chance as these blinds, if well made, were absolutely invisible 100 yards away.

The largest bags that I have reliable record of, but in which I did not personally participate, were made near Willows, Glenn County, in March, 1902. Four guns in two days shooting bagged 783 geese by actual count—an average of nearly 100 birds per gun per day.

The photograph herewith was taken in December, 1904, near Willows, shows 150 geese in one shoot by three guns; about 50 birds for each man.

My old record book, of my individual hunting trips, shows many shoots of several dozen geese. The largest shows 111 geese in two days for two guns. The friend with me on this shoot was Senor Carlos Herrera, who afterward became President of Guatemala, Central America.

The shoot was near Norman, Glenn County, the data being as follows:

December 4, 1905:

9 White geese, (*Chen hyperboreus*).
14 Grey geese (*Anser albafrons*).
20 "Mexicans" large brant (*Branta canadensis hutchinsii*).
28 "Cacklers" small brant (*Branta canadensis minima*).

71

December 5, 1905:

4 White geese (*Chen hyperboreus*).
8 Grey geese (*Anser albafrons*).
22 "Mexicans" (*Branta canadensis hutchinsii*).
6 "Cacklers" (*Branta canadensis minima*).

40

Total, 111 geese.

A BIOLOGICAL SURVEY OF SALTON SEA

By George A. Coleman.

HISTORY

According to the geological records written in the rocks of the San Jacinto Mountains, bordering the present sea on the south, there has been at sometime a vast inland sea, extending from the Lower California coast to a considerable distance beyond the west end of the present sea.

"Tertiary deposits in these mountains contain great beds of fossil sharks teeth and univalves (oyster shells one foot in length), at 1000 feet above the present sea level."[1] Showing that there was a marine population equivalent to any great area of the Pacific Ocean at that time. The hydrogeological record as evidenced by the waterline marks still visible on the walls of the cliffs of these same mountains show a very changeful history.

The more recent written history, since the discovery of the sea by Captain Blake in 1853-54[2] shows that it has varied in extent from a body of water thirty-five miles wide, one hundred miles long and eighty-five feet in depth as reported by him to a dry salt bed which was worked for many years for the salt it contained by the salt works at Salton. In the year 1907, this dry salt bed was again filled by the uncontrolled waters of the Colorado River making the present sea which is about seventeen miles in width at the widest point by forty-seven miles in length at the extreme ends. The depth has varied with the amount of rainfall, but has averaged probably forty-five feet at the deepest point near the geographical center.

Present Conditions—At various times during the years 1927 '28 and '29, the author has spent considerable time at the sea in a study of the water, plankton of the open sea, algae of the shoreline and water insects found therein including a collection of the fish at present living in the sea and tide pools in order to bring our knowledge of these conditions up to date and form a scientific basis for the introduction of the proper species of fish into the sea.

Sea Level—The existence and maintenance of an adequate supply of plankton, crustacean and insect life, especially in the shallow waters of the east end of the sea and the entire shoreline depends to a large extent upon the level maintained by the surface of the sea. Any material change in this level would greatly alter the character and quantity of this life, especially along the shoreline, upon which the species of minnows now living and breeding in the sea depend for food. Since any of the larger species of fish which we may introduce into the sea will necessarily depend largely upon the supply of minnows for their food, it is as well for us to know as far as possible what to expect regarding the sea level in the future.

With this idea in view, the author obtained from M. J. Dowd, chief engineer and general superintendent of the Imperial Irrigation District the records of the elevations taken since 1921.[3]

It is evident from these records that the level of the sea has raised almost three feet from 1921 to 1929. Since a variation of three feet would make but little difference in the character of the plankton and insect life, the author believes the division is perfectly safe in making a study of the present conditions—the basis for its fish introduction plans.

It is also shown that since the sea level has been under the control of the irrigation district it has been possible to keep it under control and to maintain an almost constant level. The variation of three feet being caused largely by an extremely heavy ranifall. Mr. Dowd assured me that it is their intention to maintain this level in the future.

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[1] McDougall, D. T. 1914. The Salton Sea. Carnegie Institution Publ. No. 193, p. 182.

[2] Blake, Wm. P. 1853. Lake Coahuilla. San Francisco *Commercial Advertiser*.

