A

B I O L O G I C A L   S U R V E Y

OF

L O S T   L A G O O N.

by

George Clifford Carl.

A Thesis submitted for the Degree of

MASTER OF ARTS

in the

Department of Zoology.

THE UNIVERSITY OF BRITISH COLUMBIA.

April, 1932.

CONTENTS

April 27. 1932.

Accepted.

I N T R O D U C T I O N

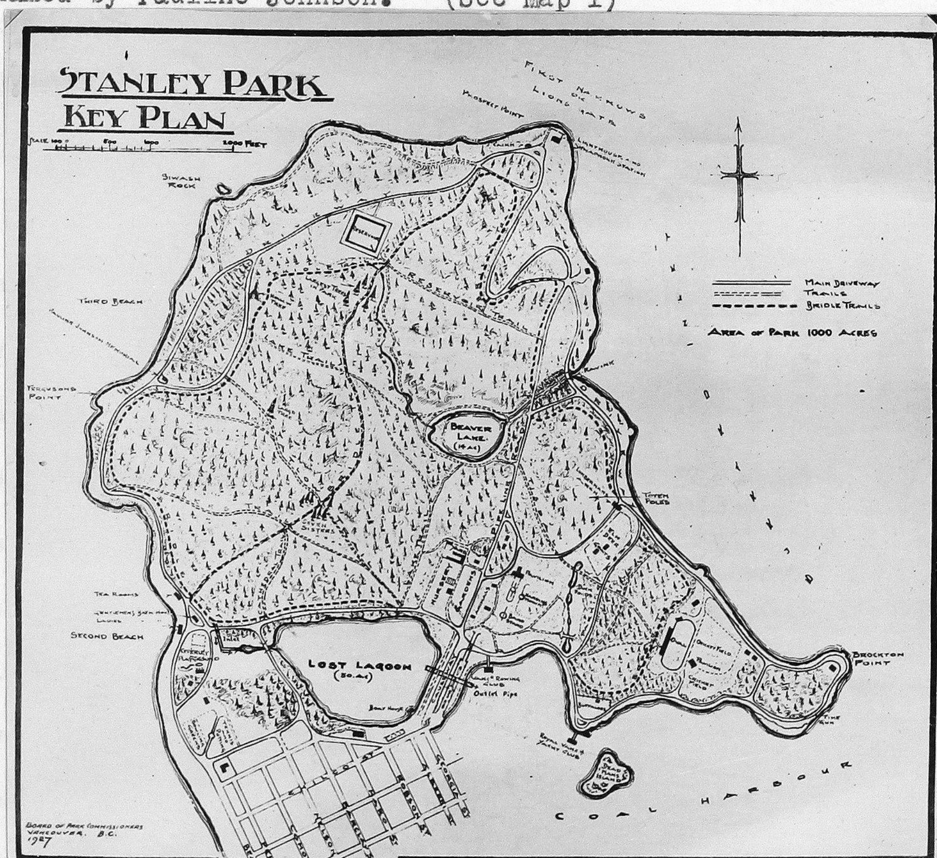
During the past few years Lost Lagoon has been becoming more and more of interest especially to certain anglers of the city. In due time a fly fishing association was formed by those most interested in the Lagoon for the purpose of making it into a fresh-water pond to provide fishing for trout within the limits of Stanley Park. Since the time that this idea was first considered various members of the staff of the Pacific Biological Station at Nanaimo, B. C. have investigated conditions existing in the Lagoon at intervals during the years 1929 and 1930. But as the problem was thought to be worthy of a more intensive study the present work was suggested by Dr. C. McLean Fraser to be carried on during the winter session of 1931-32.

Since a work of this kind necessitated obtaining information and identifications from a number of outside sources the writer is indebted to the following: Dr. C. McLean Fraser, Professor of Zoology in the University of British Columbia, for suggesting and supervising the investigation, Dr. W. A. Clemens, Director of Pacific Biological Station, Nanaimo, B. C. for helpful suggestions and literature, Mr. C. McMottley of the Station, for suggestions and literature, Mr. G. H. Wailes, also of the Station, for identification of plankton, Professor G. J. Spencer, Assistant Professor of Zoology for photographic work and identification of insects, Professor John Davidson, Associate

Professor of Botany, for identification of plants, Mr. P. A. O. Sankey Secretary of Stanley Park Fly Fishing Association for literature and assistance, Mr. A. S. Wooton, Park Board Engineer, for maps and information.

HISTORY OF LOST LAGOON.

Lost Lagoon is that body of water lying near the entrance to Stanley Park, Vancouver, B. C. It is separated from Coal Harbour on the east by the causeway which forms the main entrance to the Park. Before the year 1916 the Lagoon formed the most western tip of the Harbour and therefore consisted of salt water with typical marine flora and fauna. As the water flowed in and out with the tide the greater part of the lagoon bottom was exposed during low water. Due to the fact that the Lagoon was "lost" to boating at low tide it was so named by Pauline Johnson. (See Map 1)



Map 1

On the completion of the sea-wall in the summer of 1916 the Lagoon was definitely cut off from the rest of the salt water. This wall consists of rocks held in place by wooden piling with the spaces filled in with mud pumped in from the harbour bottom.

The reason for building this embankment and causeway was to take the place of the bridge which formed the main entrance to the Park up to that time. In 1920 plans were completed which included the laying out of boulevards along the causeway, construction of walks around the Lagoon, and formation of one or two islands near the centre of the Lagoon for bird sanctuaries. The boulevards along the entrance were finished in 1925 but the other projects have not yet been carried out except for some construction work undertaken by relief gangs during the winter of 1931-32.

During all this time, namely from 1916 until 1930 the water of the Lagoon remained stagnant except for occasional replenishments from the salt water of the Harbour. This addition of more salt water to water that was already concentrated by evaporation during the summer months tended to raise the salinity a great deal. On the other hand the influx of fresh water during the rainy season and the consequent overflowing through the outlet pipe into the harbour tended to lower the salinity. This seasonal fluctuation in salt content could not have been favourable for any organisms to establish themselves in the Lagoon. Nor could these extreme conditions be considered the best preparation for the establishment of a fresh water pond although this project was not thought of at the time.

HISTORY AND ACTIVITIES OF FLY FISHING ASSOCIATION

However, in the spring of 1929 a number of anglers of the City became interested in the Lagoon as a possible fresh water pond which would provide fly fishing for trout. Accordingly, an organization called the Stanley Park Fly Fishing Association was formed for the purpose of raising sufficient funds to cover the necessary expenses. The money was to be used for converting the Lagoon into a fresh water Lake, operating a fish hatchery at Beaver Lake and providing retaining ponds at the Lake for holding trout for replenishing the Lagoon. Operations were commenced at once.

