs" have been noticed since yellow has been used.

Morris-Knutsen Construction Company, with large highway contracts in Nebraska, reports that it requires all its equipment to be painted yellow. That color makes it easier for operators to see other equipment in dust and during operation in bad weather.

The Montana Fish and Game Department requires that all automotive equipment it uses be painted yellow. It reports that vehicles are easier to see and the change has aided in law enforcement. Other state agencies in the West are ordering all automotive equipment in yellow for added safety.

Oil drilling companies in Montana and Wyoming have workers' helmets painted yellow. They report quicker observation of workmen by others in the area.

The use of yellow in highway advertising billboards has increased during the past two years. A survey made between San Francisco and Toledo, Ohio, showed an average of one-third of the highway billboards had yellow predominating.

The San Francisco Bay Area Bridge Authority reports that the yellow lights used on the bridges are far superior to any other color during fog.

Practically without exception sporting goods stores in the West are ordering yellow wearing apparel for hunters, based on popular demand. Their ready acceptance is due to the fact that hunters in the field can readily spot other hunters wearing yellow and are convinced of its higher visibility.

SUMMARY AND CONCLUSIONS

Field tests of the relative visibility of various colors were conducted at four different locations representing varied types of hunting conditions.

Golden yellow proved to be the most easily visible color under all conditions of testing.

It is important that yellow was found to be readily visable to people with color deficient vision.

It is recommended that for greatest safety in hunting that yellow clothing be worn and that enough yellow colored clothing be used to cover the hunter's torso. The yellow used should be saturated and not mixed with white (575 to 590 millimicrons). This is especially important in big game hunting where the game is hunted with high powered rifles and it is necessary to identify objects at long range.

Because yellow is readily visible to color deficient individuals there is no need for legislation restricting hunting by this group as a safety precaution.

ACKNOWLEDGMENTS

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- Army, Fort Lewis, Washington
- Army, Fort Ord, California
- California Department of Fish and Game
- California Optometric Association
- Massachusetts Society of Optometrists
- Michigan Optometric Association
- National Rifle Association
- Oregon Optometric Association
- Oregon Game Commission
- Washington Game Department
- Washington Optometric Association
- Wyoming Optometric Association

Special recognition should be made of the complete co-operation of the United States Army at Fort Ord, California, and Fort Lewis, Washington. Their contribution of men and equipment made the project possible.

In addition, a special note of appreciation is extended to press, radio and television media for their co-operation in disseminating the results of the various tests to the public. In this regard the following were especially helpful: Mrs. Elaine Davis, Public Relations Counsel for the Santa Clara County Optometric Society; Tom Siatos, Western Outdoor News, Los Angeles; William Woods, Public Relations Counsel, Fort Lewis, Washington; Tom Herbert, free lance writer, Seattle, and the Army's public information officers at Fort Ord and Fort Lewis.

The authors also wish to acknowledge the co-operation of certain manufacturers who made their products available, particularly Arthur Kahn Company, New York, and Eddie Bauer of Seattle.

APPENDIX I

EVALUATION OF SPECTROPHOTOMETRIC COEFFICIENTS

By DR. GORDON L. WALLS
School of Optometry, University of California

C.I.E. Illuminant C is a standard white light representing average daylight illumination, as from a slightly overcast sky. The chromaticity coefficients are derived from calculations based upon the spectrophotometric curve for the sample, and enable one to plot the sample as a point on the chromaticity diagram, together with a point representing the illuminant. The dominant wavelength and excitation purity of the sample are then obtainable graphically. The dominant wavelength specifies the hue of the sample; it is the wavelength of monochromatic light, the hue of which, to the eye of the usual observer, would be the same as the hue of the sample viewed in illuminant-C illumination. The excitation purity specifies the saturation (color strength) of the sample; if a sample has a purity of 25 percent, this means that the saturation of the sample is the same as that of a mixture of monochromatic light at the wavelength of the sample's dominant wavelength, and white light as emitted by Illuminant C, with the monochromatic light comprising 25 percent of the monochromatic-white mixture. The white light reflectance of the sample indicates how light or how dark it will appear in Illuminant-C illumination—the higher the reflectance, the brighter the sample to the eye.