[3] Salton Sea Elevations. July, 1921, to January, 1929.
July 1, 1921—249.1 feet.
January 1, 1922—249.2 feet.
July 1, 1922—249.2 feet.
January 1, 1923—249.9 feet.
July 1, 1923—250.2 feet.
January 1, 1924—249.1 feet.
July 1, 1924—249.0 feet.
January 1, 1925—250.2 feet.
July 1, 1925—249.9 feet.
January 1, 1926—249.2 feet.
July 1, 1926—248.8 feet.
January 1, 1927—247.8 feet.
July 1, 1927—247.0 feet.
January 1, 1928—246.4 feet.
July 1, 1928—246.0 feet.
January 1, 1929—246.5 feet.

CHEMICAL CONTENT OF THE WATER

Any study of the living organisms of the sea would be incomplete if it did not also include the chemical analysis of the water.

From 1907 to 1913, the United States Geological Survey made several

FIG. 73. Seining for minnows during biological survey of Salton Sea. Photograph by George A. Coleman, March 21, 1929.

analyses of the water. The Carnegie Report No. 193 for June 13, 1913, is most complete and is as follows:

Total solids	1,002.56
Water of occ. and hyd.	32.6
Sodium (Na)	323.08
Pot. (K)	3.45
Calc. (Na)	19.75
Magnesium (Mg)	16.22
Aluminum (Al)	.125
Iron (Fe)	.038
Manganese (Mn)	None
Zinc (Zn.)	None
Lead (Pb)	None
Copper (Cu)	None
Lithium (Li)	None
Chlorine (Cl)	473.89
Sulphuric (SO_4)	124.65
Bicarbonate (HCO_3) (vol)	15.74
Carbonic (CO_2) Total (grms)	11.28
Silicic (SiO_4)	2.18
Phosphoric (Po_4)	Trace
Nitric (No_3)	None
Nitrous	None
Oxygen consumed	.110
Boric acid	None

In conversation with Captain Charles Davis at his Mullet Island residence on May 21, 1929, I learned that he assisted in taking the above sample for analysis and that they were all taken just off shore in the sea opposite Mullet Island, the shoreline at that time covering this island.

MUD POTS

Situated about one-quarter of a mile inland and an equal distance from Mullet Island, these so-called "mud pots" which form quite a series of boiling mud springs, furnish a never failing source of supply of various minerals which find their way into the sea and are no doubt the main source of the minerals found in the sea water.

MINERAL WELLS ON MULLET ISLAND

During 1927, 1928, and 1929, two wells were bored to a depth of 900 and 1400 feet respectively through the solid rock formation of Mullet Island, at which depths a continuous flow of boiling mineral water was obtained. On May 21, 1929, the author accompanied by Paul A. Shaw, toxicologist at the Hooper Foundation for Medical Research, San Francisco, visited these wells, saw them in action and with the kind assistance of Captain Charles Davis secured samples of the flowing water for analysis. Mr. Shaw's analysis is as follows:

Ion	*Grams per 100cc*	*pH=6.5*
Carbonate		
Bicarbonate	0.03	
Ferrous Iron	0.005	
Chlorides	6.80	
Sulphates	0.02	
Calcium	1.60	
Magnesium	0.40	
Sodium and Potassium	2.04	
Nitrates	0.105	
Total solids	11.000	

The water flowing from these wells is allowed to run into a series of settling ponds where the minerals crystallize out and form a series of incrustations varying from white to yellow, green and purple, according to the mineral crystallizing. Here one can see nature's laboratory at work on a tremendous scale. When perfected, this system of settling ponds, will no doubt secure the most of the minerals contained in the water in a solid form leaving only a few unimportant ones in solution to pass into the sea.

Analysis of water of the open sea: On March 21, 1929, the author secured a sample of water near the geographical center of the sea and also from tide pools near Fish Springs where there is abundant evidence that the top minnow (*Gambusia affinis*) breeds.

Analysis of water from the open sea by P. A. Shaw, as follows:

Sampled March 21, 1929	*Grams per 100cc*
Carbonate	0.002
Bicarbonate	0.024
Chloride	1.63
Sulphate	.35
Calcium	.05
Magnesium	.15

Sampled March 21, 1929	*Grams per 100cc*
Sodium and Potassium	1.00
Total as analyzed	3.206
Borate	Positive
Nitrate	Negative
Total evaporated solids (105°C) =	3.68
Total solids ignition at low red =	3.32
Specific gravity at 20 degrees as compared to water at 4 degrees	1.033
Hydrogen-Ion Conc. pH. =	8.5

FIG. 74. Magdalena grass, food of the famous Salton Sea mullet. Photograph by Charles Davis.

