AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

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BATCH # 18

1. SUBJECT CLASSIFICATION	A. PRIMARY Agriculture	AM10-0000-G530
	B. SECONDARY Fishing methods,techniques,and equipment--Peru	

2. TITLE AND SUBTITLE
Potential trout production and management of lakes in central and southern Peru

3. AUTHOR(S)
Shelton,W.L.; Davies,W.D.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1974	44p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Auburn

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

10. CONTROL NUMBER PN-RAA-940	11. PRICE OF DOCUMENT
12. DESCRIPTORS Peru Trout	13. PROJECT NUMBER
	14. CONTRACT NUMBER CSD-2270-GTS
	15. TYPE OF DOCUMENT

AID 590-1 (4-74)

POTENTIAL TROUT PRODUCTION AND MANAGEMENT OF LAKES IN CENTRAL AND SOUTHERN PERU

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W. L. Shelton
Alabama Cooperative
Fishery Unit
U. S. Fish and Wildlife
Service

W. D. Davies
International Center
for Aquaculture
Department of Fisheries and
Allied Aquacultures

Auburn University
International Center for Aquaculture
Auburn, Alabama 36830
December 15, 1974

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Auburn University
Agricultural Experiment Station
Auburn, Alabama 36830

1.0 INTRODUCTION

In response to a request by the Government of Peru and under the sponsorship of USAID, a study was conducted from August 26 to September 20, 1974 on the trout fisheries of the central and southern mountain lakes. The objectives were to provide the Ministry of Fisheries with recommendations for developing a realistic program of stocking, management and harvest for the fishery resources of these lakes.

The principal sources of information used in preparing this report were:

1. Basic chemical, physical and biological data collected from sampling expeditions to the following lakes:

   Pomacocha

   Abascocha

   Junin

   Nahuinpuquio

   Tembladera

   Carhuacocha

   Langui-Layo

2. Existing trout stocking records for the central and southern mountain lakes and rivers.

3. Interviews with personnel of the Ministry of Fisheries, USAID and Peace Corps.

Personnel of the Ministry's Department of Inland Fisheries contributed significantly to the study. In this respect, Eng. Enrique Melgar I., Eng. Carlos Florian G., Blg. Julio Molina S., Blg. Rolando Canales P., Eng. Julian J. Barra C. and Eng. Cesar Luck O., were gracious and helpful hosts. Peace Corps Volunteer John W. Sowles provided indispensable assistance throughout the study.

1.1 Central and Southern Mountain Region

The highlands make up approximately 27 percent of the land area of Peru and contain 62 percent of its population. The area is rich in river systems that begin as fast flowing rivulets in the high mountains, but soon form meandering streams in the valleys. Mining operations have contaminated many of the lower reaches of these streams making them unfit for fish life. Also, during the rainy season (October 15-April 15), many of the streams become silt laden and torrential.

Mining and agricultural practices will continue to affect water quality in the streams. Mining for copper, lead, iron, zinc and tin is expanding in the mountain region. This area also contains little additional flat land suitable for cultivation. An increasing number of small plots are being cultivated on slopes as great as 45 degrees; as a result the runoff during the rainy season is heavily laden with silt.

The area has abundant lakes ranging in size from a few hectares to approximately 8,446 square kilometers (Lake Titicaca). The number of lakes and total area is not known, but appear to be widely scattered in the region.

Rainbow trout were first successfully introduced into Peru in 1940 from the United States and eventually were stocked into many of the rivers and lakes. The native fish fauna that existed in these waters were *Orestias* sp. (tooth carps) and *Trichomycterus* sp. (catfishes) and, in some cases, supported a subsistence fishery. At least one species of *Orestias*, which was a favorite food item of inhabitants of the area, was climinated in Lake Titicaca after trout were introduced.

Many of the lakes however, have no or very limited spawning areas; therefore a stocking program is necessary for a sustained yield of trout. Also, enforcement of the closed season (June through September) is probably not effective. Most lakes in this region can be characterized by low water temperature (10-18 C) and high transparency; also they are relatively deep (average depth $>$ 7 meters) and with moderate levels of total dissolved solids. While such waters are capable of supporting trout growth, production can not be as great as warm water lakes supporting a variety of fish species.

1.2 Fish Marketing and Consumption

In 1972, the reported catch of fish for human consumption in Peru was approximately 221,624 tons (Keith, 1974). Of this, 127,000 tons were destined for local consumption. No information was available on the quantity of trout produced. Trout, however, are generally considered to be an export item, although restaurants in the mountain regions and in Lima offered fresh trout on the menu.

Per capita consumption of fish in Peru is estimated to be 13.5 kg annually and is one of the highest in South America. The consumption rate may be influenced by the relative high cost and availability of fish when compared to other meat products:

Price [1]/kg in soles (s/.)[2]

Product		Lima	Mountain Region
Marine			
Corvina	(drum)	55.00	55.00
Mackeral		28.00	28.00
Kingfish		20.00	20.00
Coco	(drum)	16.00	16.00
Whale		*	25.00
Freshwater			
Trout		85.00	23.00
Pejerrey	(silverside)	*	20.00
Suche	(catfish)	*	20.00
Challwa	(tooth-carp)	*	5.00
Other meat			
Chicken		*	60.00 - 80.00
Alpaca		*	10.00
Llama		*	11.00
Beef	(steak)	90.00 - 110.00	20.00 - 35.00
Mutton		*	17.00 - 34.00
Pork		*	15.00 - 30.00

1 National Price list and market survey
2 43.38 Soles = 1 US dollar
* Not observed

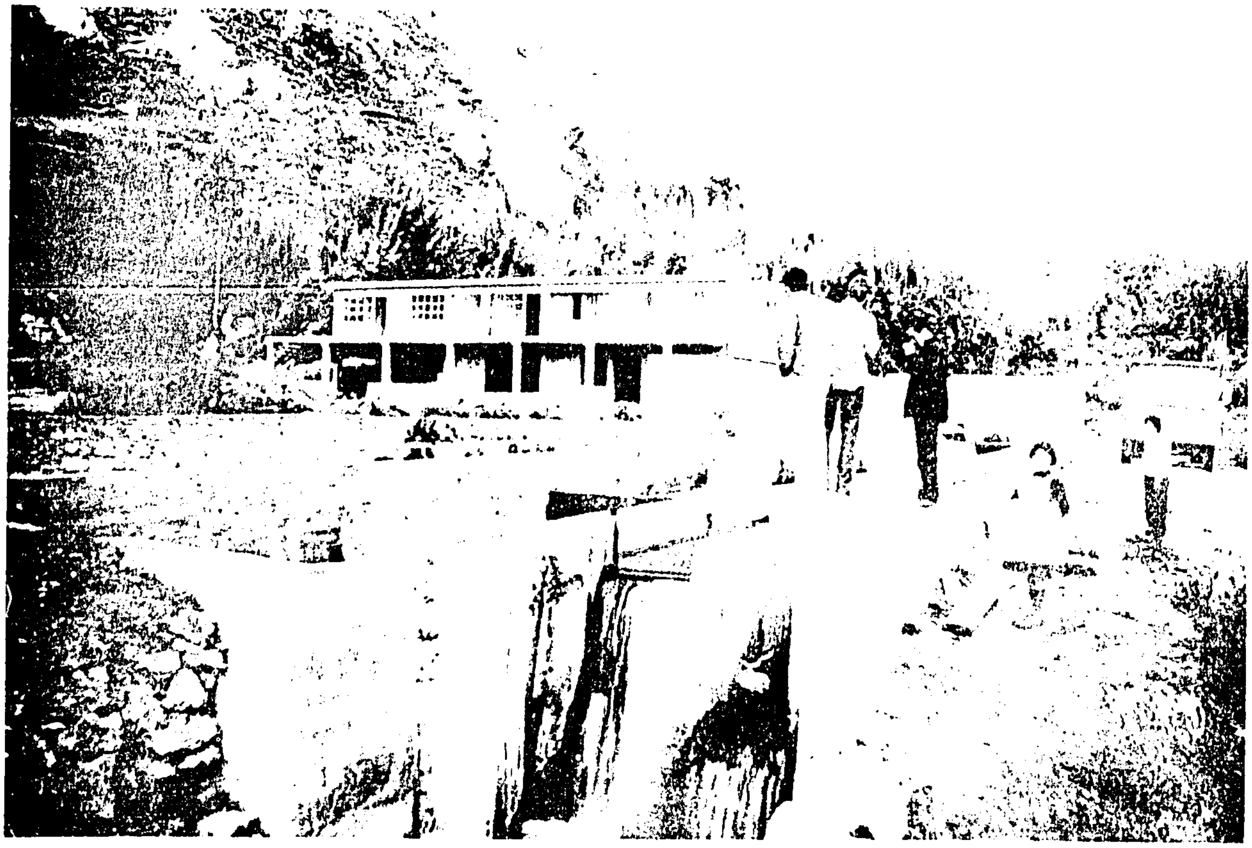

Figure 1. Private trout raceways-Ingenio, Department of Huancayo. The Ministry of Fisheries encourages these operations through their trout production hatcheries.