The Dominion Government supplied 130,000 Kamloops Trout eggs which were hatched at Beaver Lake. Although the water of the Lagoon was still quite salty (3.4 grams of Chloride per litre) 100,000 of these Kamloops fry were liberated during July and August. All of these young fish must have died as none were seen after the first few days. A short time before this, namely in May, one hundred full grown Cutthroat Trout and two hundred yearlings were removed from Beaver Lake and were also liberated in the Lagoon. It is quite possible that most of these fish managed to exist at least for a time as Cutthroat Trout are able to adapt themselves to brackish water fairly easily.

It was not until the spring of 1930 that an automatic outlet was constructed and fresh water from the City supply was first introduced. As the water was now slowly becoming less brackish further attempts were made to introduce fresh water fauna and flora. In March waterlilies and other aquatic plants were transplanted from Beaver Lake. As these appeared to be thriving fairly well, about five thousand shrimp ([illegible]) from Red Lake and Merrit Creek, in the interior of B. C., were introduced along with water-weed (Myriophyllum) from their natural habitat. In the following year, namely 1931, another lot of five thousand shrimp were placed in the Lagoon. As none of these crustaceans were seen again it is presumed that they failed to survive in their new and perhaps unfavourable surroundings. About the same time two hundred six to eight-inch Cutthroats were also introduced from Beaver Lake. These apparently fared much better as fish were seen rising at various times during the year and a few were removed by angling at the end of the summer. These were in good condition and showed considerable growth.

It was at first estimated by the association that all work would have been completed and trout would have been of sufficient size to permit angling by the spring of 1931. However, the opening was postponed chiefly on account of the fact that an insufficient number of trout were present, and at the time, no others were available for stocking the Lagoon.

The opening of the Lagoon to fishing was again postponed in 1932 owing to construction work carried on by the Parks Board and Water Works Department which necessitated lowering the level of the water throughout the winter. At the present time, March, 1932, it is planned not to introduce more fish or aquatic plants until all disturbing work shall have ceased and conditions in the Lagoon shall have returned to normal.

STATEMENT OF PROBLEM

Although the main purpose of the investigation was to make a biological survey of the Lagoon, a secondary intention was to determine its suitability for maintenance of trout of sufficient size to provide game for fly fishing. In order to determine this suitability it was necessary to make a study of the physical and chemical conditions of the water and of the relationships existing between the organisms found there together with the possible food-cycle for the Lagoon.

DESCRIPTION OF THE LAGOON

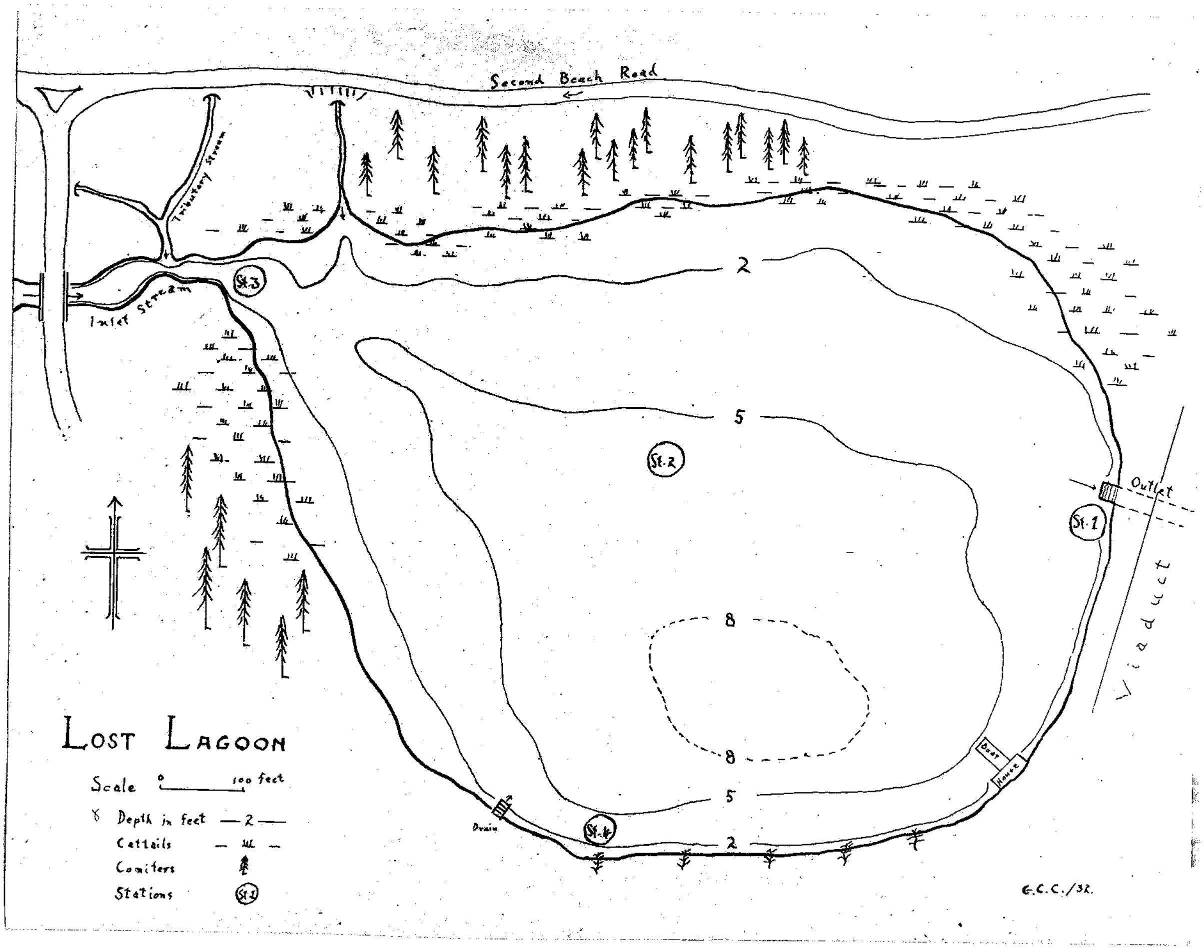
Size And Shape

As mentioned before, the Lagoon was originally the western tip of Coal Harbour before the present viaduct was built. It therefore consists of a somewhat shallow basin, the average level of which lies between a 9.5 and a 10.5 foot tide. The fact that it is below sea-level during tides higher than 10.5 feet is rather important as will be shown later.