NOTE: For the three "Sun Bonded Day Glo" samples, designated D30, R4, D30 E2, and D30 Y4, the Standards Laboratory of our (the University of California) College of Engineering obtained spectrophotometric curves and calculated chromaticity coefficients, but, I found that these samples fluoresce so strongly within the visible spectrum that the spectrophotometric curves are meaningless. For instance, if a pigment absorbs in the green and re-emits the energy as red light, the spectrophotometer will register the re-emitted energy as though it were green light and will give a falsely high reflection factor for the green region of the spectrum, but when the instrument is scanning the red region and is sending only red light to the sample, it will, of course, fail to record the red light that would be coming to it from the sample if green light were falling on the sample. At the present time and with existing instruments, it is impossible to give specifications of dominant wavelengths and purity for fluorescent samples—they can only be described clumsily, by difference from a non-fluor sample.

TABLE A-1

An Evaluation of the Chromaticity Coefficients of the Colors Used in the Tests
(For the Nonfluorescent Samples Only)

	Chromaticity coefficients		White light reflectance	Dominant wave length	Excitation Purity (percent)
F 65 R1 S-W Kem Lustral 42 line Vermilion	0.5014	0.3107	12.7	621.4	50.0
F 65 E1 S-W Kem Lustral 42 line Orange	0.5094	0.3687	25.8	595.4	67.5
F 65 Y2 S-W Kem Lustral 42 line Lemon Yellow	0.4672	0.4613	53.3	578.7	80.8
F 65 G6 S-W Kem Lustral 42 line Medium Green	0.3026	0.4186	16.8	547.3	26.0
F 65 L3 S-W Kem Lustral 42 line Light Blue	0.2152	0.4186	19.7	481.0	43.0

APPENDIX II

SOME FACTS ABOUT RED VERSUS YELLOW

By ARTHUR C. HEINSEN, JR., O.D.

1. Red has a smaller visual field than yellow. Yellow can be recognized as a color farther from a central vision point than red.

2. Yellow is a stable color; red is not. Stable colors are those which do not change in hue in different parts of the visual field but become more unsaturated until they fade into colorless gray.

3. One yellow can be differentiated from another yellow if as little as one millimicron in wavelength is present. The quality of hue discrimination is less for red than for any other color. In other words, one red looks much like any other red. As many as 35 millimicrons difference in two hues cannot be noted in the red end of the spectrum.

4. Red has no photochromatic interval. That is, red changes directly from red to black. It has no gray zone.

5. Approximately 10,000 times as much energy is necessary for red as yellow in order to get a threshold stimulation.

6. Eight percent of the male population is color blind and confuse red with green. Clinical studies have indicated that the only color that can be consistently identified by the color deficient is a golden yellow.

7. The eyes of vertebrates have much the same pattern of sensitivity as the simple eye of the horseshoe crab. In this eye a beam of red light must be made 600 times more intense than one of yellow-green light to elicit the same rate of nerve impulses.

8. During early morning or late evening daylight hours when the eye is not light adapted, the ability to see in the shadows of trees is often limited to the characteristics of scotopic (night) vision. Scotopic vision lacks the power to discriminate between slight differences in light intensities, a property which in conjunction with exact localization forms the basis of form perception. Red appears as black in scotopic vision, yellow in shades of gray. The perception of form under such adverse conditions would be more possible if the object were yellow.

NOTES

OBSERVATION OF PORPOISE PREDATION ON A SCHOOL OF PACIFIC SARDINES

On the morning of February 25, 1959, Joseph Balesteri and the writer were making a hydrographic cruise on the Hopkins Marine Station's vessel *Tage*. We had reached a spot five miles northwest of Point Pinos, which forms the southern limit of Monterey Bay, California, when a very large number of gulls was noticed circling and diving about two miles northwest. Twelve minutes later we arrived at the scene and, after stopping the vessel's engine, drifted close to one of three schools of Pacific sardines, *Sardinops caerulea*. These schools were under attack by several hundred harbor porpoises, *Phocaena vomerina*, 30 to 50 sea lions, *Zalophus californianus*, and several thousand gulls. They probably were remnants of a single school that had been disrupted and fragmented by the onslaught. The one we observed stayed from one-half to two feet below the surface of the water, and Balesteri, formerly a commercial fisherman with long experience, estimated it contained 10 tons of eight- to nine-inch fish. During the one-half hour we kept it under observation, it appeared to remain relatively stationary. The presence of our 40-foot boat deterred the gulls from feeding on this school, and they shifted their attacks to the other two. The porpoises and sea lions were not deterred, however, and continued feeding on the observed school.