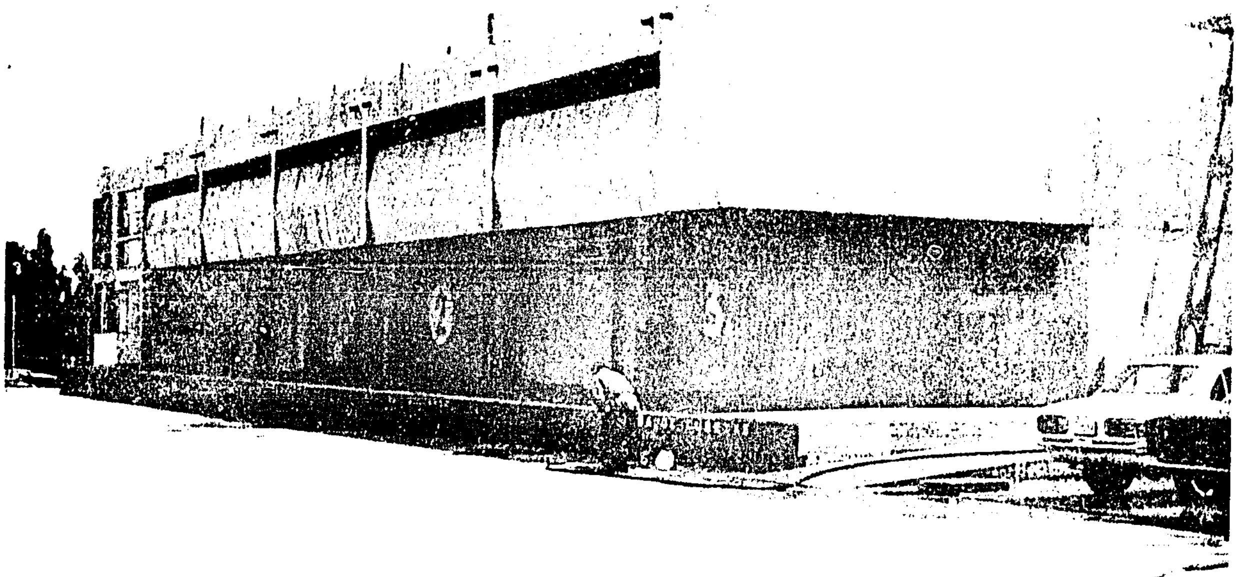

Figure 2. Modern EPSEP freezing facility-Huancayo. Fishes are distributed throughout the country and, because of these facilities, fish products

Fish products are usually sold fresh. In Lima, no freshwater fish were observed in the markets. However, this study was conducted during the period (June-September) when inland waters were closed to trout fishing. Trout sold to restaurants during this period were from government or private fish farms and government approval is required for their sale. In Huancayo a government operated refrigeration plant with a combined storage and freezing capacity of 35 metric tons receives and sells fish in the area. For example, the plant will buy trout from fishermen or fish farms at 75.00 s/. per kg. They will, in turn, sell them to wholesalers for 82.00 s/. per kg; the consumer will pay 85.00 s/. per kg. Approximately 99 percent of the frozen fish observed were from salt water; only a few trout were on hand.

1.3 Government Division Responsible for Inland Fisheries

The Division of Inland Fisheries within the Ministry of Fisheries has responsibility for managing the fishery resources of the continental waters. The division of the country into five regions has just been recently instigated. Each Department is semi-autonomous with its own budget, management and research program.

The Division is stressing the development of both warm and cold water fish production facilities. Government trout hatcheries are capable of producing a large number of fingerlings for stocking. For example, the hatchery at Ingenio this year will produce approximately three million fingerlings. About one-half will be retained at the hatchery; the remainder will be distributed to government and private fish farms. Income from the sale of exported trout is presumable channeled back into the region's economy.

Also of interest is the use of lakes and streams for the semi-intensive culture of trout. Although trout have been periodically stocked in many of the lakes and streams, records prior to 1973 were not available. Also, very little information is available on the success of these introductions.

2.0 SURVEY METHODS AND RESULTS

2.1 Biological Productivity

Natural lakes of the central and southern Peruvian Andes were sampled to estimate potential yield of fish biomass. The estimates are based on parameters that could be rapidly measured and thereby derive a "first order" estimate of their potential. Many authors have attempted to explain variability in fish production on the basis of various biotic and abiotic factors (Jenkins, 1968; Hayes and Anthony, 1964; Huet, 1964; Ryder, 1965). We chose parameters that would yield estimates by various techniques. For example, an estimate of commercial fish harvest can be derived from total dissolved solids (Rawson, 1955) or mean depth (Rawson, 1952), or a combination of these parameters as a morphoedaphic index (Ryder, 1965).

Average depth of the lake was determined using the technique suggested by Neumann (1959) and the total dissolved solids was estimated using either of the correlates of total alkalinity or conductivity (Henderson, et al., 1973). Also, the parameters of temperature, hardness, pH and transparency were determined.

In addition to these physical and chemical parameters, the lakes were sampled for certain biological characteristics as indicators of productivity. The fish populations were sampled with gill nets and by seining.

The gill nets were 125' x 6' with five, 25' panels of 0.75-, 1.00, 1.25-, 1.50- and 2.00-inch bar mesh. Two such nets were fished overnight in each lake. Seining was done in representative habitats with a 12' x 4' seine with 3/16-inch mesh. A vertical plankton tow of 21 feet, or to the bottom, was taken near the center of the lake. The net had a mouth diameter of 10" and a mesh of 50 threads to the inch.

Benthos was sampled more qualitatively by picking organisms from the seine, from the substrate or by passing a substrate sample through a #30 screen. All biological specimens were preserved. Macrophytes were noted, but none were sampled.

2.2 Central Mountain Lakes

Lake Abascocha (Habasccocha). Abascocha is located about 27 km northeast of Conception in the Department of Junin at an altitude of 4,450 meters MSL. The surface area of the lake is approximately 36 ha with an estimated mean depth ($\bar{z}$) of 7.6 meters. The physico-chemical characteristics and calculated productivity are presented in Table 1. The lake was generally "L" shaped with the two main axes running NW - SE and N - S. There was no emergent vegetation, but submergent vegetation was abundant. A marginal zone of one to several meters wide was devoid of vegetation but from about one to three or four feet in depth, the bottom was covered with a carpet of plants up to several feet thick. Elodea- and Ceratophyllum-like plants were present (Table 2).

Table 1

PHYSICO-CHEMICAL CHARACTERISTICS AND PRODUCTIVITY OF CENTRAL SIERRA LAKES

Lake	Trans-parency (m)	Total Alka-linity (ppm)	Total Hardness (ppm)	pH	Temper-ature (C)	Con-ductivity[1] (umhos)	MEI[2]	Calaculted Yield (kg/ha/yr)[3]	Biomass (kg/ha) [4]
Abascocha Area = 36 ha z = 7.6 m	4.3	34	68	7.0	8.5	32.0	0.58	1.57	13.08
Pomacocha Area = 80 ha z = 6.8 m	1.8	-	34	7.0	7.8	24.3	0.54	1.58	13.17
Nahuinpuquio Area = 10 ha z = 6.8 m	6.4	171	222	8.5	17.0	252.0	6.76	5.04	42.00
Junin Area = 260 Km^2 z = 3 m	4.0	86	154	7.0	11.0	-	12.50	6.90	57.50
Tembladera Area = 76 ha z > 42.5 m	17.0	34	51	7.5	9.5	-	0.33	1.30	10.83
Carhuacocha Area = 184 ha z = 37.1 m	8.0	68	154	9.0	11.0	-	0.80	2.18	18.17

1 Adjusted to 20 C
2 Morphoedaphic index = total dissolved solids/mean depth (feet)
3 From Ryder, 1965
4 From Gulland, 1970

Table 2

OBSERVED MACROPHYTES OF CENTRAL SIERRA LAKES

	Abas-cocha	Poma-cocha	Nahuin-puquio	Junin	Tembla-dera	Carhua-cocha
	Lakes					
Algae						
Chara	X	X	X	X	X	X
Nitella	X	X	O	X	X	A
Vascular						
Elodea	C	O	C	X	X	O
Myriophyllum	X	X	C	X	O	A
Ceratophyllum	O	X	X	X	X	X
Potamogeton	X	X	A	X	X	X
Nasturtium	X	X	C	C	X	X
Najas	X	X	C	X	X	X
Typha	X	X	C	O	X	X
Scirpus	X	X	A	A	X	X

A = Abundant
C = Common
O = Occasional
X = Not collected

Zooplankton was very abundant. Although our plankton net selected only the larger forms, there was little evidence of phytoplankton (based on water transparency of 4.3m). Copepods and cladocera were very abundant and littoral benthos was diverse and numerous. Amphipods, although not considered a part of the benthos, were very common in the littoral zone but not in the limnetic area (Table 3).