Analysis of tide pool water, same date as above, by P. A. Shaw, as follows:

	Grams per 100cc
Carbonate	0.00
Bicarbonate	0.03
Chloride	1.83
Sulphate	0.37
Calcium	0.09
Magnesium	0.08
Sodium and Potassium	1.20
Total as analyzed	3.60
Borate	Positive
Nitrate	Negative
Total evaporated solids (105°C)	4.08
Total solids, ignition low red	3.78
Spec. Grav. 20°-comp. to water at 4°	1.034
Hydrogen-Ion Conc. pH. =	7.3

To complete our knowledge of the chemical contents of the water running into the sea, the author secured from chief engineer Dowd, the analysis of the waters of both the New and Alamo rivers made at the laboratory of the irrigation district for a number of years past.

As these are too extensive to publish in full, only the latest of January, 1929, are given here, the balance being on file in our office for reference.

Analysis of water at New River, samples taken below Reeds Dam Irrigation District. Laboratory sample No. 4302 and No. 123:

Total solids	167 parts per 100,000
Loss on ignition	30 parts per 100,000
Sodium carbonate (Na_2CO_3)	---
Sodium chloride (NaCl)	95 parts per 100,000
Sodium sulphate (Na_2So_4)	66 parts per 100,000
Silt	157 parts per 100,000

Taken January 11, 1929.

Sample from the Alamo River at North End Dam. Laboratory No. 4302 and No. 124:

Total solids	129 parts per 100,000
Loss on ignition	33 parts per 100,000
Sodium carbonate	---
Sodium chloride	57 parts per 100,000
Silt	182 parts per 100,000

The chemicals coming in from these two rivers are confined to a small per cent of sodium chloride which does not have any harmful effect on the growing crops where it is used for irrigation. For our purposes, therefore, these two rivers may be considered as fresh water streams.

SALTON SEA A REAL SEA

The chemical analysis of the water of the sea itself shows these waters to be comparable to that of the open ocean. Of recent years, biologists

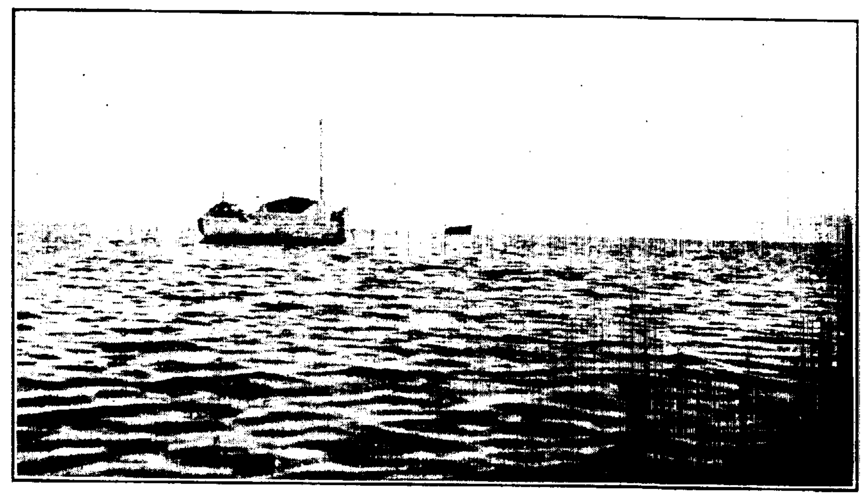

FIG. 75. Salton Sea fishing fleet now abandoned. Photograph by Charles Davis.

and biochemists have accumulated a large amount of experimental data upon the relation of the hydrogen-ion concentration of the water to the living organisms therein. So much real knowledge is now available on this subject that this reaction of the water (known for short as the pH value) may be taken at least at a predictive value upon which the biologist may prognosticate the forms of life which will flourish therein.