The body of water is quite small having an area of about 50 acres and a volume of about forty million gallons according to the Parks Board engineers. It is roughly oval in outline with only one prominent indention formed by the mouth of the inlet stream which enters the Lagoon on its western shore. (See Map 2)

Shoreline

The length of the shore-line not including the banks of the inlet stream is about 1400 yards as shown by the Parks Board Map. The stream banks which are really an important part of the shoreline would add on another 300 yards. Of this total of 1700 yards about 35% is composed of clay and sand, 50% of stones and boulders with reeds and cat-tails and the remaining 15% of loamy banks mainly along the stream, supporting water-cress and creeping bent grass.



Map 2.

Depth

The average depth of the Lagoon is approximately four feet and the maximum is about ten feet. As shown by the contour lines on the map of the Lagoon (Map 2) the deepest portion lies near the south-east bank. The map also shows that the shallowest parts lie along the northern shore and part of the western shore. The inlet stream itself is about three feet deep and is lined by fairly precipitous banks, parts of which are reinforced by stone-work.

Water Supply

The main water supply for the Lagoon comes from a pipeline which taps the nearby city water system. The water is conveyed by a two-inch pipe which empties into the upper end of the inlet stream. This pipe is capable of delivering about 500,000 gallons of water per day but unfortunately the supply was cut off during the greater part of the investigation to enable certain construction work to be carried on.

The construction work mentioned above consisted of dredging and widening the inlet stream, building a concrete bridge over it, reinforcing the banks with stone-work and later on excavating along the east shore next the viaduct for a new water-main.

During the wet seasons of the year the Lagoon has additional sources of water in the form of small streams which drain the higher ground lying chiefly along the northern shore. The largest of these tributaries empties into the inlet stream a short distance from the mouth of the latter. (See Plates IV and V) This particular streamlet is of interest in that it carries into the water of the Lagoon a fairly constant though small supply of protozoa and diatoms. Other small drainage ditches empty into the Lagoon at various points along the shore. However, no polluted water enters the Lagoon.

Overflow System

The overflow system which was installed in the spring of 1930 consists of a ten-inch overflow pipe which empties into a thirty-six inch out-let pipe communicating with the Harbour on the other side of the fill-in. An automatic valve is present which prevents the entrance of salt water when the level of the Harbour is above that of the Lagoon, i.e., at high tide. The system is also provided with an arrangement which allows the level of the Lagoon to be lowered two feet when necessary for construction work. Because of the nature of the material forming the fill-in and of the smallness of the overflow pipe the system is not 100% efficient as it allows small amounts of salt water to seep past it at high tide and does not permit fast enough outflow of water during heavy rains.

APPARATUS AND METHODS

Collecting

As the experimental work consisted primarily of the collection and examination of the living organisms both macroscopic and microscopic, no special apparatus was necessary. An ordinary dip-net was employed for collecting material along the shore amongst the weeds and the same net which was of fine mesh was used in obtaining samples of bottom ooze with its characteristic fauna. Plankton samples were collected by means of a plankton net of number 20 silk bolting cloth with a circular mouth eight inches in diameter. The shape was that of a simple cone two feet in length and ending in a 125 c.c. bottle. The net was either towed behind a boat or held in the current of the inlet stream.

In all cases the organisms collected were taken to the laboratory and placed in aquarium jars in which they were studied and identified. In the case of some microscopic forms such as protozoa and a few species of algae, cultures were reared in the laboratory from samples of water and bottom ooze. Representatives of the more important types of macrofauna were preserved in alcohol or formalin for future reference.

By the examination of stomach contents and the study of feeding habits of the different forms, the various food-chains and the food-cycle for the whole Lagoon was determined.

Sampling

In order to interpret the data collected regarding numbers and distribution it was necessary to determine the physical and chemical properties of the water in which the organisms were found. Four stations chosen by Carter on a previous occasion (Report Nov.,1930, Mottley and Carter, 19) were again used so that results could be compared. Of these stations No. 1 was located near the outlet pipe close to the causeway, No. 2 approximately in the middle, No. 3 at the mouth of the supply stream and No. 4 in a slight bay on the south shore as far removed as possible from the disturbing factors of the water entering at Station 3 or possible salt water seeping through the causeway near Station 1 (See Map 2)

In most cases as the water was very shallow samples, temperature and pH readings were taken from the surface layer. The water samples were collected in pint bottles and the water was analyzed for chloride content by the usual Mohr Method of tit~~u~~ation using r large samples (50 c.c.) when the amount of Chloride was small. The temperature for both air and water was taken by means of an ordinary thermometer and the hydrogen ion concentration (pH) was determined at the same time by the colorimetric method using the La Motte Standard, Brom-thym~~a~~ol Blue or Cresol Red. Readings were taken at roughly weekly intervals when time permitted.

PHYSICAL AND CHEMICAL CONDITIONS IN THE WATER

To show the condition of the water in the Lagoon from the time when observations were taken first, until the present investigation Table 1 has been constructed. The data has been taken from the reports of former investigations carried on by various members of the Biological Board (16,17,18 & 19). These are unpublished reports made available by the kind permission of Dr. W. A. Clemens, Director of the Biological Station.

Date	Depth	Temperature °C	Temperature °F	Oxygen c.c.'s per litre	Chlorinity gms. per litre	pH
July 13/29	Surface	23·5	75·0	4·64	3·4	7·65
	Bottom	23·2	74·8	4·33	—	—
August 31/29	Surface	21·5	71·2	—	2·0	8·4
	Bottom	—	—	—	—	—
Nov. 29/29	Surface	7·2	45·2	6·15	1·47	7·0 ?
	Bottom	6·7	44·0	—	—	—
Nov. 3/30	Surface	9·0	48·3	7·42	·3 50	7·0
	Bottom	8·8	48·0	7·59	·4 11	7·4

Table 1.

The table shows a series of temperatures and water analyses taken at various times and in various parts of the Lagoon. It is particularly interesting in that it covers the time when the Lagoon was changing from salt to comparatively fresh water.

Observations taken on July 13, 1929, indicate that the temperature of the water is capable of reaching a rather high maximum. The amount of dissolved oxygen, although lower than that found at other times, was still large enough to be favourable for fish-life. Although fresh water other than rain and drainage had not been introduced as yet the salinity was fairly low. The average value was about one third of that found for the water in Coal Harbour but still over eight hundred times that of nearby Beaver Lake.