Only one species of fish (Orestias sp.) was collected and only in marginal areas where sediment had formed a muddy bottom; none were collected over the more common rocky bottom. It does not appear that this species would seriously compete with introduced trout fingerlings for food; nor would they serve as a significant source of forage for larger trout.

Trout were apparently stocked in Abascocha in the past; however, because of the lake's close proximity to the road, heavy fishing pressure has probably eliminated the initial stock. Abascocha has no tributaries suitable for trout reproduction.

Lake Pomacocha. Pomacocha is located about 25 km Northeast of Conception, adjacent to Abascocha. The lake is elongate with the main axis running NE-SW. The lake level has been raised 1 meter by a partial damming of the outlet in 1971 - 1972 and presently has an area of approximately 80 ha; mean depth equals 6.8 meters. The recently inundated area presents an atypical shoreline in that it is relatively shallow and free of larger rocks. The physico-chemical characteristics and calculated productivity are presented in Table 1.

Table 3

RELATIVE ABUNDANCE OF ZOOPLANKTON AND OTHER INVERTEBRATES

Organisms	Lakes					
	Abas-cocha	Poma-cocha	Nahuin-puquio	Junin	Tembla-dera	Carhua-cocha
Cladocera*	A	O	A	C	O	C
Copepoda*						
Callonoid	A	C	X	C	C	C
Cyclopoid	X	O	X	X	X	X
Amphipoda	A	X	A	-	C	C
Hydroacarina	O	X	X	-	X	X
Insecta						
Trichoptera	A	X	X	-	C	C
Diptera	C	O	X	-	C	C
Hemiptera	C	O	C	-	X	O
Coleoptera	C	C	X	-	X	X
Odonata	X	X	C	-	X	X
Plecoptera	X	X	X	X	C	X
Annelida						
Hirudinea	X	C	C	-	X	X
Oligochaeta	C	X	X	-	X	X
Mollusca						
Bivalue	O	X	C	-	X	O
Univalue	C	X	C	-	X	O
*Total volume of plankton net sample (ml)	6.75	<0.25	2.00	<0.10	<0.05	<0.10

A = Abundant
C = Common
O = Occasional
X = Not collected
- = Not sampled

The lake was unusual in its low transparency. An abundance of filamentous bluegreen algae resulted in a visibility of only 1.8 meters. The gill nets were completely covered with this algae. Submerged vegetation was not as evident as in Abascocha, perhaps due in part to the recent rise in water level. Chara and some Elodea were collected in water greater than 5 - 6 meters. Plankton and benthos were sparce, although the same forms were present as in Abascocha. Pomacocha had no tributaries suitable for trout reproduction and, like Abascocha, fishing has apparently eliminated the initial stock of trout.

No fish were collected in the gill nets. Only a few specimens of Orestias sp. were collected over a mud-bottom backwater area.

Lake Nahuinpuquio. Nahuinpuquio is located 15 km NW of Chupaca or 20 km from Huancayo in the Department of Junin. The lake is located in a fertile valley at an altitude of about 3,350 meters. The surface area is 10 ha with an average depth of 6.8 meters. The immediate lake environs are boggy with abundant spreading aquatic vegetation and marginal emergent forms (Scirpus sp. and Typha sp.). The basin is roughly oval. The lake is surrounded by a residential area and is considered a community lake.

A tributary feeds the lake and maintains a stable water level. The majority of flow (10 ft^3/sec) in the tributary was diverted through a series of concrete raceways, and then into a canal before entering the lake. Submerged vegetation filled the canal (Potamogeton, Myriophyllum, Nasturtium, Elodea and Najas).

The water transparency (6.4 m) and an average depth of 6.8 meters indicated that a large portion of the lake was in the euphotic zone. Other physico-chemical characteristics are included in Table 1. The zooplankton in Nahuinpuquio was fairly abundant (Table 3), but included only cladocera most of which were subadult.

No trout were captured in the overnight set of gill nets. Reportedly the lake was stocked 3 - 4 years ago with 5,000, 4-to 6-inch trout fingerlings, but community members reported very few trout were presently being caught. The main tributary has potential as a spawning area; last year approximately 70 trout were observed in the raceway, apparently seeking a suitable spawning site. None were reported this year and there was no indication that trout had ever spawned successfully.

Although the lake is heavily fished, it has a relatively high productivity (calculated biomass of 42 kg/ha). Due to its close proximity to the fish hatchery at Ingenio and the close control the community exerts over the lake, it would seem an ideal location to test the recommended stocking rates and obtain better data on growth, mortality and gear selection. Also, the existing concrete raceways could be made more suitable for trout reproduction by regulating water flow and adding suitable spawning substrate.

Marginal seining and tributary sampling resulted in the capture of one species of Trichomycterus and possibly two species of Orestias.

Lake Junin. Junin is located within the Department of Junin approximately 250 km north of Huancayo at an elevation of 4,100 meters MSL and with a surface area of 260 km^2. The lake is approximately 35 km long and 15 km wide and oriented NW - SE. These dimensions include a band of vegetation (Spirpus sp.) around the lake that extends at times 2 - 3 km from the shore. The water level fluctuates probably as much as 1 meter between the dry and wet season. Because the lake is located on a flat plain, a great expanse of lake bottom is exposed during the dry season. The lake basin is "saucer" shaped with a reported maximum depth of 10 meters and an estimated average depth of 3 meters. See Table 1 for other physico-chemical characteristics and productivity calculations. Plankton was sparce but included copepods and cladocerans.

The lake is probably best known for its frog fishery although there is a fishery for the challwa (Orestias) and bagre (Trichomycterus). Both fish species are apparently abundant in the lake. Gill netting produced 0.4 challwa and 0.013 bagre per meter of net. Challwa sell for 5.00 soles per kg; bagre are less bony and are preferred, selling for as much as 20.00 soles per kg.

Frogs, however, sell for 120 (small) to 160 (large) soles per dozen. Apparently there are only a few fishermen that actively take frogs. During the wet season there are approximately 40 individuals while in the dry season there are only ten.

All of the fishermen around the lake, except those living in the villages of Carhuamayo, Matapato, Huayre and Uco, are members of the "Association de Cazadores (hunters) y Pescadores (fishermen) de Junin". The Association has imposed upon itself a closed season on frog hunting

(January through February) and ducks (July through September). The president of the Association, Sr. Benedicto Tueros, explained that before the closed season the take of frogs was only three per person per day, but after the closed season the take increased to 5 - 12 per person per day. Presently, he estimates that the catch of frogs from the entire lake to be about 100 dozen per month during the wet season.

There are numerous springs flowing into the lake. One, the Chaca-Chimpa River arises at the southeast end of the lake. Another, the Caracochan River orginates just west of the town of Ondores. Seining produced what appeared to be other species of challwa and bagre. Water quality and flow are sufficient for trout production if ponds or raceways were constructed. However, trout will most certainly escape into the lake and may have adverse affects on the local fauna.

The River Montaro is dammed just south of the connection with Lake Junin. The dam is used to regulate the water supply to the hydro-electric plant at La Oroya. During the wet season water is stored, which causes the flow of the river to enter the lake. Since the Montaro River is badly polluted from mining operations around Cerro de Pasco, the infiltration creates a "dead zone" for approximately 3 - 4 months. During the time of the study, the water chemistry at the outlet was essentially the same as the lake proper.

Lake Tembladera. Tembladera is located on a cooperative, SAIS Tupac Amaru, 36 km SW of Canchayllo in the Department of Junin. The lake is a cirque-type lake at an altitude of 4,490 meters and is surrounded

Figure 3. Fishery survey of Laguna Tembladera. This very deep lake located on the SAIS Tupac Amaru, Department of Junin is at an altitude of 4,493 meters.