As shown by Shaw, the water of the open sea has a pH of 8.5 and the tide pools of 7.3. The author's own determinations at various times come very close to this, *viz*, open sea= pH 8 -8.5 tide pools pH 7-7.8. It varies considerably during the season according to the temperature. According to Harvey [4] (pp. 72–73) "Sea water from the open ocean has a hydrogen-ion concentration of between 10^{-8} and $10^{-8.3}$ grams per liter, or pH 8.1-8.3." Hence the reaction of the waters of Salton Sea to plant and animal life could be expected to be very close to that of the open ocean.

However, owing to the small area of Salton Sea and its shallow depth, the winds which sweep it from end to end daily keeping the water in almost constant motion and circulation make it impossible for any extensive development of any pelagic plankton. We have, therefore, to depend upon the shallow water of the shoreline to produce the plankton, insect and crustacean life needed to support the fish life in the sea. Fortunately, this area is large in proportion to the area of open sea, especially at the east end where the Alamo and New rivers enter the sea.

SILTING UP OF THE SEA

According to estimates made by the United States Geological Survey of 1911–1913, the rate of silting up at that time would completely cover and eliminate the sea in eighteen years. To date only a very small area at the mouths of the New and Alamo rivers has been covered.

In order to protect the breeding ground of the forms furnishing food for young fish, the channels of these two rivers should be kept open directly into the sea, so that the silt coming down in the water does not spread out too soon and choke out the growth in the shallow water. At the author's recent visit this was not being done and consequently there was a great area in which the water was only a few inches deep and in which great numbers of pelicans and other fish-eating birds were feasting on the minnows and young fish coming down these rivers which would otherwise enter the sea and form food for larger and more desirable sport fish. Chief Engineer Dowd has assured me that these channels would be kept open in the future.

BENTHAL AREA

The area in which benthal organisms which include all forms that are attached to the shore and bottom, or to plants growing on the shore and bottom and a host of other forms, which, though free swimming are associated with the attached forms, covers the entire east end of the sea, especially at the mouths of the New and Alamo rivers. These areas may be roughly located by the growth of cattails and other coarse water plants. There are other limited areas at the mouths of small streams, springs which flow directly into the sea and small stream at the west end with artesian wells for their source. I would estimate that in all about one-eighth of the area of sea is so covered. We have, therefore, this area in which the food for support of the minnow population, upon which the larger sport fish must depend for food and for the support of such fish as may subsist directly on plankton, insects and crustaceans. Any fish which we may introduce will therefore concentrate in this area especially in the younger stages and should be protected by not allowing any fishing in this area at any time.

[4] Harvey, H. W., 1928. Biological chemistry and physics of sea water. (Macmillan Company, New York, Ed. of 1928), pp. 72-73.

FISH BREEDING AREA

The area to be so reserved is easily marked by township lines, *viz*, beginning at the northwest corner of township 11 south, range 11 east, San Bernardino Meridian, thence following township line to northeast corner of same; thence north on township line of township 10 south, range 12 east, San Bernardino Meridian, to the northwest corner of same, thence east on north line of township 10 south, range 12 east, San Bernardino Meridian to northeast corner of same. All sport fishing will then be confined to the open sea outside of this line. The area inside of this line, to, and including, the mouths of the Alamo and the New rivers as far as the first dams thereon to be set aside as a fish nursery for the express purpose of maintaining a supply of fish for Salton Sea.

If this is done we will have a basis to work on which will give us a reasonable assurance of being able to maintain a sufficient supply of sport fish in the sea to meet any demands made upon it by real sportsmen.

Commercial fishing in the sea, being now at an end as far as any profit in it is concerned, should be prohibited entirely.

FISH OF SALTON SEA

The first published account of the fish of Salton Sea, as far as I am able to find, is that of Dr. B. W. Evermann, in the *Copeia*.[5]

Dr. Evermann lists six species of fish as occurring in the sea at that time:

Common carp (*Cyprinus carpio*). The most abundant species at that time.

Bony-tail (*Gila elegans*). Said to be not uncommon. (I saw no specimens.)

Humpback sucker (*Xaurophen sypho*). Rather common. (I saw several specimens. They all had a starved appearance.)

Colorado River trout (*Salmo pleuriticus*). Although the water of the Salton Sea is quite brackish, strongly alkaline and very warm, this trout seems to thrive in it amazingly well. It is said to be fairly common. (I saw one fine example about 16 inches long. It was in excellent condition, albeit somewhat bleached in color.)