The records for August of the same year show a considerable improvement in general conditions. Although the temperature was found to be still quite high, the salinity was found to be reduced to a value almost half of that reported in the previous month. The one and oñly pH reading upon which it is perhaps not sufficient to base conclusions, showed a definite rise in alkalinity.

The data collected in November of the same year show a still greater change in conditions. Along with the much lower temperature a corresponding larger amount of available oxygen was found as might be expected. The value for the salinity was found to be still lower possibly owing to the influx of rain and drainage water during the wet season. The pH showed a sudden decrease which might be explained by assuming the presence of organic acids produced by the rapid decay of algae.

From the last set of readings until the next set is an interval of almost a year during which time no observations were taken. However, according to the report of November 3, 1930, the conditions were found to be very similar to those noted during the first observation (July 13/29). The fact that the salinity does not appear to have been decreased as much as might be expected although fresh water had been entering the Lagoon continuously for several months, may be explained in two ways; either salt water had been entering through the outlet pipe or through the sea-wall or else salt was being slowly leached from the bottom mud which had been deposited while the Lagoon was still connected with the Harbour. Subsequent investigation showed that the source of the salt water must have been through or around the outlet pipe as small trickles were found entering the Lagoon near that spot during high tides.

To show the condition of the water during the course of the investigation, Table 2 has been prepared. Although it is far from being complete it is sufficient to illustrate the conditions existing in the Lagoon for the greater part of the winter.

The temperatures show a gradual decrease until November 22 when ice covered most of the surface of the water. During the coldest part of the season the temperature remained fairly constant except at Station 1 at which point warmer salt water was making its entrance from Coal Harbour. After the disappearance of the last covering of ice, about February 10, the records indicate a slow rise in temperature. In general the temperature of the water approaches

Date	Station	Temperature °C	°F	Chlorinity Grams per litre	pH
Oct.14/31	1	13·0	55·1	·47	7·2
Oct.18	1	12·8	55·0	·47	7·4
	3	12·0	54·0	—	—
Oct·25	1	7·7	48·0	·55	7·3
	3	10·1	50·5	—	—
Oct·31	1	9·8	50·0	·51	7·3
	3	10·4	51·0	—	—
Nov·7	1	7·7	48·0	·46	7·2
Nov·22	1	-·2	31·8	·42	7·2
Nov·29	1	0·0	32·0	—	—
Feb·1/32	1	5·3	42·0	15·30	8·4
	3	0·0	32·0	·02	7·2
Feb·7	1	4·4	40·5	15·19	8·2
	3	-·2	31·8	·06	7·0
	4	0·0	32·0	·03	7·0
Feb·14	1	·9	34·0	·31	7·4
	3	2·0	36·0	·02	6·8
Feb·29	3	7·1	45·0	·02	7·0

G.C.C./32

Table 2.

nearer and nearer to that of the air as the water circulates from the inlet to the outlet.

Most of the salinity values in the table, given as weight of Chloride per litre, are from samples taken at Station 1 near the outlet. The values are comparatively uniform except on certain occasions when salt water was found to be entering the Lagoon in large quantities. At these times samples were also taken at Station 3 near the inlet as a check on those taken at the outlet. These samples showed that although there was only a small trace of salt present in the freshest parts the salinity was still five times that found for Beaver Lake by Carter (19). On the whole the waters of the Lagoon still contain an appreciable amount of salt ranging from five to over one hundred times the amount usually found in bodies of fresh water such as Beaver Lake.

The readings for hydrogen ion concentration of the water show nothing unusual except on the same occasions when salt water was entering the Lagoon. At these times the water immediately around the outlet showed a pH value of 8.2 to 8.4 which might be expected to be the case in conjunction with the high salinities found at the same time. At other times the pH was on the alkaline side except at Station 3 where it approached neutrality and even slight acidity on one occasion.

On the whole the water of the Lagoon during the winter months, may be described as cool, slightly turbid, slightly brackish and slightly alkaline.

TYPES OF BOTTOM AND PLANTS

There are roughly four types of bottom present in the Lagoon each supporting its own characteristic but scanty flora.

Type A

The first and most barren type is composed of hard clay intermixed with pebbles and patches of gravel. It is at present quite bare of plant-life except perhaps for a few waterlilies (Nuphar polysepala) introduced from Beaver Lake. This unproductive type of bottom is found near the shore along the southern and eastern banks (Plate IV Fig. 2) and includes about 35% of the shoreline. Perhaps as conditions become more favourable some form of plant life such as Nitella or Myriophyllum will become established and convert this waste bottom into an important part of the Lagoon.

Type B

The next type of bottom is composed of soft mud in which are imbedded scattered stones and boulders (Plate V Fig. 6). More introduced waterlilies, small clumps of Myriophyllum Verticillatum and Water Shield (Brasenia Schreber) are found here in the deeper parts while in the shallows and in the marshy section lying above the water level are found dense growths of cat-tails (Typha Latifolia) and a reed (Scirpus robustus). The cat-tail is rapidly extending its limits out into the water by the production of "runners" at right angles to the shoreline. As the outermost border is extended thus, the network of roots so formed is gradually filled in with sediment and decaying material so that the shoreline is slowly creeping out into the water.

The reed which is found mixed in with the cat-tail is of particular interest as it is usually associated with brackish water. It no doubt became established when the Lagoon still contained salt water and has continued to exist under the changed conditions. It will be interesting to note if it continues to thrive by becoming adapted to its new environment.

This type of bottom with emerging reeds and cat-tails extends the full length of the northern shore and along most of the western shore on either side of the mouth of the inlet stream. It makes up approximately 50% of the total shoreline.

Type C

The third and most interesting type of bottom is composed of black loamy soil which provides an anchorage for semi-aquatic plants such as Water-cress (*Radicula Nasturtium-aquaticum*), Creeping Bent Grass (*Agrostis*) and submerged *Myriophyllum*. The Cress is rooted at the water's edge but grows out from the bank forming excellent cover for insect larvae and small crustacea. The Creeping Bent grass is found in the same places but is more terrestrial in its origin. Along the bank it grows in its typical form but the large masses which have crept into the water show a characteristic growth of elongated rootlets and long curved leaves which emerge from the surface of the water. It also provides excellent shelter amongst its matted roots and stems. The *Myriophyllum* is typically aquatic, being found some distance from shore. It has been introduced from Beaver Lake where it is very prolific. This loamy type of bank and bottom is found only in the inlet stream, the bed of which has been excavated from this type of soil (See Plate IV, Fig. 4). It makes up the remaining 15% of the shoreline.