Figure 4. Ministry of Fisheries personnel removing gill net catch from Laguna Tembladera. The adult rainbow trout were in reproductive condition.

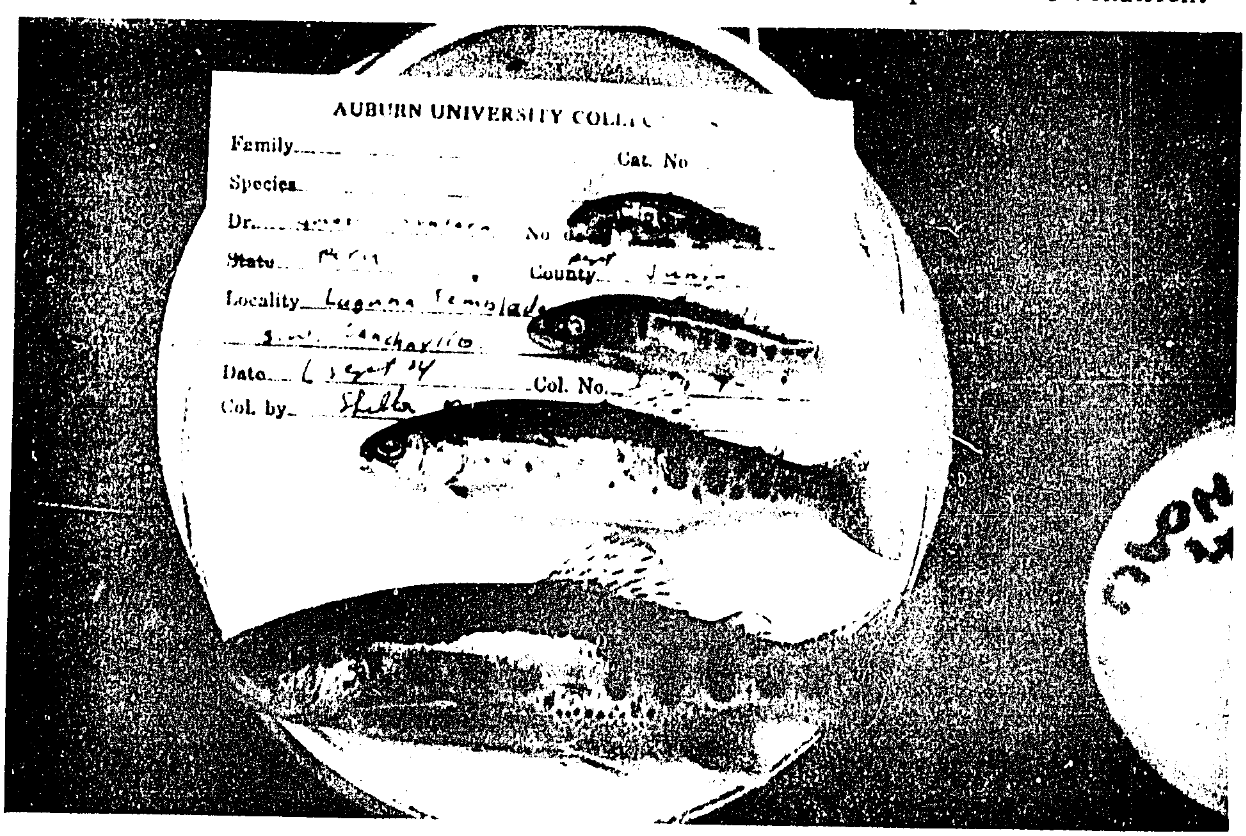

Figure 5. Seining sample from Laguna Tembladera outlet. The collection of eggs, alevins and juveniles of rainbow trout indicated a naturally reproducing population.

by abrupt terraine. It is 76 ha in size with an average depth in excess of 42 meters and is extremely clear (17 m transparency); however, there were few macrophytes. The basin shape is essentially oval. Alkalinity and total hardness are low in comparison with other lakes surveyed. The minimal drainage and granitic substrate would suggest such chemical characteristics. Plankton was very sparce and consisted of only copepods.

An overnight gill net set produced six rainbow trout. All fish were in excellent condition and were examined for stomach contents, annular marks on the scales and reproductive condition. This sample was combined with those taken from sampling Lake Carhuacocha.

Seining the lake margin produced no fish, but fish eggs (considered to be of Orestias sp.) were recovered from the substrate. Seining the outlet produced a wide array of evidence to indicate natural reproduction. A breeding male (51.1 cm) was captured as well as viable eggs, alevins and yearlings. Juveniles were most abundant downstream from the outlet after a considerable and abrupt descent to a meandering segment. It is possible that trout from Tembladera were spawning in the outlet, or that trout from the lake below (Carhuacocha) had ascended to the outlet and were spawning.

The two tributaries entering the lake had extremely steep gradients. Gravel alluvial fans formed at the inflows might possibly serve as spawning areas for trout.

Lake Carhaucocha. Carhaucocha is also located in the SAIS Tupac Amaru Cooperative and receives the outflow from Tembladera plus one other major and several minor tributaries. The lake level is 4,420 meters MSL with a surface area of 184 ha.. The lake is elongate and oriented E - W. Transparency (8 m) is considerably less than the average depth (37 m). Alkalinity and hardness were higher than in Tembladera. Extensive submergent vegetation occurs on the extreme ends of the lake where the water is less than 5 meters. The pH reading (9.0) is probably not typical as it was taken during mid-day along the shore adjacent to the vegetation.

Plankton was not highly abundant but included copepods and cladocera. Amphipods were abundant in the vegetation.

Seining in the tributary produced juvenile trout. Orestias sp. was collected over a mud bottom near the outlet. An overnight gill net set collected 23 trout, but no other species. Stomach contents and reproductive information was combined with data for Tembladera.

No annuli or spawning marks were detected on any of the scales examined. The annual temperature flucuation is very slight and perhaps the growing season is more or less continuous. This survey was taken during the late winter and the trout were feeding actively.

Food habits differed somewhat between the two lakes (Table 4). Tembladera fish appeared to be feeding more heavily (76.0 percent frequency of occurrence) on amphipods with dipteran pupae the second most abundant food item (20 percent). In Carhuacocha, dipteran pupae were the most frequent item (68 percent) and amphipods the second (21 percent) most abundant. Trout eggs appeared in the stomach of one fish in Tembladera; an Orestias sp. occurred as a food item in Carhuacocha.

Table 4

PERCENT OCCURRENCE OF VARIOUS FOOD ITEMS

Lakes	Trout eggs	Fish	Amphipods	Diptera: Pupae	Diptera: Larve	Trichoptera	Molluses: Bivalue	Molluses: Univalve	Hemiptera	Lepidoptera	Coleoptera
Tembladera (11 fish)	2.0	0	76.0	20.1	1.5	0.3	T	0.1	0	0	0
Carhuacocha (24 fish)	T	0.5	21.0	67.6	10.6	T	T	0	T	0.2	T

Size distribution of fish captured in each mesh is presented in Table 5. Mesh sizes 1.25 - and 1.50-inch bar measurement were most effective in capturing trout in these two lakes.

Reproduction was evident as mentioned earlier by the recovery of eggs and juveniles from the tributary. In addition, four females were ripe and ranged in size from 32.1 to 37.0 cm with Gonadal Somatic Indexes ranging from 8.5 - 14.2 percent. Fecundity estimates ranged from 320 (32.1 cm fish) to 960 (37.0 cm fish) eggs. Several of these fish appeared to have spawned a portion of their eggs. All other females had only immature eggs and had already spawned. This compares with spawning information from hatcheries where the peak reproductive season is during July and August.

2.3 Southern Mountain Lakes

Lakes of this region were visited in an attempt to compare them with the central mountain region. Time was insufficient to make a meaningful analysis and therefore, an adequate comparison. However, information of general interest that was obtained is included here.

Lake Langui-Layo. Langui-Layo is located 20 km south of Sicuani in the Department of Cusco. The surface area is 5,905 ha and is at an altitude of 3,891 meters. Attempts of obtain good data on the average depth of this lake were not successful. However, it was found that the average depth exceeds 97 meters. Limnological information was provided by the Ministry's Institute of the Sea for January through March, 1974. Water temperature varied from 10.9 - 11.6 C in the morning to 14.7 - 17.0 C at mid-day and in late afternoon the temperature was 12.1 - 14.1 C.