Common mullet (*Mugil cephalus*).[6] Next to the carp the most common species. Numerous examples were seen. It is said to reach a large size (as much as 6 pounds) and to be unusually fine as a food fish.

Desert cyprinodont (*Cyprinidon macularius*).[7] This interesting little fish was found in Figtree John Spring in a small oasis near the north end of the lake and some 7 miles southwest of Mecca. This spring, or

[5] Evermann, Barton Warren. 1916. Fishes of the Salton Sea. *Copeia,* No. 34. pp. 61-63, August 24, 1916.

[6] Thompson, Will F and Bryant, Harold C. 1920. The mullet fisheries of Salton Sea. CALIFORNIA FISH AND GAME, Vol. 6, No. 2. pp. 60-63, 3 figs. April 19, 1920.

[7] This cyprinodont appears to be found in many of the isolated springs and water holes in the deserts of southern California. Only this week (June 1) Samuel Hubbard of Oakland, brought me 14 fine specimens from Saratoga Springs, Death Valley, where Mr. Hubbard says they are very abundant.

waterhole, was grown up thickly with cattails (*Typha latifolia*) and the surface of the water was covered with a thick coating of algae of various species. The water was only a few inches deep and quite warm, perhaps as warm as 90 degrees to 100 degrees on hot days. The fish, however, were active and in good condition. I caught a number of them and succeeded in bringing two alive to San Francisco. One of them died a few days ago—the other is alive and doing well.

FIG. 76. Fishermen examining nets used in taking mullet in the Salton Sea. Photograph by Charles Davis.

PRESENT STATUS OF FISH LIFE

In his several trips to the Salton Sea, the author has paid particular attention to checking up on the number of species of fish now found in the sea and their abundance.

The carp disappeared several years ago in what seemed to be an epidemic. Captain Charles Davis says they came up in shoals of dead fish on the shore at and near Mullet Island, the stench being almost unbearable for sometime. Most of these fish were carp, but there were other fish mixed with them.

The mullet have also almost disappeared. I interviewed the mullet fishermen while they were working this spring. They stated that they could find but one small school of large fish and they moved about all over the sea. They say what they do catch are all large fish and in the proportion of about one male to 100 females. They believe the mullet are not now breeding in the sea. In a trip of forty miles on the sea over their supposed haunts, I saw only one good sized mullet on March 21 of this year.

The Colorado River trout is occasionally seen near the east end of the sea.

The humpback sucker is reported as rather common.

The author, assisted by several deputies, during the trip in March, made quite an extended search for the desert cyprinodont and found it at nearly every point where we touched shore, from a spring about seven miles above the Hartley Salt Works on the north shore of the sea, around to Fish Springs and Figtree John Spring where Dr. Evermann

originally discovered it. We found it abundant in all these places, but especially so along the shore near the Hartley Salt Works. Here it thrives amazingly in the open sea water and Mr. Hartley states that it gets into their salt vats and will live in salt water up to 50 per cent saturation, at which point it begins to die. It evidently breeds in the tide pools and fresh water coming from these springs in among heavy growths of cattails.

While hunting for the cyprinodont at Fish Springs, the author discovered a small viviperous minnow breeding in the spring and also in tide pools of sea water along this shore. These were turned over to W. I. Follet, of Oakland, who has kindly identified them as *Gambusia affinis*, Baird and Girard. Since this time the author has found this minnow to be quite abundant at several points around the shore.

Mr. Follet also identified the cyprinodont collected as *Cyprinodon macularius*, Baird and Girard, or the same species listed by Dr. Evermann.

These two minnows are in sufficient abundance in the sea to form the food of a considerable population of sport fish since they are found all around the shoreline and seem to be able to maintain themselves against a horde of fish-eating birds of various species.

RECOMMENDATIONS FOR STOCKING

After a study of the present conditions and a fairly good knowledge of the habits of the striped bass, I believe if the young bass were introduced into the area designated as breeding grounds at the east end of

FIG. 77. Recession of the Salton Sea has left great shallow flats and made necessary this method of transporting fishing gear and catch. Photograph by Charles Davis.

the sea late in the season (October would be probably the best time) they would have a good chance to succeed. Since we have no precedent by example of introducing the striped bass into a landlocked sea, it will be in the nature of an experiment, but one which I believe to be well worth trying. Certainly no fish could be more desirable as a sport fish.