Type D

The fourth type forms the major part of the Lagoon bottom as it includes all the bottom except those parts already mentioned as lying along the shoreline. It is made up of the original mud deposit over which lies a fairly thick layer of ooze and organic detritus which, in shallow places, is easily stirred up by wave action. This type of bottom is also rather interesting as it supports a thick growth of alga (Genus Enteromorpha) which is undoubtedly of marine origin. This alga is composed of elongated cylindrical branching filaments which grow up to the surface of the water except in the deepest part. By the middle of August when the weather is warmest the growth is so thick, according to the boat-house manager, that boats have great difficulty in making progress through it. Towards the end of the summer it begins to die down and by November it has all disappeared except for decaying masses which float near the surface or are cast up on shore. Although it is a hindrance to boating in summer this alga is beneficial to the Lagoon as a whole as it provides shelter in one season and food through decay for bacteria, protozoa, rotifers, etc., in the next. It also adds materially to the organic detritus which is a very necessary base of supplies for maintenance of aquatic life. It will also be interesting to note if this marine form continues to exist in the fresh water of the Lagoon or fails to survive the change.

QUALITATIVE

EXAMINATION OF FAUNA.

LIST OF ORGANISMS FOUND IN LAGOON.

ALGA.

Aphanocapsa elachista

Hapolosiphon intricatus

Scenedesmus quadricauda

Enteromorpha

Spirogyra

Botryococcus

Mougeotia

Hormidium

Golenkinia

Chlorosphaera

DIATOMACEA.

Fragilaria capucina

Campylodiscus

Navicula

Odontidium

Diatoma

PROTOZOA.

Sarcodina

Difflugia constricta

" globulosa

Difflugia oblonga

" pristis

" bacilliarum var. elegans

" olliformis

" pyriformis

Nebela americana var. retorta

" collaris

" tincta

" dentistoma

" tubulosa

" griseola

Pseudo difflugia gracilis

Centropyxis aculeata

Trinema lineare

" enchelys

Englypha ciliata

" strijosa

" brachiata

Quadruella symmetrica

Arcella sp.

Acanthocystis spinifera

" myriopoda

Pompholyxophrys punicea Archer

" ovuligera

MASTIGOPHORA.

Oikomonas termo

Bodo globosus

Astasia sp.

CILIATA.

Paramoecium

Spirostomum

Urocentrum

Halteria

Oxytricha

Glaucoma

Trichoda

Colpoda

Colpidium putrinum

Vorticella

ROTIFERA.

Rattulis cylindricus (?)

Asplanchna priodonta (?)

Brachionus sp.

ANNULATA.

Tubificidae sp.

Lumbricus sp.

BRYOZOA.

Plumatella polymorpha var. oppressa

CRUSTACEA.

INSECTA.

<u>Collembolla</u>.

One species

<u>Ephemerida</u>.

One species (larva)

<u>Odonata</u>.

Zygoptera - Chromogrion sp.

Anisoptera - at least one species

<u>Trichoptera</u>.

One species (larva) Family Phryganeidae

<u>Hemiptera</u>.

Callicorixa praeustus

Nepidae species

<u>Diptera</u>.

Culicidae - Anopheles species

Tipulidae, one larva

Chironomidae - several unidentified species

<u>Cladocera</u>.

Daphnia pulex var. obtrusa

<u>Copepoda</u>.

Cyclops fuscus

Canthocamptus sp.

<u>Isopoda</u>.

Exosphaeroma oregonensis (Dana)

Asellus tomalensis

<u>Hydracarina</u>.

Arrhenurus globator (?)

PISCES.

Gasterosteus cataphractus

Cottus asper Richardson

Salmo clarkii

NUMBERS, DISTRIBUTION AND ASSOCIATIONS.

A L G A E.

Most of the algae being of microscopic size, was collected in the plankton net or was found in cultures of water taken from various parts of the Lagoon. Disregarding the branching filamentous type of marine origin the amount of algae present was very small except on a few occasions. The amount of diatoms was also very small especially in the more open parts of the Lagoon away from the water supply. Diatoms were found in greatest abundance in the very small stream flowing into the main inlet stream about twenty yards above its mouth (See Plates Fig. 5).

The dominant species here during the winter months was *Fragilaria capucinia* which occured in long, flat filaments but which was found only in small numbers. The scarcity of these important forms of algae and diatoms has a decided effect on the fauna of the Lagoon as they form the basis of all food.

P R O T O Z O A.

Fairly large numbers of protozoa were found, possibly on account of masses of decaying algae (*Enteromorpha*) floating near the shore. Most of the ciliates and flagellates were identified, into genera only, from cultures prepared from these decaying masses. The other protozoa, principally Rhizopoda and Heliozoa, were found in the small tributary stream along with the filamentous diatoms. The protozoa are important only in that they are used as food by other small animals.

R O T I F E R A.

The Rotifers were represented mainly by two species, Rattulis cylindricas and Asplanchna priodonta (?) which occured in large numbers during the fall months. These Rotifers made up the greatest part of the plankton during this time and appeared to be universally distributed. Possibly their great abundance at this time was due to the presence of large numbers of protozoa which were feeding on the decaying algae found everywhere in the Lagoon.

B R Y O Z O A.

Although no Bryozoans were found in the Lagoon at the time, colonies of Plumatella polymorpha appeared in cultures on standing in the warm laboratory. These must have arisen from statoblasts collected by accident along with the water sample. The fact that these fresh-water forms of Bryozoa form winter buds or statoblasts which are easily transported from place to place explains how Plumatella probably became distributed from Beaver Lake where it is quite common. As Bryozoans do not generally form an article of diet for other animals they are mentioned here as being interesting only on account of their possible origin.

INSECTA.

The insects found to be most abundant in the Lagoon were water boatmen (*Callicorixa praeustus*) and May fly larvae both of which are important as fish-food. The boatmen were found along the shore wherever vegetation in the form of rushes, grass or water-cress existed. The May fly larvae were found only in the weeds along the inlet stream. As both these forms feed only on plant tissue or detritus they form a direct link in the food-chain between plants and fishes.*

Several unidentified species of midge larvae (*Chironomidae*) were found by examining the ooze on the bottom of the inlet stream. Although Chironomids are an important article of diet for fishes they were not present in large enough numbers to be of much use as food.

A few dragon-fly, damsel-fly, and mosquito larvae were also found in the masses of weed in the stream but these also were present in small numbers.

* In the laboratory some boatmen were observed feeding upon live chironomial larvae but this is probably an exceptional case.

CRUSTACEA.