Table 5

EXPERIMENTAL GILL NET CATCHES OF RAINBOW TROUT
(Lakes Tembladera and Carhuacocha data combined)

Mesh Size-Inches (Bar Measurement)				
75	1.00	1.25	1.50	2.00
	35.4	29.2	37.3	33.1
	22.6	26.6	29.6	38.0
	$\bar{X}$ = 29.0	26.8	32.3	36.7
		30.6	24.4	42.3
		27.2	38.7	$\bar{X}$ = 37.5
		30.5	29.7	
		32.8	34.5	
		$\bar{X}$ = 29.1	37.2	
			39.0	
			35.9	
			37.0	
			35.3	
			39.1	
			35.9	
			29.7	
			32.7	
			$\bar{X}$ = 34.3	

Day to day variation in water temperature from January to March was minor. The surface water temperature in the morning of our visit in September was 11.1 C. Other chemical data provided by the Institute of the Sea are as follows:

Transparency (m)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Calcium Hardness (mg/l)	pH	NO_3 (mg/l)
4.8-9.5	104-109	287-347	254-287	8.3	42.6-53.5

Macrophytes were abundant and included *Potamogeton*, *Myriophyllum*, *Chara* and *Nitella*. In addition, *Cladophora* was common on rocks along the east side of the lake.

No gill nets were set, but reports indicate that there is a fishable population. Shell (1971) provides a brief history of the trout fishery in the lake. He reports that 255,000 fingerlings were stocked in 1971 to re-establish the depleted population. Annual introductions since then are presented below:

Year	Total No. Fingerlings		No./ha
1972	240,000	345,000	58.4
	105,000		
1973	4,872		0.8
1974	80,000	90,000	15.2
	10,000		

Although these stocking rates are low, natural reproduction does occur in the main tributary, the Rio Pallajchuma, and should augment recruitment. Based on a maximum MEI for Langui-Layo we estimate the maximum harvest to be no more than 1.5 kg/ha/year or a total of 8,858 kg/year.

Lakes Saracocha and Lagunillas. Saracochá and Lagunillas are located about 115 km west of Puno in the Department of Cusco. They have a surface area of 1,310 and 5,000 ha respectively. They are at an altitude of 4,050 meters. No information was available on the physico-chemical characteristics, although they are thought not to be excessively deep. Stocking was reported to be 180,000 fingerlings in 1971 (Lagunillas) and 17,000 in 1973 (Saracocha). Growth to date (probably maximum) is reported to be 45 cm in Lagunillas and 15 cm in Saracocha.

Lake Titicaca. The trout fishery on Lake Titicaca was briefly discussed by Smitherman and Moss (1970). The fishery apparently has not recovered to any great extent. Trout are being stocked, but only in token numbers. Also, the problem of enforcing laws prohibiting fishing on the spawning grounds remains. Ministry personnel indicated that more emphasis is being placed on the fishery for native species, namely *Orestias* sp. and *Trichomycterus* sp. The trout fishery, however, is now being investigated by the Institute of the Sea.

Two fishing villages were visited on the lake, one shore based village (Barco) and an island location (Uros). Fishermen are using very fine nylon, multi-filament gill nets about 50 meters in length by 0.5 meters in depth with a bar mesh ranging from 0.75 to 1.00 inch. Nets are set in the evening along the edge of the reeds (*Scirpus*) and fished until the next morning. Using data collected at Barco the catch composition was as follows:

Figure 6. Aymara girl with gill nets–Laguna Titicaca. A fishery for native species is being encouraged while the trout population recovers from an earlier decline.

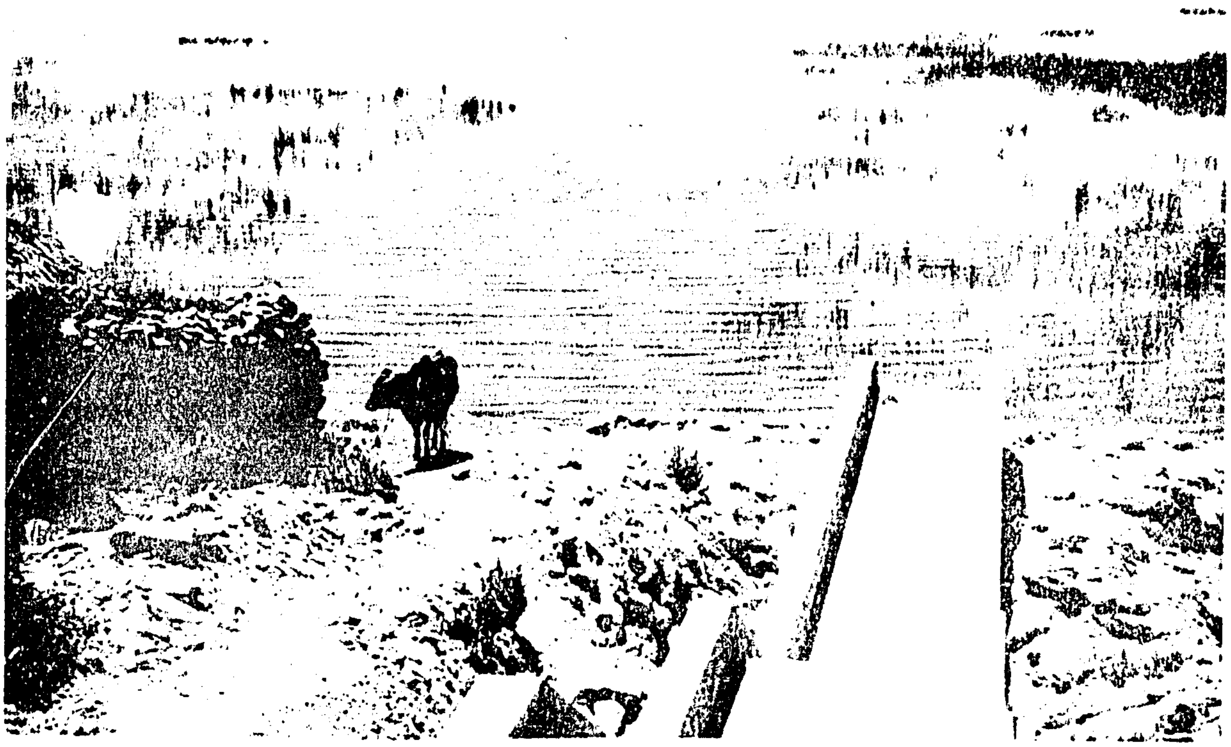

Figure 7. Docking facility under construction at Barco on Laguna Titicaca. Fishermen of the Puno area will be encouraged to use this location so that records of harvest can be maintained.

Percentage	Name	Remarks
70	carachi	Includes two species of <u>Orestias</u>
20	bagre	Includes <u>Trichomycterus rivulatus</u> (also called mauri) and <u>T. dispar</u> (also called suche)
10	trout	Only during October through May.
Trace	pejerrey	<u>Basilichthys bonariensis</u>

Two other orestias species deserve mention. Ispi, a small species that contributes some to the catch, is usually dried and sells for 1.00 sole for 30 - 50 individuals. Boga, a larger species, is infrequently caught.

The pejerry was introduced into Lake Titicaca via the River Desaguadero in Bolivia and has generated interest because of its growth potential which is reported to be 1.5 kg in two years. The Ministry of Fisherie~ is presently planning to initia:e culture operation for this ~pecies. The Ministry is also interested in the culture of ~uche. This species is a more desirable fish than mauri but is caught less frequently. Also, a comparison of rainbow versus brook trout planting is planned in various streams in the Puno area.

3.0 DISCUSSION

3.1 <u>Management Techniques</u>

of trout populations in the mountainous regions of Peru that is readily transferred into management policy. Therefore, data necessary for production estimates were gleaned from published reports (Hartman, 1959; Reimers, et al., 1955) where similar climatological, edaphic and morphometric conditions exist. Yield estimates were determined by relating the catch from moderately to heavily fished north-temperate lakes to Peruvian lakes with similar morphoedaphic indexes. These estimates apply to reproducing populations (for example, in the lakes Tembladera and Carhuacocha).

Standing crop values were determined by back-calculating from the yield estimates using the relation of potential yield to "virgin" biomass proposed by Gulland (1970). It was assumed that the fishery could divert somewhat less than one-half (0.40) of its biomass to yield and that natural mortality remained a constant at 0.30. The assigned coefficients in this situation are probably somewhat optimistic. Standing crop estimates were used to recommend a stocking program where "recruitment" depends upon the annual introduction of trout fingerlings (for example in Lakes Abascocha, Pomacocha and Nahuipuquio).

Although, the procedures described above may be questioned by some biologists, we believe the estimates serve as a reasonable first order approximation and illustrate the type of information required for management as the fishery develops.

