PREHYDRO EXISTING USE BASELINE

Madsen 1980, Lake Ogallala Creel Census

27,752 anglers fished 109,965 hr. $\bar{x}$ 3.9 hr./trip

caught 36,427 fish weighing 29,864 pounds

28,518 trout (78%)

CPH .33 (all) .26 trout

Rainbow trout average 11.5 inches, .64 pounds

"The census and concurrent rainbow trout tagging studies showed a return to the angler of the 8-10" rainbow stocked of 28.3% by number and 64.5% by weight. Wilkens (1967) suggests that management efforts be directed to at least a an ultimate return of 50% by weight to justify a trout stocking program... Most rainbow trout stocked in L. Ogallala are caught within a five month period. At harvest the fish averaged 11.5 inches and weighed .64 pounds... Fishery of outstanding quality from 1971 through 1980... Many trout which leave Ogallala are harvested downstream... The degree of downstream migration and angler harvest is unknown."

note error

note McConaghy 2-3% return 30,000 Trout

-Co

Rainbow trout stocking and returns from creel census of July 1, 1977 - June 30, 1978.

Rainbow Trout Stocked

?
Aug. 1976

Date	Fingerlings (5.3 in., 16.1/lb., .062 lb.) 28gm.	Catchable (10.1 in., 2.2/lb., .455 lb.) 257mm 205g.
October 1976	13,500 ~~(5.3", 16.1/lb., .062 lb.)~~	4500
April 1977		1,755
July 1977		15,909
October 1977	20,250	6,152
March 1978		5,000
April 1978		12,000
May 1978		15,200
TOTALS	33,750 (2,092 lbs.)	60,566 (27,479 lbs.)

TOTAL all trout 94,316 (29,571 lbs.)

Catch, July 1, 1977 - June 30, 1978

Rainbow trout 25,417 fish weighing 16,404 lbs.

average size 11.5 inches (292 mm) .64 pounds (291 gm.)

stocked 257 mm - 205 gm

Re. % wt. return of catchable trout stocked

$\bar{x}$ wt. stocked	.45 lb.	(205 gm)	length 257mm
$\bar{x}$ wt. caught	.64 lb.	(291 gm)	292m
net increase	.19 lb.	(86 gm)	35mm

percent increase **42%**

Thus, 28% return by number of catchable trout = 40% return by weight, not 64%.

To achieve a 50% wt. return with this percent wt. increase, a 35% return by number is necessary.

Consideration of contribution of fingerling stocking to catch (unknown) but ca. 20%

and allowance for depletion of 6,255 catchables stocked before July, an my estimate estimate of 35% by number and 50% by wt. of the catchable trout stocked during 1977 and 1978 can be roughly approximated. This is in general agreement with tag returns from these groups of stocked catchable trout: 540 tags returned from 2114 tagged fish of four separate stockings (25%) - which was inflated for estimated 30% nonreturned tags to 33% total returns of catchable trout by Hutchinson (1986).

In summary, the baseline prehydro fishery that is comparable to the 1987 fishery, indicates that catchable trout basline for comparison stocked at 257 mm and 205 gm. were caught at size averaging 292 mm. and 291 gm. at a return to angler rate of 35% by number and 50% by weight of catchable trout stocked. Average growth from stocking to catching 35 mm, 86 g.