Large numbers of Cladocer~~eus~~ans (*Daphina pulex*) were found by sweeping with a net under bunches of overhanging grass and water-cress along the banks of the inlet stream. With them were found numerous copepods all of one species (*Cyclops fuscus*) which were apparently feeding upon the same plant material as the cladocerans.

Both crustaceans were being eaten by sticklebacks (*Gasterasteus*) which were collected at the same time.

In the first collections most of the cladocerans were found to contain summer eggs or developing young but towards the end of the season numbers were found bearing ephippia containing winter eggs. Soon after this the numbers of *Daphnia* decreased rapidly, possibly on account of the oncoming of cold weather and large numbers of winter egg-cases were found floating among the weeds on the surface of the water.

The copepods appeared to remain more constant in numbers although the older ones bearing egg-masses disappeared before the end of the season. Copepod nauplii were found at all times in the plankton of both the open Lagoon and the stream.

The copepods and cladocerans no doubt originated from Beaver Lake by being carried over on water plants, in samples of water or by birds which frequent both bodies of water.

I S O P O D A.

Of the two isopods found in the Lagoon one in particular, viz; *Exosphaeroma oregonensis*, was of especial interest as it is of salt-water origin (Plate VI). It is a common form found everywhere in Puget Sound, on the beach at low tide, under rocks and on wooden piling. (2)

This isopod appeared to be doing quite well in spite of the great change in its habitat. It was found in fairly large numbers in all parts of the Lagoon even where the water was freshest. It occured under stones, bits of wood along the bare shore and amongst grasses and water-weeds along the inlet end of the Lagoon. Although no individuals were found carrying eggs at that time of the year many small specimens were taken showing that breeding must have taken place. It is to be hoped that this is true and that they continue to thrive as these isopods were found to form a large part of the diet for trout.

The other isopod was a typical fresh-water form of the genus *Asellus*. It agrees with the description of *A. tomalensis*, as given by Fee (2) in every respect but in that of the proportions of the head. This crustacean was possibly introduced along with the water plants from Beaver Lake where *Asellus* occurs in fairly large numbers. Only a few of these isopods were found, all in the freshest part of the Lagoon near the inlet stream.

The Prickly Bullhead (*Cottus asper*) is another fish present in the Lagoon in fairly large numbers. As it is often found in brackish water near the mouths of rivers and streams it probably was present in the Lagoon before it was cut off from the Harbour. This sculpin is universal in distribution being found in all parts of the Lagoon particularly amongst the aquatic plants of the inlet stream. It preys upon the sticklebacks which are most numerous there but also feeds on earthworms, grubs and aquatic insect larvae. As there is considerable range in size in the specimens collected, the smallest being about 5 centimetres long and the largest about 12 centimetres, it is presumed that these bullheads are breeding in the Lagoon and may increase in numbers. Although they are probably not directly harmful to mature trout they do no good since they help in depleting the available food supply.

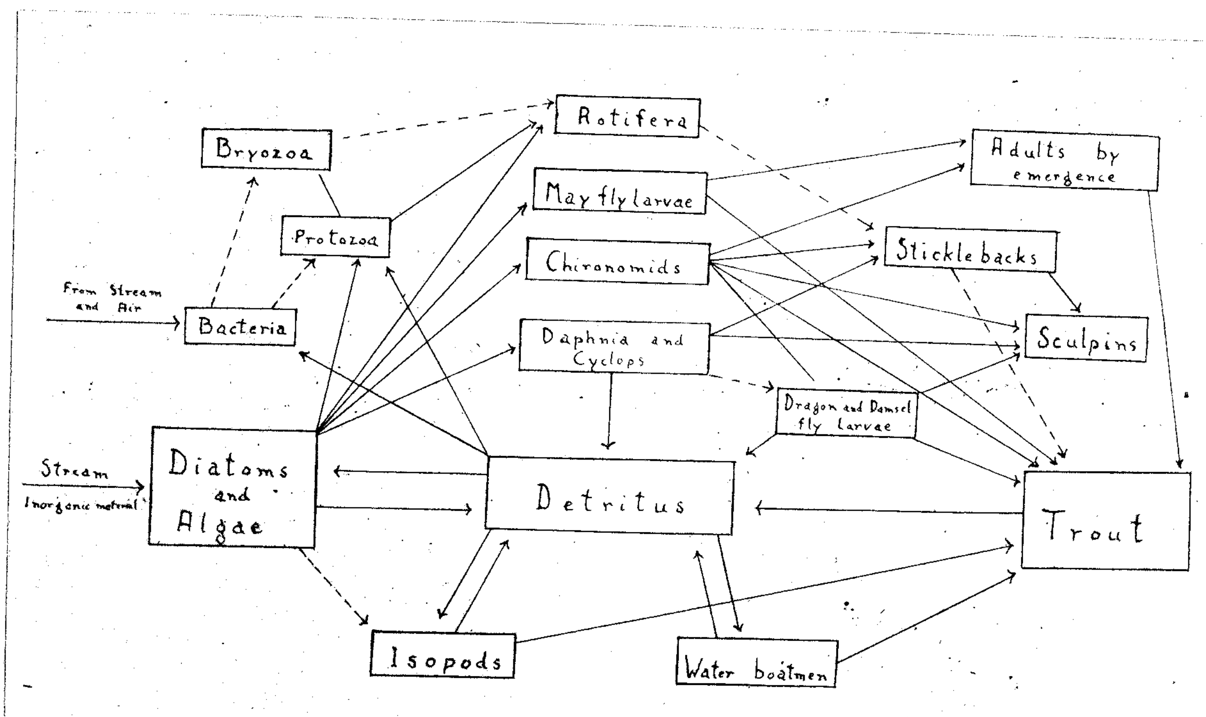
Although two species of trout (Salmo clarkii and S. rivularis ? Kamloops) were introduced into the Lagoon it is probable that only the former is now present since the Kamloops trout were introduced as small fry when conditions were very unfavourable. During the investigation no trout were seen at any time except one dead specimen found early in October. This particular fish appeared to be in good condition and had plenty of food in its stomach. No cause of death was apparent.

Another type of marine fish seen in the Lagoon during the first part of the Survey was a species of flounder. As no specimens were obtained the fish was not identified. It is unlikely that these flat-fish will become adapted to the fresh water since several dead ones were seen early in the season.

FOOD CYCLE.

Since the Lagoon has so recently been changed to fresh water the interrelations of the plants and animals present there do not form such a complex maze as is found in an older lake. An attempt has been made therefore, to note the relationships of the more important forms and to determine food-chains which go to make up the food-cycle for the Lagoon.

Diagram 1.