The following calculations illustrate populations that can be structured by annual stocking; the variables are the expected growth (g) in grams and natural mortality (i). Note that the "weight change factor" during the third year is less than one which means that the biomass is decreasing.

Age	Mean Length (cm)	Mean Weight[1] (gms)	Rates: Growth (g)	Rates: Mortality (i)	Weight Change Factor (e^{g-i})
0	Stocking	3			
			1.20	0.35	2.34
1	9	10			
			1.79	0.35	4.22
2	18	60			
			0.98	0.35	1.88
3	25	160			
			0.22	0.35	0.88
4	27	200			

[1] Length-weight relationship from Tembladera and Carhuacocha

The initial total weight of fish (Age 0) depends upon the number stocked. Table 6 shows the calculations to determine the "biomass" after four years of annual stocking with 100, 150, 200 or 300 fingerlings per hectare.

Lakes Abascocha, Pomacocha and Nahuinpuquio were three lakes where past stocking of trout had not resulted in reproducing population. The carrying capacity of these lakes is calculated to be 13.08, 13.17 and 42.00 kg/ha respectively (Table 1). As is evident in Table 6, annual stocking of approximately 100 trout fingerlings per hectare per year would be appropriate for Abascocha and Pomacocha; harvest could commence when the trout reached legal size (>25.0 cm) or during the 3rd year after stocking. Harvest would be approximately 5 kg/ha (Table 6) each year thereafter if all the trout of legal size were caught. Nahuinpuquio would require approxi-

Table 6

NUMBER FINGERLINGS STOCKED
(Av wt = 3 gms)
Biomass (kg/ha) [1]

Time (Years)	Fingerlings 100	150	200	300
0				
	0.7	1.05	1.40	2.11
1				
	2.96	4.43	5.92	8.89
2				
	5.57	8.33	11.14	16.72
3				
	4.90	7.33	9.80	14.71
4				
Total	14.13	21.14	28.26	43.43

1 Based on growth rates from literature cited since fish scales examined possessed no growth rings.

mately 300 trout fingerlings per hectare per year to reach carrying capacity in three years. During the third year and thereafter, approximately 15 kg/ha/yr of trout could be harvested.

The harvest rate for stocked lakes is approximately 2 to 3 times that for lakes having reproducing populations. Because of the need for maintaining a sufficient spawning population, only a portion of the adult standing crop can be harvested each year. For example, Tembladera and Carhuacocha with reproducing populations, the yield to the fishery was calculated to be 1.3 and 2.2 kg/ha/yr respectively (Table 1). These lakes were similar in calculated biomass (10.83 and 18.17 kg/ha) to Abascocha and Pomacocha (13.08 and 13.17 kg/ha). However, the latter two could yield approximately 5 kg/ha/yr from annual stocking.

3.2 Program Recommendations

Although lakes in the mountainous regions have been irregularly stocked with trout for a number of years, virtually no data are available on catch per unit of effort, size composition of the catch or gear selection. This information is necessary to adequately evaluate the program and manage the fishery. Stocking rates appear to depend upon the availibility of trout after other demands (for example, stocking fish culture farms) have been satisfied. Also within the Department of Junin, no specific individual has the responsibility for the region's trout fishery.

The demands on the Department's biologists time are substantial, especially in the areas of promotion and fingerling production for supplying trout farms. Production data from these farms were not available, nor was an estimate of the number and total area of the lakes in the regions. Therefore, no comparison was possible in terms of production and benefits to the economy of the region.

Obviously the establishment of fish farms provides opportunities for capital investment; however, a carefully followed program of lake stocking would result in a sustained and predictable harvest of fish which would provide income to a segment of society essentially out of the investment market.

If the Ministry decides that a lake stocking program has potential, it is recommended that a full-time biologist be assigned to one Department (for example, Junin) to document the following:

1. The number of lakes and total area suitable for trout production.
2. The approximate total number of trout required for initial and annual stocking in the region.
3. Estimates of rates of growth, mortality, catch and gear selection in a pilot project, for example, in Nahuinpuquio and Abascocha.
4. Costs of fingerling production versus benefits to the region's economy from potential harvest.

It is also recommended upon request of USAID/Peru, the International Center for Aquaculture, Auburn University, provide future technical assistance to include:

1. One biologist for 20 man-days to help initiate the survey, experimental stocking of lakes and outlining a suitable work-plan.
2. Ten man-days approximately four months later to review progress and assess the need for additional technical assistance.

Minimum equipment needs are:

1. One 14' light-weight boat (US $200)
2. Life jackets ($25 each)
3. One 10-H.P. motor ($400)
4. Conductivity meter ($200)
5. Portable depth recorder ($400)
6. Four experimental gill nets (250' x 6' with ten, 25-foot panels of 0.50-, 0.75-, 1.25-, 1.50- and 2.00-inch bar mesh constructed of material readily available to fishermen, $125 each).

A summary of the study with appropriate recommendations for developing a feasible trout management program should then be presented to the Ministry of Fisheries at which time the AID Mission should seriously consider the extent to which it could assist the Ministry in developing a program.

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5.0 ITINERARY

August 25	Arrived Lima, Peru.
August 26	Conference with officials of USAID and the Ministry of Fisheries to arrange itinerary.
August 27	Travel to Huancayo.
August 28 - 29	Lakes Abascocha and Pomacocha.
August 30 - 31	Lake Nahuinpuquio.
September 1	EPSEP Frigorifico, market and Ingenio fish cultural station.
September 2 - 4	Lake Junin.
September 5 - 6	SAIS Tupac Amaru, Lakes Tembladera and Carhuacocha.
September 7	Analyse data from surveys.
September 8	Visit EPSEP hatchery at Quichuay.
September 9	Travel to Lima.
September 10	Conference with Ministry of Fisheries to obtain basic physiographic and climatological data.
September 11	Visit carp and goldfish station in Lima.
September 12	Travel to Cusco, conference with personnel at Ministry office.
September 13	Lake Langui-Layo and travel to Puno.
September 14	Visit fishing villages (shore and island), Ministry trout farm at Chucuito and market in Puno.
September 15	Return to Lima.
September 16 - 18	Preliminary report preparation.
September 19	Visit Institute of the Sea, marine fishing industry and fish market.
September 20	Presentation of report and final conference with officials of USAID and Ministry of Fisheries.

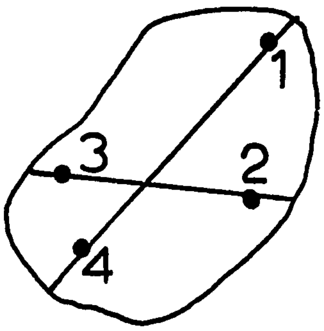
6.0 APPENDIX

Data from Lake Nahuinpuquio is used in the following example calculations:

I. Average Depth:

Procedure

1. Determine two main axes
2. Estimate 1/6 distance from each end of axes
3. Determine depths
4. Compute average depth as follows:



1 = 23'
2 = 24'
3 = 28'
4 = 20'

$$4 \overline{)95} = 23.75$$

$$\frac{23.75}{}\ \times 2 = 47.5$$

47.5 x 0.467 = 22.18' = average depth estimate.

II. Determine Total Dissolved Solids.

1. Directly or,
2. Estimate from conductivity (Appendix, Figure 1) after correcting for temperature, or,
3. Estimate from total alkalinity (Appendix, Figure 2)

240 umhos @ 17 C = 252 umhos @ 20 C;
then TDS = 150 ppm

III. Compute Morphoedaphic Index (MEI)

$$MEI = \frac{\text{TDS (ppm)}}{\text{average depth (ft)}} = \frac{150}{22.18} = 6.76$$

IV. Estiate Yield from Appendix, Figure 3

MEI of 6.76 = 4.5 to 5.0 lb/acre/yr (5.0 - 5.6 kg/ha/yr)

V. Estimate Standing Crop by Back-Calculating From Yield Estimates Using the Relationship

y = ab biomass

where y = yield, a = the proportion of the biomass that can be diverted to yield and b = the expected annual natural mortality. In our calculations we assumed that a = 0.40 and b = 0.30. Using 5 kg/ha, then biomass = 42 kg/ha.