Repeatedly, five to seven porpoises aligned themselves parallel to one another and about a foot apart. The outer members took positions somewhat in advance of the central ones, so that together they assumed a crescentic formation, with the points of the crescent forward. This group would then plunge through the greatest length of the ovoid school, in spite of the fact that it constantly contracted and expanded and varied the direction of its axis. By concentrating on an individual porpoise, I was often able to observe sardines being caught. Under ideal conditions for observation (with the axis of the school parallel and adjacent to the boat) I counted as few as five and as many as 12 fish eaten by a single porpoise in its rush through the school. Immediately after an attack, the group would dive beneath the school and diverge, keeping the prey near the surface. In the meantime, other porpoises that were neither attacking the school nor keeping it from diving, continually circled with a great deal of splashing and jumping, and kept the sardines concentrated. As soon as one group had made its feeding attack and taken station beneath the school, another formation would assault the sardines.

The sea lions generally attacked the periphery of the school, and although they may have been very successful, in only one instance did I actually see one catch a fish. It may be mentioned that my attention was focused primarily on the porpoises.

A few horned grebes, *Colymbus auritus*, were seen swimming below the surface pursuing sardines. Once a grebe set out after a particular fish, it continued the chase and ignored all other fish even though some were closer than the intended victim. They were never observed catching any fish, but this was not surprising considering their bill size and the sizes of the individual sardines. I can make no statement as to the success of the gulls, as they were not close enough to observe critically.

One would be hard pressed to hazard a guess as to the portion of the sardine school consumed by these predators. If the attack had continued a few more hours (there were numerous other porpoises in the general area) there probably would have been few survivors.

Our observations were possible only because the water was clear and it was a bright, sunny day. In an adjacent area a plankton net of half-meter diameter was distinctly visible to a depth of 18 meters.

Brown and Norris (1956) reported on the feeding behavior of porpoises, but did not observe harbor porpoises, and their descriptions of the habits of other species differ from those observed and described in this paper.

REFERENCE

Brown, David H., and Kenneth S. Norris.
1956. Observations of captive and wild cetaceans. Jour. Mamm., vol. 37, no. 3, pp. 311-326.

Bernard D. Fink, Hopkins Marine Station, Pacific Grove, California, February, 1959.

A SOUTHERN RANGE EXTENSION OF THE AMERICAN SHAD TO TODOS SANTOS BAY, BAJA CALIFORNIA, MEXICO

On July 16, 1958, an adult female American shad, *Alosa sapidissima* (Wilson), was given to me by officials of the cannery Pesquera del Pacifico, located in El Sauzal, Baja California, Mexico. Within a week after preservation in formalin, the fish was 386 mm. in standard length and weighed 757 grams. This specimen was taken, together with other shad, in purse seine catches of sardines (*Sardinops caerulea*) in the Todos Santos Bay area (32 degrees, 50 minutes north latitude, 116 degrees, 50 minutes west longitude). According to officials of several canneries in the area, a number of shad were landed with the regular sardine catch at this time. Shad also were taken throughout the Southern California area during July, 1958. Three specimens taken in Los Angeles Harbor were examined by personnel of the California Department of Fish and Game.

The previous southernmost locality of record is in the vicinity of San Diego, California (Roedel, 1953, Fish Bulletin 91, California Department of Fish and Game), some 68 miles north of the present locality. This southern range extension is of particular interest in a period of warming surface temperatures and the northward extension of many forms.

The specimen is now number 177948 in the collections of the U. S. National Museum.—*L. G. Claussen, Fishery Research Biologist, Biological Laboratory, U. S. Bureau of Commercial Fisheries, La Jolla, Cali-*

fornia, February, 1959. (Published by permission of the Director, U. S. Bureau of Commercial Fisheries.)