Circulation of Food Materials in Lost Lagoon

This is shown in Diagram 1 which includes only those organisms which are most important or most numerous. The arrows represent the processes by which the food materials may be transformed, that is, the paths by which nutritive materials may circulate. Wherever doubt is present as to the relationship between different "links" it is designated by means of dotted lines. The diagram can only represent, then, possible paths for food materials and can not give any idea of relative importance of the different processes or relative numbers of the different organisms.

Some of the separate food-chains such as Detritus - Isopods - Trout can be said to be present in any part of the Lagoon as each "link" of the chain is more or less universally distributed. However the whole cycle as represented, can take place only in the sheltered water of the inlet stream since that is the spot where all the forms representing the links are found. Thus it can be seen that as new types become established changes will occur in the various relationships which will affect the food-cycle and may even cause the extinction of some forms already existing.

FACTORS INFLUENCING SUITABILITY FOR TROUT.

According to Rawson (12) "The physical and chemical conditions that control the life and life processes in a lake may be unified by tracing them back to two fundamental conditions. The first is the shape of the lake which must include its depth, area and conformation of its shores. The second is the geographical position of the lake including the nature of its drainage area and the climatic conditions ~~are~~ of the region. These conditions are linked up with the fauna and flora of the lake to form a working unit or microcosm."

Such conditions as the temperature and the chemical properties of the water are commonly spoken of as factors limiting the life of the pond or lake. However, they cannot be looked upon as simple or isolated factors but rather as the culmination or result of a number of agencies. These physical and chemical factors are interrelated and interdepend~~a~~ent in a most complex manner. In an equally complex manner the biological activities of the lake are interrelated both among themselves and with the physical and chemical activities. But for convenience in investigation and discussion these "factors" must be dealt with separately.

The factors determining the suitability of the Lagoon for maintenance of trout are discussed in the following order:

WATER CONDITIONS.

Temperature range

Oxygen supply

pH

Salinity

BIOLOGICAL CONDITIONS.

Plants, protective and food relations

Animals, associations and competitions

WATER CONDITIONS.

TEMPERATURE.

According to Gutsell (3) "a sufficiently low temperature has been considered the prime requisite of trout waters since trout culture began, and for an untold number of years before that. For the present, at least for "normal" water containing abundant oxygen and free of toxic substances, low summer temperature must be considered the limiting factor requisite for the trout and tolerated by the associates".

Unfortunately, as the investigation was carried on only during the winter months very little is known about water conditions in the Lagoon during the summer. However, the little that is known shows that the temperature conditions are far from being ideal for trout. As shown by the table the highest temperature recorded on August 2/29 was 24.2° C (76°F.) and the lowest taken at the very head of the stream was 15.0°C (59°F.).

August 2/29	Temperature	
In Lagoon	24.4°C.	76°F.
Inlet stream below bridge	21.9°C.	72°F.
Inlet stream above bridge	18.8°C.	68°F.
Head of stream	15.0°C.	59°F.

TABLE 3 - Summer temperatures in Lagoon.

It is true that had the artificial water supply been running at that time the temperature would not have reached such a high maximum. Nevertheless it is doubtful that any trout could survive such temperature extremes even assuming that plenty of oxygen was present.

Although the high temperature in summer is the result of a number of agencies the greatest cause is undoubtedly the shallowness of the water. This lack of depth prevents the formation of a thermocline or stratum of water separating the warm surface layer from a very much cooler deeper layer. It has been shown by Pearse (10) that in the summer, organisms tend to migrate from the warmer layer to the cooler waters beneath. This migration of course is impossible in the Lagoon where the bottom water is very little cooler than the surface.

O X Y G E N

Again the records are very scanty for this important factor, especially for the summer months which is the most critical time. Jewell and Brown (4) found that even bog lakes "with the lowest oxygen content found (2.56 c.c. per litre) contained adequate oxygen at the time of study for the maintenance of fish life". They also noted that the low oxygen content was produced by processes of putrefaction common to bogs. It is probable then, that the amount of free oxygen which is large during the cooler seasons may, in the Lagoon, be considerably reduced during the late summer by the rapid decay of large quantities of algae together with the high temperature.

It is unfortunate that no data is available for this critical period except that given in Table 1.

pH.

As a result of their investigation of the fauna of bog lakes Jewell and Brown (4) were convinced "that pH as such is rarely a limiting factor to the distribution of fresh-water fish in natural waters". In general more fish are found in alkaline or neutral water than in acid water. It can be said then, that as far as pH is concerned the Lagoon, which has a pH of 7.2 - 7.4 is not unfavourable to fish life.

S A L I N I T Y

Since very little is known about the effect of dissolved salts on fresh-water fish little can be said about the effect of the slightly brackish water of the Lagoon on trout. It is possible that the small amount of salt present does not harm the Cut-throats in the Lagoon as this species of trout is capable of entering the sea. However, the salinity of the water does effect the trout indirectly since it prevents the establishment of most fresh-water organisms necessary for food.

BIOLOGICAL CONDITIONS.

It has been shown already that although the amount of life in the Lagoon is comparatively scanty the relationships between the various forms are very complex. The effect of these relationships on trout should now be considered.

PLANTS

The ultimate source of all food is found in plants which are represented in the Lagoon chiefly by algae and diatoms. Although a variety of forms are present, in actual numbers they are very scanty. This effects the well-being of trout indirectly as the amount of available food is limited commencing with the first "link" of the food-chain.

The larger aquatic and semi-aquatic plants are important mostly as shelter for the smaller forms of life and to a lesser extent as food. Most of those found in the Lagoon have been introduced from Beaver Lake and therefore their numbers are very few as yet. This scantiness also has an indirect effect upon trout-life, in that it limits the number of small forms which usually find refuge in sheltering plants.

ANIMALS

The effect of animals or animal communities on trout is also a matter of food. As illustrated in the diagram of the food-cycle for the Lagoon (Dia. 1) trout depend upon a number of different organisms for food. Perhaps the most important groups in the food-chain is that formed by Daphnia and Cyclops. These crustaceans are present in fairly large numbers and help to form the link between plants and many other animals which are dependent upon them. Using terms suggested by Elton (1) they may be called "key industry" animals and may be said to fill a definite "niche" in the community. It can be understood then, that with a limited supply of food for these important forms as is the case in the Lagoon, the supply of food for trout must likewise be limited.

C O N C L U S I O N.

Considering the fact that the Lagoon, as a fresh-water lake, is so young it has made good progress in productivity from conditions which might be called zero as far as fresh-water food types are concerned. This rapid progress has been brought about mainly by introduction of aquatic plants and animals from nearby Beaver Lake where they are well established. But in spite of this progress towards a fresh-water unit conditions in the Lagoon can hardly be said to be favourable for the well-being of trout.