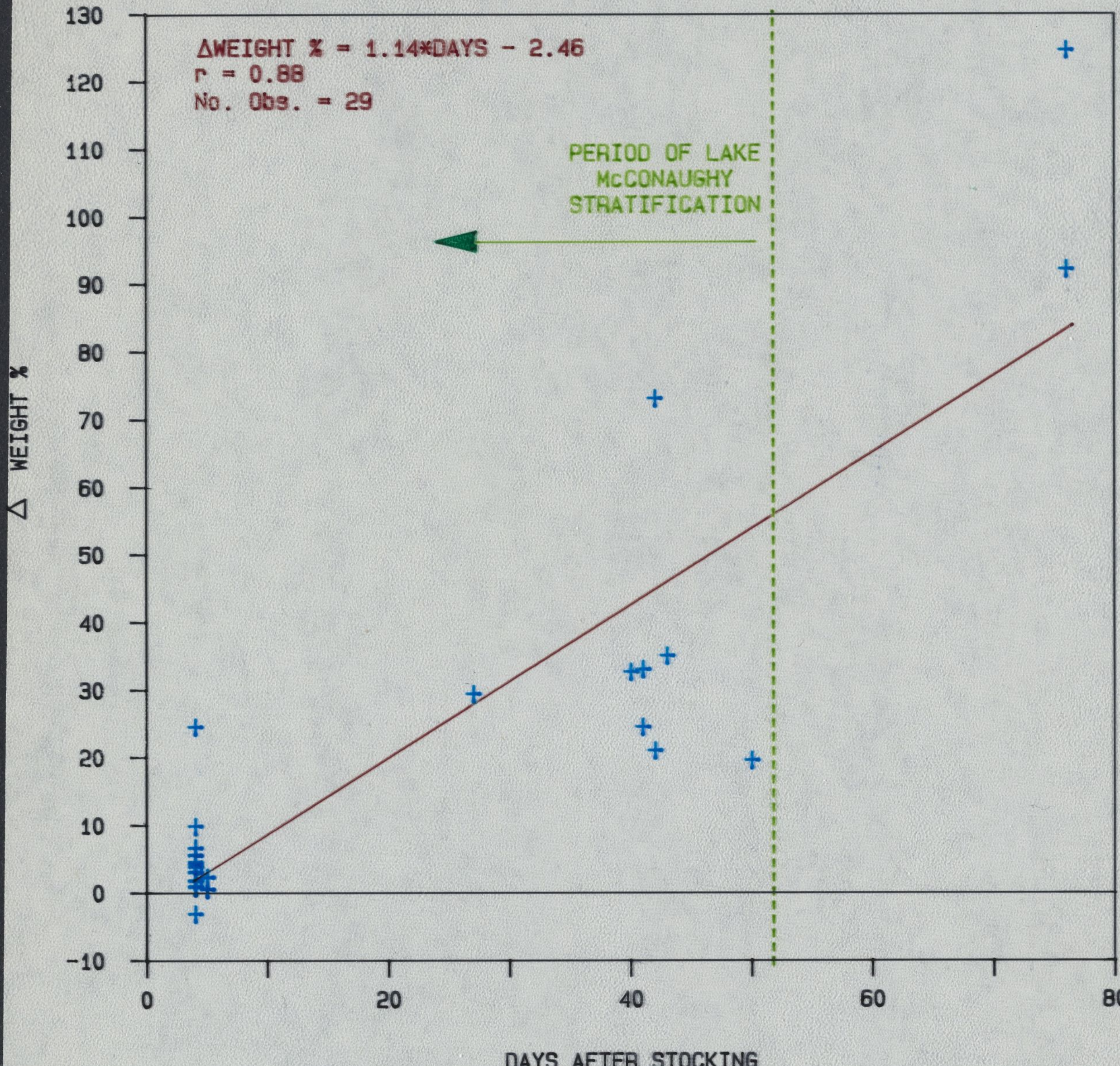
Re "Carryover" (Madsen, 1986) 540 tags returned from 2114 tagged catchable trout, the last tag was returned 11 months after stocking (stocked Oct. 1976, last tag Sept. 1977-- July tags 100% 4 mo., Apr. tags 97% 4 mo., Aug., 99% 5 mo.

ca. < 1% 'carryover'