5 kg/ha = 0.40 (0.30) biomass

VI. Estimate Stocking Rates by First Structuring Populations with Various Rates of Recruitment

The calculated biomass was then compared with the estimated standing crop. The instantaneous rates of growth (g) and mortality (i) were calculated. For example, the average weight of age-1 and age-2 fish (from length - weight relationship, Appendix, Figure 4) were used to calculate "g" where:

$$\text{weight (Age 2)} = \text{weight (Age 1)}\ e^{g}$$

The instantaneous rate of growth is easily calculated using natural logs. The instantaneous rate of mortality was obtained using Ricker's (1958)[1] table of exponential functions. When survival (S) = 70 percent, the instantaneous rate = 0.35. The change in stock size within a year was calculated by combining g and i to give the change in bulk, using the expression:

$$W_{(age\ 1)} = W_{(age\ 2)}\ e^{(g-i)}$$

Where $e^{(g-i)}$ is the weight change factor.

The resulting weight from annual stocking (after 4 years) at 300 per hectare equals 43.43 kg/ha. Nahuinpuiquio has an estimated standing crop of 42 kg/ha. Therefore, it appears that an annual stocking of approximately 300 fingerling/ha is appropriate.

1 Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bulletin, No. 119, 300 p.

Conductivity -
Dissolved Solids Relationship

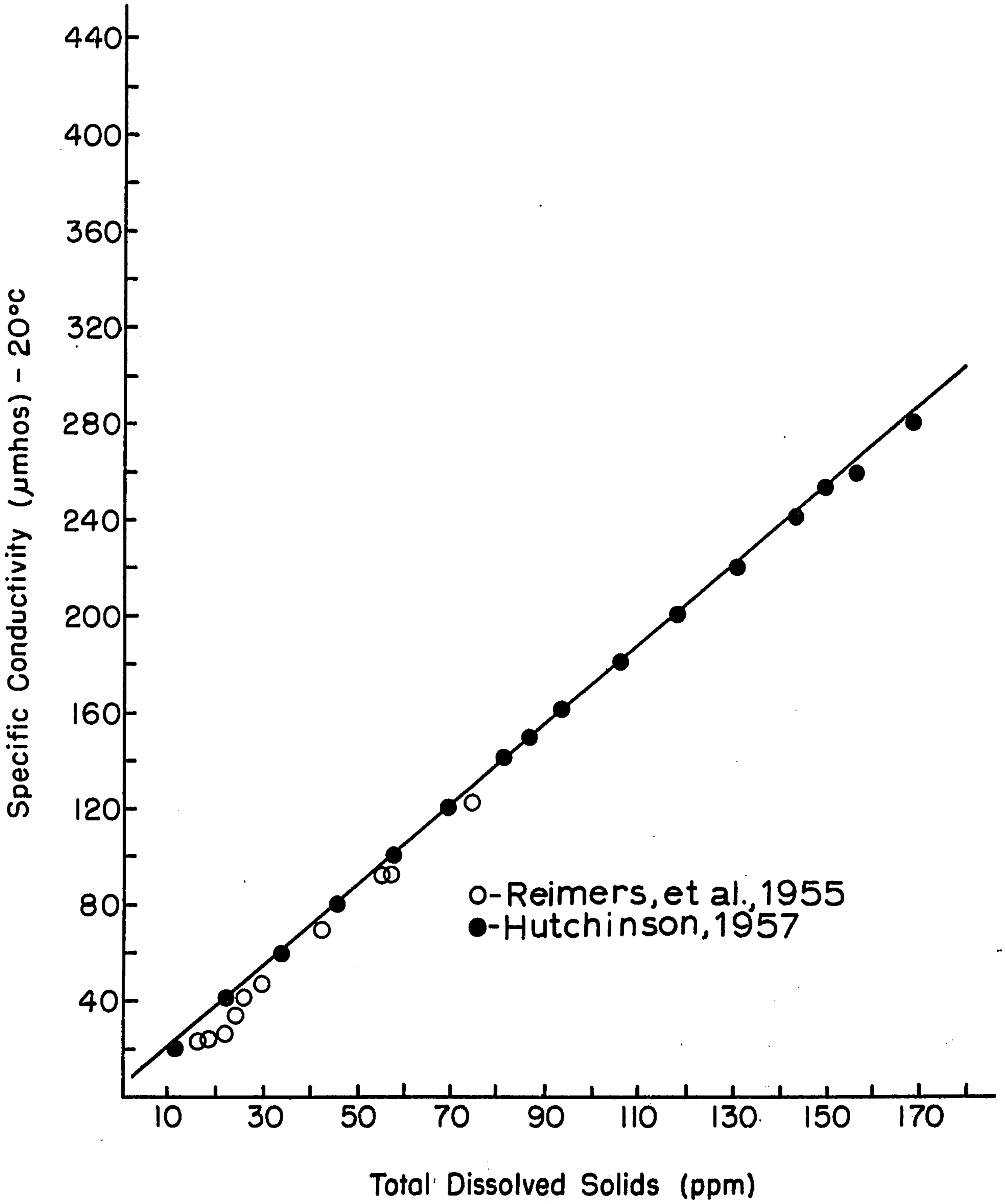


Figure 1

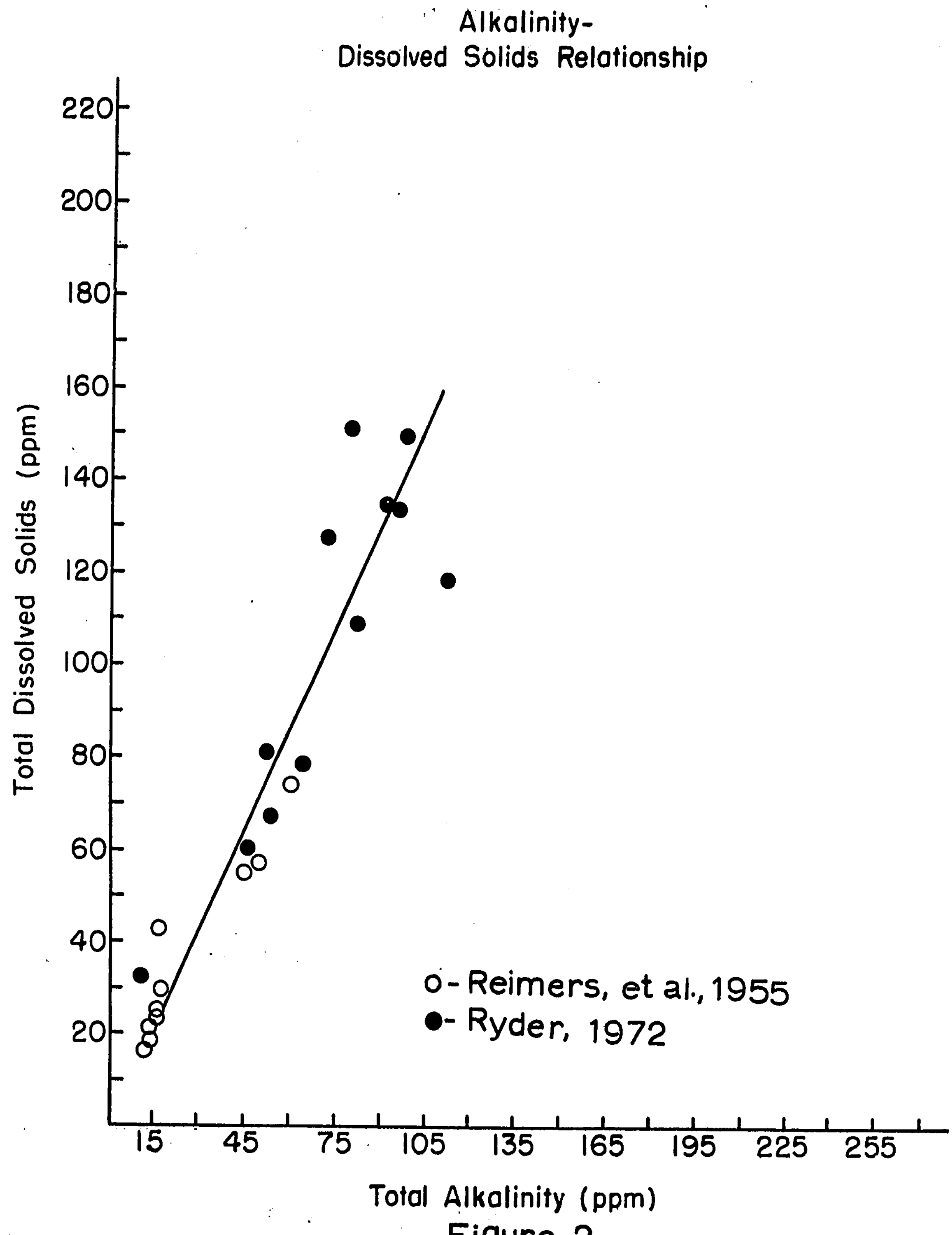
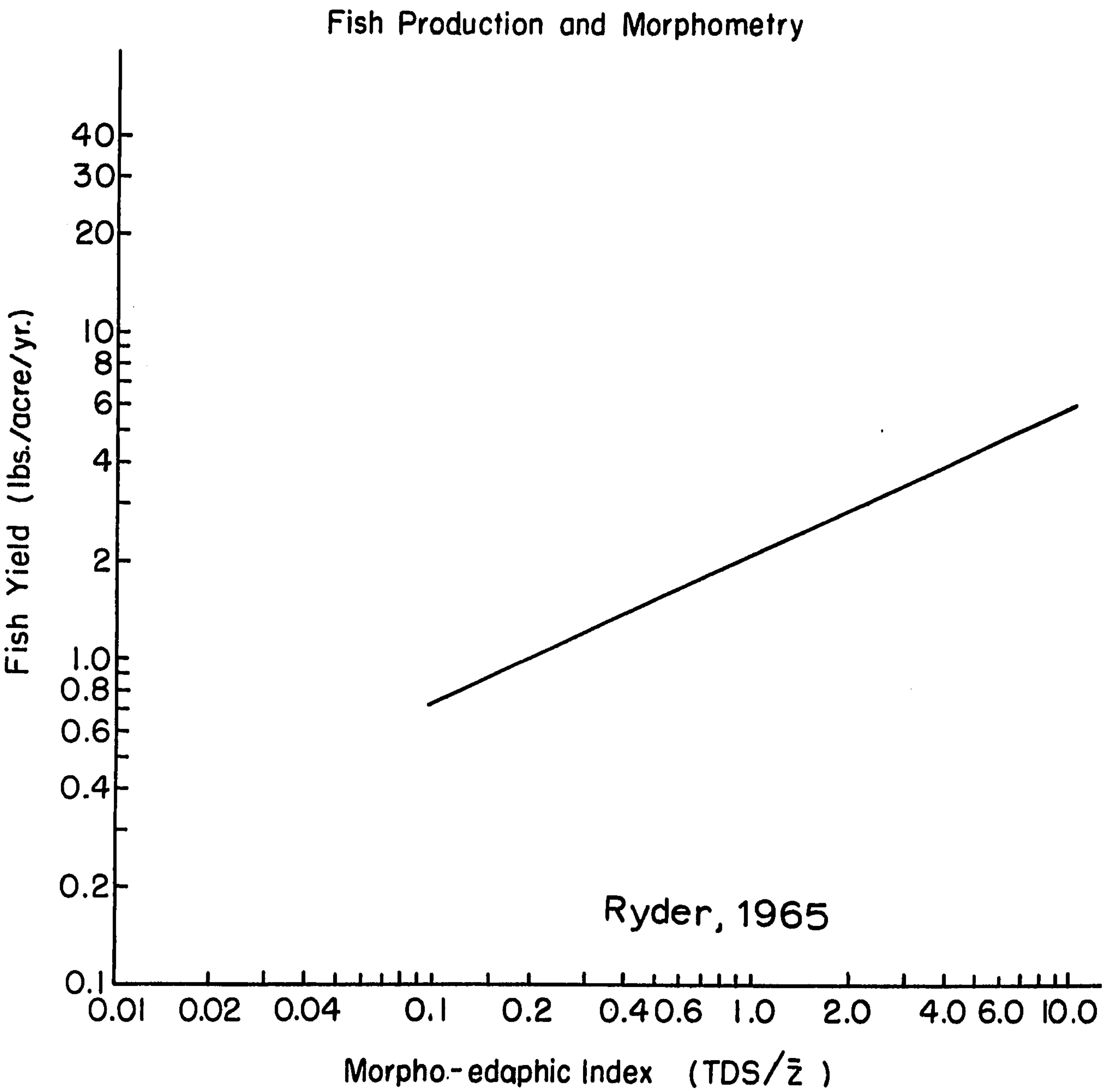
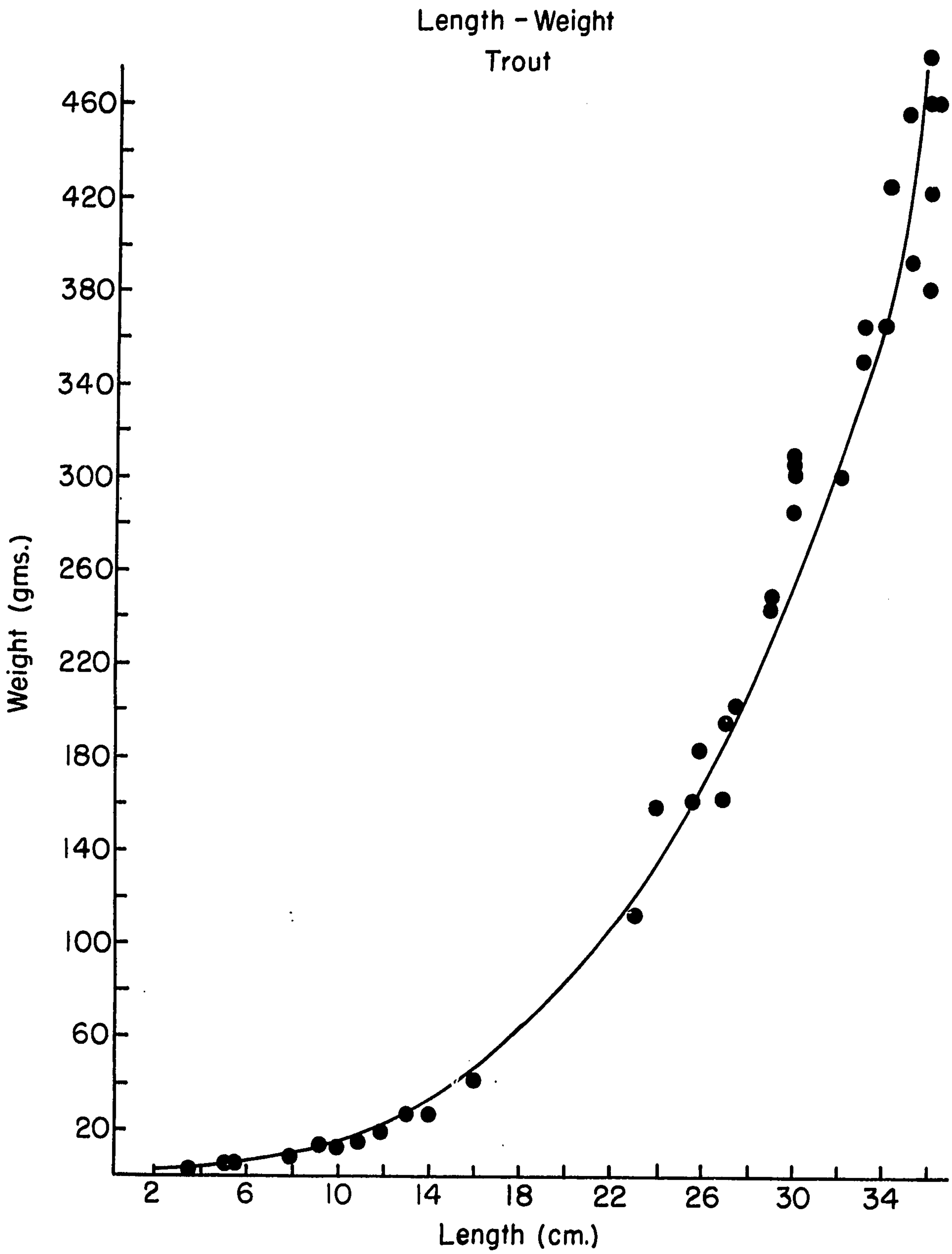

Alkalinity-
Dissolved Solids Relationship
Total Dissolved Solids (ppm)
220
200
180
160
140
120
100
80
60
40
20
15
45
75
105
135
165
195
225
255
Total Alkalinity (ppm)
o- Reimers, et al., 1955
●- Ryder, 1972

Figure 2



Fish Production and Morphometry
Fish Yield (lbs./acre/yr.)
40
30
20
10
8
6
4
2
1.0
0.8
0.6
0.4
0.2
0.1
Ryder, 1965
0.01
0.02
0.04
0.1
0.2
0.4
0.6
1.0
2.0
4.0
6.0
10.0
Morpho.-edaphic Index (TDS/z̄)

Figure 3



Length - Weight
Trout
Weight (gms.)
460
420
380
340
300
260
220
180
140
100
60
20
2
6
10
14
18
22
26
30
34
Length (cm.)

Figure 4