It is true that the amount of available food in the water is not sufficient to supply more than a few trout but this difficulty could be overcome to a certain extent by artificial feeding. It is also true that the water still contains an appreciable amount of salt especially at the eastern end. This condition in itself does not harm the fish but it does have a detrimental effect on the food-types of the trout. This is made evident by the fact that nearly all the aquatic organisms present in the Lagoon are found where the water is freshest, that is, in the inlet stream. No doubt, as the water becomes fresher these important organisms will spread to other parts of the Lagoon and thus this fault will be corrected.

The greatest factor which presents the Lagoon from being favourable to the maintenance of trout is the unnaturally high temperature of the water during the hot weather. An attempt was made in the previous section to explain the cause of this abnormal temperature and its effect on trout. In the following section a few suggestions are offered on controlling this condition.

In general then, it is the opinion of the writer that Lost Lagoon is still unfavourable for trout for the above reasons but that it is capable of being made a successful trout-pond if some means are found for correcting these unfavourable conditions.

RECOMMENDATIONS.

The following recommendations are more in the nature of suggestions and it is asked that they be looked upon as such.

(1) It has been shown that the factor which has the greatest effect on trout is the excessively high temperature of the water in the summer months. It has also been shown that the Lagoon would not be unfavourable to trout-life if this high summer maximum were avoided. This extreme temperature could be lowered in three ways:

(a) By increasing the depth through dredging. One or two deep parts could be produced by pumping or dredging out mud from the deeper portions that are already present. The material from this work could be used to form an island which would provide more shade and shelter for aquatic life.

(b) By raising and maintaining the water-level. Increasing the depth by raising the level of the water even as little as a foot would also help to lower the mean summer temperature.

(c) By increasing the flow of water from the inlet. This would be the simplest and least expensive way of controlling the temperature. It would certainly produce a sufficiently low temperature at least in the inlet stream if not in the Lagoon as a whole. In order to handle the increased amount of overflow it would likely be necessary to increase the diameter of the outlet pipe.

(2) Next in importance to a favourable temperature is the presence

of suitable water plants to serve as food and shelter to the various animals upon which the trout depend. It is suggested then, to continue introducing aquatic plants from Beaver Lake and other sources until these desirable forms have become definitely established in the Lagoon. As conditions are approaching nearer and nearer to those of a fresh-water lake this should be accomplished in the near future.

(3) Steps should be taken to prevent the entrance of more salt water from the harbour since the presence of dissolved salts in the Lagoon tends to limit all fresh-water organisms to the inlet stream by rendering the rest of the Lagoon unfavourable for them.

(4) If it should happen that trout fail to establish themselves in the Lagoon in sufficient numbers to allow angling, it is suggested, as an alternative, to introduce some other form of fish-life which would thrive under present conditions. Such fish as bass, sunfish, perch or carp could be tried to determine which might be most suitable. Although these fish are much less desirable than trout they would supply a form of sport at least to some people.

BIBLIOGRAPHY.

1. Elton, Charles

   1927 Animal Ecology

   Sidgwich and Jackson, Ltd. - London.

2. Fee, A. R.

   1926 Isopods of Departure Bay and Vicinity with Description of Near Species, Variations and Color Notes. Contributions to Canadian Biology & Fisheries. (New Series Vol. 111 No. 2)

3. Gutsell, James S.

   1929 Influence of Certain Water Conditions; especially dissolved Oxygen, On trout. Ecology - Vol.X - No. 1 January /29.

4. Jewell, M. E. and Brown, H. W.

   1929 Studies of Northern Michigan Bog Lakes. Ecology - No. 4, October 1929.

5. Jordan and Evermann

   1898 - Fishes of North and Middle America, United States National Museum, Washington.

6. Kudo, Richard R.

   1931 - Handbook of Protozoology

   Chas. C. Thomas, Baltimore, Maryland.

7. Matheson, R. and Hinman, E. H.

   1930 - Seasonal Plankton of Spring fed chara pool vs.

Temporary Woodland pool in relation to Mosquito Breeding. American Journal of Hygeine Vol. Xl #1.

8. Needham, J. G. and Lloyd J. T.

1916 - Life of Inland Waters.

Comstock publishing Co.

9. Noland - Lowell E.

1925 - Factors limiting Fresh-water Ciliates

Ecology. Vol. Vl. No. 4 October /25.

10. Pearse, A. S.

1926 - Animal Ecology

McGraw-Hill Publishing Co.

11. Petersen, Walburga

1926 - Seasonal Succession of Animals in a Chara - Cattail Pond.

Ecology Vol Vll. No. 3 July 1926.

12. Rawson, Donald S.

1930 - Bottom Fauna of Lake Simcoe and Role in Ecology of the Lake. University of Toronto Press, #34 Ont. Fisheries, Research Laboratory.

13. Reed, G. & Klugh, A. B.

1924 - Correlation between Hydrogen ion Concentration and Biota of Granite and Limestone Pools.

Ecology Vol. V. No. 3, July /24.

14. Shelford, V. E. and Eddy, Samuel

1929 - Methods for Study of Stream Communities.

Ecology #4, October 1929.

15. Wailes, G. H.

1930 - Munday Lake and its Ecology.-Museum and Art Notes. - September 1930, Art, Historical & Scientific Association, Vancouver, B. C.

UNPUBLISHED REPORTS OF PACIFIC BIOLOGICAL STATION.

16. Clemens, W. A.

1929 - July 13 - Report on Lost Lagoon.

17. Mottley, C. McC.

1929 - August 31 - Lost Lagoon Report.

18. Hart, J. L. and Pritchard, A. L.

1929 - November 29 - Examination of Lost Lagoon.

19. Mottley, C. Mc C. and Carter, Neal M.

1930 - November 3, Report on Beaver Lake and Lost Lagoon.

PLATE III

Fig. I Lost Lagoon, looking north-west.

Fig. 2 Looking east along southern shore towards the Viaduct.

PLATE IV

Fig. 3 Northern shore from Station I. Cattail marsh in foreground.

Fig. 4 Inlet Stream looking east towards its mouth. Tributary entering on left.

PLATE V

Fig. 5 Tributary entering muddy water of the Inlet Stream.

Fig. 6 Mouth of Inlet Stream. Reeds and cattails in the background.

PLATE VI

Fig. 7 Exosphaeroma oregonensis (Dana) A marine isopod found in the fresh water of Lost Lagoon.