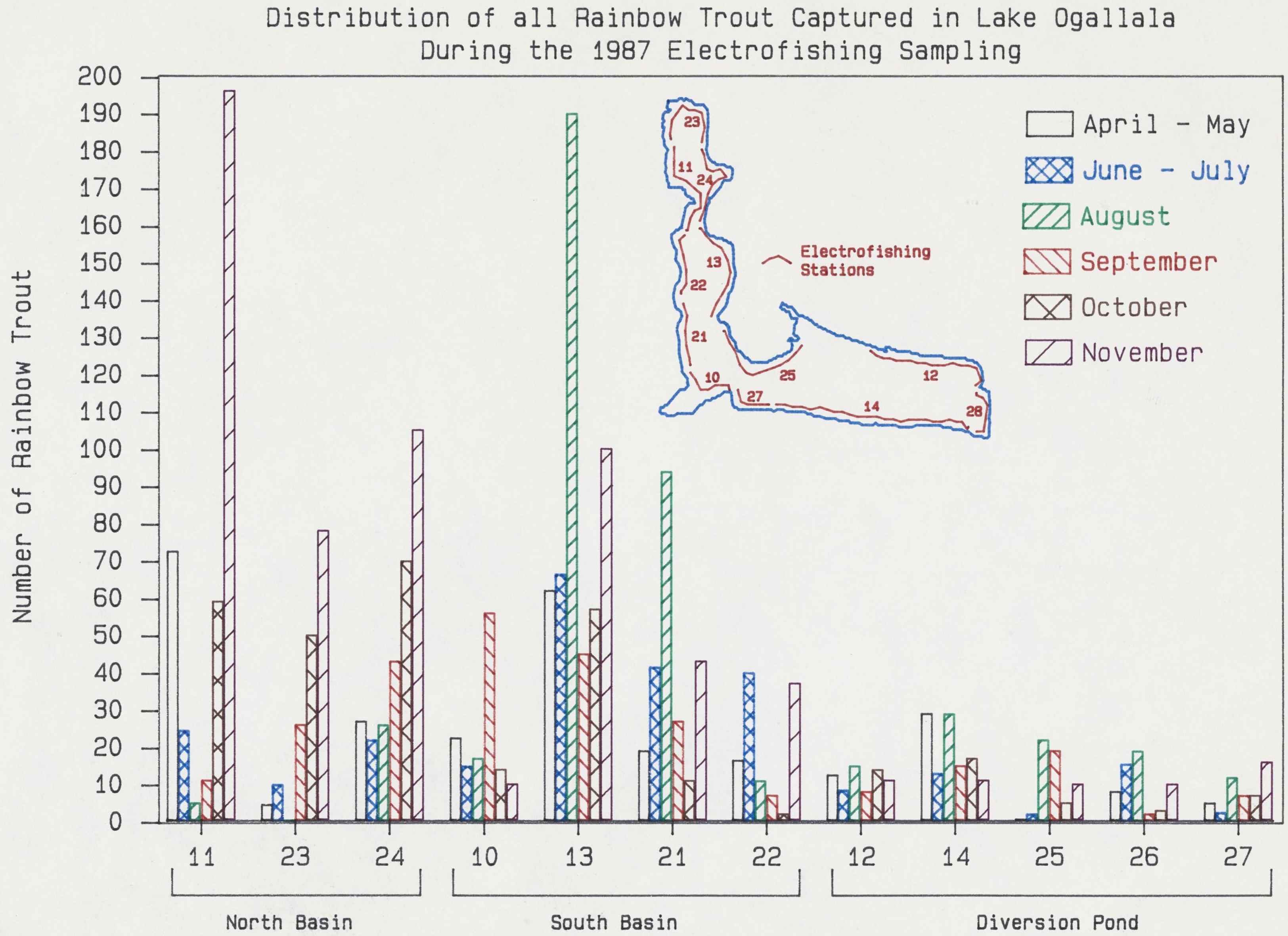
Lake Ogallala

GROWTH OF STOCKED RAINBOW TROUT

AUGUST PLANT - 1987



C-LINE #62027



Distribution of all Rainbow Trout Captured in Lake Ogallala
During the 1987 Electrofishing Sampling
Number of Rainbow Trout
April - May
June - July
August
September
October
November
Electrofishing Stations
North Basin
South Basin
Diversion Pond

12 months | Madsen" | " | 7 months

1977-78 | | 1987

36,427 (29,864 lb) TOTAL CATCH 31,897 (≈ 35,000 lb)

RB 25,417 (16,404 lb.) 15,597 (15,113) (14,792)

x̄ size stocked

10.1 in (257 mm) | 10.3 in (262 mm)

.45 lb. (205 gm) | .49 lb. (225 gm.)

size caught

11.5 in (292 mm) | 13.3 (333 mm) 13.2 (330)

.64 lb. (291 gm.) "put-grow-take" net increase | .97 lb. (440 gm)

+ 35 mm [condition] | + 73 mm ↙ grow

+ 86 gm (42%) 1.17 — 1.19 | + 215 gm. (95%)

% return

est
35% by #
50% by wt.

project → 50% ..
→ 100% wt.

carryover

540 of 2114 | 807 (86) 7m → 100
July - 100% 4 mo. | ~3%
Apr. 97% 4 mo
Aug. 99% 5 mo.
Oct. 76 - last Sept. 77 11 mo.
~ < 1%

CPH .33 — .53 — note July - Aug white bass

Trout .26 .26 but > 50% 291 vs. 440 gm.

Out migration

91 - 9
88 - 12

cladocera - sightings

Re. No Impairment of Existing Use

Prehydro (1977-78) || Posthydro (1987)

Fishery based ~~for~~ cathable rainbow trout stocking

	Prehydro (1977-78)		Posthydro (1987)
x̄ size stocked	10.1 inches (257mm) .45 lb. ~~.64 lb. (291 gm)~~ (205gm.)	vs.	10.3in (262 mm.) .49 lb. (225 gm.)
x̄ size caught	11.5 inches (292 mm) .64 lb. (291 gm)	(x) figure condition factor / vs.	13 (320) ① ✓ .97 lb. (440 gm.)
length increase	1.4 inches (35mm)	vs.	3 in (70 mm)
wt. increase	.19 lb. (86gm. or 42%)	vs.	.48 lb. (215gm or 96%)

compare — put-grow-take — More grow!