DEER FORAGE FROM COMMON MISTLETOE

Common mistletoe (*Phoradendron villosum*) is a flowering plant parasitic chiefly on oaks in the foothills of the Coast Ranges and Sierra Nevada, and south to Southern California, east to Arizona, and north to Oregon. The stems are woody and brittle. The leaves are fleshy and $\frac{1}{2}$ to $1\frac{1}{2}$ inches long. Mistletoe occurs as bunches on tree limbs and may become four feet or so in diameter. At Hobergs in the North Coast Range, a large clump of mistletoe weighed 32 pounds when cut from the tree, two-thirds being stems and one-third leaves. The leaves contained 64 percent moisture.

FIGURE 1. Large oak tree fenced for studies of mistletoe drop during the winter. In a three-month period nearly five pounds of green leaves and fine twigs were gathered beneath the tree.

Game experts have long known that common mistletoe is a favorite food of deer. The plant is regularly used as bait in deer traps. At Hobergs, deer were observed eating fallen leaves of mistletoe picking them up one by one. It was thought that mistletoe might be quite an important food item for deer in winter when other forage in this area is often scarce. Accordingly, measurements were made of the amount of mistletoe falling during February, March, and April, 1958. For this purpose a fence was erected beneath two trees, a large one supporting 24 bunches of mistletoe, a small tree nine bunches. Oven-dry weights for each month were as follows:

Month	*Large tree (Grams)*	*Small tree (Grams)*
February	202	49
March	614	132
April	529	295
Total	1,345	476

The amount of leaves falling varied from week to week depending somewhat upon winds, rain, sleet, etc.

Chemical analyses of mistletoe have shown the leaves to contain 9.79 percent protein and 59.79 percent starch, sugar, etc. (Calif. Sta. Rpt. 1915, pp. 32, 33).—*H. H. Biswell, University of California, Berkeley, April, 1959.*

RESIGNATION

JOSEPH H. WALES

Joseph H. Wales, dean of fisheries biologists with the Inland Fisheries Branch, resigned from the California Department of Fish and Game to accept appointment as Associate Professor in the Department of Fish and Game Management, Oregon State College, Corvallis, Oregon, effective May 1, 1959.

A graduate of Stanford University, Mr. Wales joined the California Department (then Division) of Fish and Game in 1931. At the time, he was the only freshwater biologist employed by the organization, and so has been the senior member of the present staff.

During his more than 27 years of service, Mr. Wales has made innumerable contributions to the knowledge of California's fishes and fisheries. His writings in the field of freshwater fisheries research and management, including some 35 technical articles and over 80 formal administrative reports, have brought him international recognition. He will be remembered best for his Castle Lake studies and his fish disease investigations.

His popular booklet, ''Trout of California'', first published in 1957, has attracted wide interest among sportsmen and the lay public generally. Ninety-five thousand copies have already been published and another printing is planned.

In his new position, Mr. Wales will conduct research on basic trout stream ecology. A team of specialists will work with him. His colleagues and many friends wish him well in his new endeavor.—*Leo Shapovalov, Inland Fisheries Branch, California Department of Fish and Game.*

REVIEWS

Salmon of the Pacific Northwest—Fish vs. Dams

By Anthony Netboy; Binfords and Mort, Portland, Oregon, 1958; 122 pp., illus., $3.

Author Netboy as a writer for the Booneville Power Administration had a ringside seat at one of the greatest shows on earth, the fish vs. dams controversy in the Columbia River Basin. The book is extremely well written and packs into its small size a tremendous amount of factual information. However, despite his stated purpose of objectively reporting the action as he saw it, the interpretation will appear to many conservationists as slanted toward the power interest viewpoint. Development of the text centers around the following themes.

1. The fishery was declining before the advent of the power dams.

"Too much gill netting can be as injurious to a sensitive creature like the chinook salmon as too much concrete." There is little question that the effects of overexploitation of the fishery by commercial interests was in evidence in the late Nineteenth Century. The history of all these combined land and water uses is a tale of spawning rivers blocked, damaged or ruined. The principle causes of the decline, such as logging, pollution and small dams are reviewed, indicating that between 50-75 percent of available spawning areas have now been lost. Advantage is taken of the fact that assessment of damage done by any one limiting factor such as power dams cannot be individually isolated for analysis.

2. The power dams are not so bad and efforts are being made to protect the fishes.

Here emphasis is placed upon the corrective efforts, tremendous in both scope and cost, carried out to perpetuate these runs. At Booneville alone, $7,000,000 was expended on fish facilities. Grand Coulee, the world's largest dam, cut off 1,140 linear miles of salmon spawning grounds. The limited successes of the relocation of these salmon and steelhead runs to tributaries below the dam are emphasized without one getting the full picture of resulting losses. These efforts are described as "successful to a degree exceeding expectations." He does concede that "Despite all these efforts, the total catch of Columbia River chinook has declined due to many factors of which high dams is one."

The postwar power shortages and plans for such dams as McNary, John Day and The Dalles and resultant politico-economic issues filled the tent with so much emotional smoke that the facts of both engineers and biologists were obscured.

3. Power dam development will inevitably continue coupled with efforts to preserve the fisheries.

The author's opinion may well be correct. Only about one-fifth of the available water power of the Columbia Basin has been harnessed to date. Finding strong opposition in the upper basin, planners have cast their eyes on sites in the lower basin which may well spell doom for the fisheries. "How well the protective devices will work when the Columbia River and its major tributaries are fully dammed is anybody's guess."

No attempt is made to justify the need for power development, nor are alternative sources of power discussed. A finale of current philosophy is expressed with the statement that "Civilization has usually advanced without consideration for resources which conflict with industrial progress." Conservationists will not all agree that such "progress" is inevitable and live in hopes that mankind will utilize our past history constructively through more intelligent development of our available resources including both fisheries and power.

Despite any criticisms the author has succeeded in bringing into focus this controversial problem in probably the most informative report on the subject available. This is a book which should be read by every Californian interested in the future of the salmon and steelhead fisheries of our State. Although our problem is mainly one of water uses other than for power, it is nevertheless the same basic issue of fish vs. dams. Perhaps we can profit from the pages of this historical account in directing the future of our anadromous fish resources.—*Willis A. Evans, California Department of Fish and Game.*

Principles of Field Biology and Ecology

By Allen H. Benton and William E. Werner, Jr.; McGraw-Hill Book Company, New York, 1958; vii + 341 pp., illus., $6.50.

This is a text for an elementary college course in field biology and ecology. Chapters on American naturalists of the past, taxonomy, animal behavior, and biological literature, supplement those on ecology, plant succession, animal populations, and economic biology.

The book is generously illustrated with good photographs. There is extensive reference material, including a glossary and an appendix.

Amateur naturalists, as well as college biology students, will find this book interesting and useful.—*Alex Calhoun, California Department of Fish and Game.*

Poisons: Properties, Chemical Identification, Symptoms and Emergency Treatment

By Vincent J. Brookes and Morris B. Jacobs; D. Van Nostrand Company, Inc., Princeton, New Jersey, 1958; 272 pp., illus. $6.50.

This handbook was written to provide vital information needed to diagnose and treat cases of poisoning. It contains basic information on the various types of poisoning incurred by humans and is especially designed for use in the fields of criminal investigation and other police work, medicine and pharmacology, civilian defense and other related fields.

There is nothing in this book pertaining to the effects of poisons on wildlife, but the conservationist may be interested in learning a little self-conservation to be used in the event of an unexpected exposure to poison. If this is the case, he will find ample material on the effects of and remedies for poisoning by snakes, spiders, plants, and food. Advice on how to protect himself from chemical warfare agents, radiation hazards and industrial hazards is also offered. However, most of the space devoted to these last three subjects pertains to what to do if you don't take the advice.

The presentation of material on the multitude of poisonous substances is well classified and is presented in useable form. A section on emergency information for immediate reference gives the reader in tabular form an alphabetical list of poisons, their use, symptoms, and the emergency treatment to be administered before the doctor arrives. Included in these tables is a listing of the ingredients of familiar products by class that may contain toxic substances. Some examples of products so classified are: antifreeze, brake fluids, canned heat, detergents, hair lotions, lighter fluids, polishes, waxes, and many others.

Many tips and pointers are provided for those who are short on experience but may be saddled with the investigation of human poisoning. They include data on special properties of poisons such as physical appearances, industrial and medical use, normal and fatal doses and their identification by chemical means.

I believe this would be a worthwhile addition to a personal library where an easily understood general reference book on poisons is desired. It has many little extra features such as a glossary, table of weights and measures, and a well documented first aid section that add to its usefulness.—*Eldridge G. Hunt, California Department of Fish and Game.*

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