Of number stocked	approximate estimate		Total To date	Projections
% return by no.	.35%	vs.	42% (Ogallala 38%)	> 50%
% return by wt.	50%	vs.	82% (Ogallala 74%)	> 100%

(night angling?)

Catch-per-hour	Ogallala only		
All fish	.33	vs.	.53
Trout only	.26 (includes brown trout)	vs.	.26
x̄ wt. of trout	291 gm.	vs.	440 gm. ① (460gm - all) (50% larger)

more grow in put-grow-take 1987

✓ - by month - fishery (CPH) quality during critical period

per trout stocked > 40% greater return ✓

Total Use & Catch 1977-78			Seven months 1987 (Apr - Oct)
Total hours	109,965	→	60,087
? Total catch	36,427 (= 29,864 lbs.)	→	31,897 (= 35,000? 30,000 lb.) [46,000 lb.]
of which, trout =	28,518 (= 16,404 lbs.)		15,597 (= 15,756 lbs.)
	(10oz. vs. 16oz.)		① includes carryovers, unknowns (similar to 1977-78) = x̄ wt. 1.01 lb. (460 gm)

91% lake 9% outmigration

1.18

2464 | 2920

2464

4560

2464

2920000 / 24642171

209600

19712

292 mm

291 gm.

291 × 291 = 84681

84681 × 291

84681

762129

169362

24642171

1.13 16.

42/5

12

35 | 42

35

71

16

155 | 253

155

980

19

858 | 1711

858

853

10

136 | 142

136

60

8135

from: Lake Taneycomo White Paper (by L.T. Mgt. Comm.)

DEPARTMENT OF FISHERY AND WILDLIFE BIOLOGY

MEMORANDUM

L. Taneycomo Vital Statistics

ca. 2000 surface acres (figure)
20 mi. long

Table Rock Dam releases - spring 6-8°C - winter 10-11°C

x̄ D.O. 1982-85: Sept. 1.6 - 4.5
Oct. 0.1 - 0.8
Nov. 0.1 - 0.3

weekly min. x̄ lake D.O.

	I	II	III	IV
Oct. 22-28	2.7	4.1	3.9	3.1
Oct. 29 - Nov. 4	2.6	4.9	4.9	5.6

1981-85

Stocking annual totals 1.1 - 1.6 million made up of 780,000 - 1.2 million catchable (9-12 inches) and 370,000 - 590,000 subcatchable (6-8 in.) ca. 70% catchable 30% subcatchable + 30,000 - 60,000 brown trout

Harvest, annual harvest (trout kept by anglers): 370,000 - 590,000 for Catch Per Hour from .29 to .39 (.35) + about same for catch-and-release (total CPH .6 - .8)

Return to Creel of stocked trout 25% to 35% (30) of all trout stocked (30-50% [40] of catchable)

Average size of all rainbows harvested 11.6 inches
" " " " released 9 in.

Growth 3/4 in. (18 mm) per month

Relative wt (Wr 14-20)

	Brown	RB
1979	126	103
1980	101	101
1981	118	98
1982	109	92
1983	110	103
1984	108	95
1985	96	85

Anglers: 61% bait, 19% lures, 8% flies, 12% combin.

quality perception:

Excellent	10%
Good	24%
Fair	19%
poor	49%

Angler use: 1.2 - 1.5 million hrs/yr.
600 - 700 hr./acre
x̄ trip 4.3 - 4.8 hr.

Regulations: 5/day, brown trout 1, min. size 20", encourage to release 12-16 in. fish. (voluntary)

Why 70% unaccounted for?

Subcatchable size (< 10 in/11 in) - mostly released - w/ 60+% bait and ca 40% mortality.

Food supply - Amphipods; isopods - 1981 mainly amphipods, >1981 mostly isopods

Gammarus decline w/ loss productive littoral zones - vegetation lost when lake drawn down 7 ft. and shore frozen + large sediment inputs in key areas from development

- Great increase in white suckers - eat 10X more *Gammarus* than trout - suckers consume immature *Gammarus*.

Outmigration to Bull Shoals Res. during flood flows.

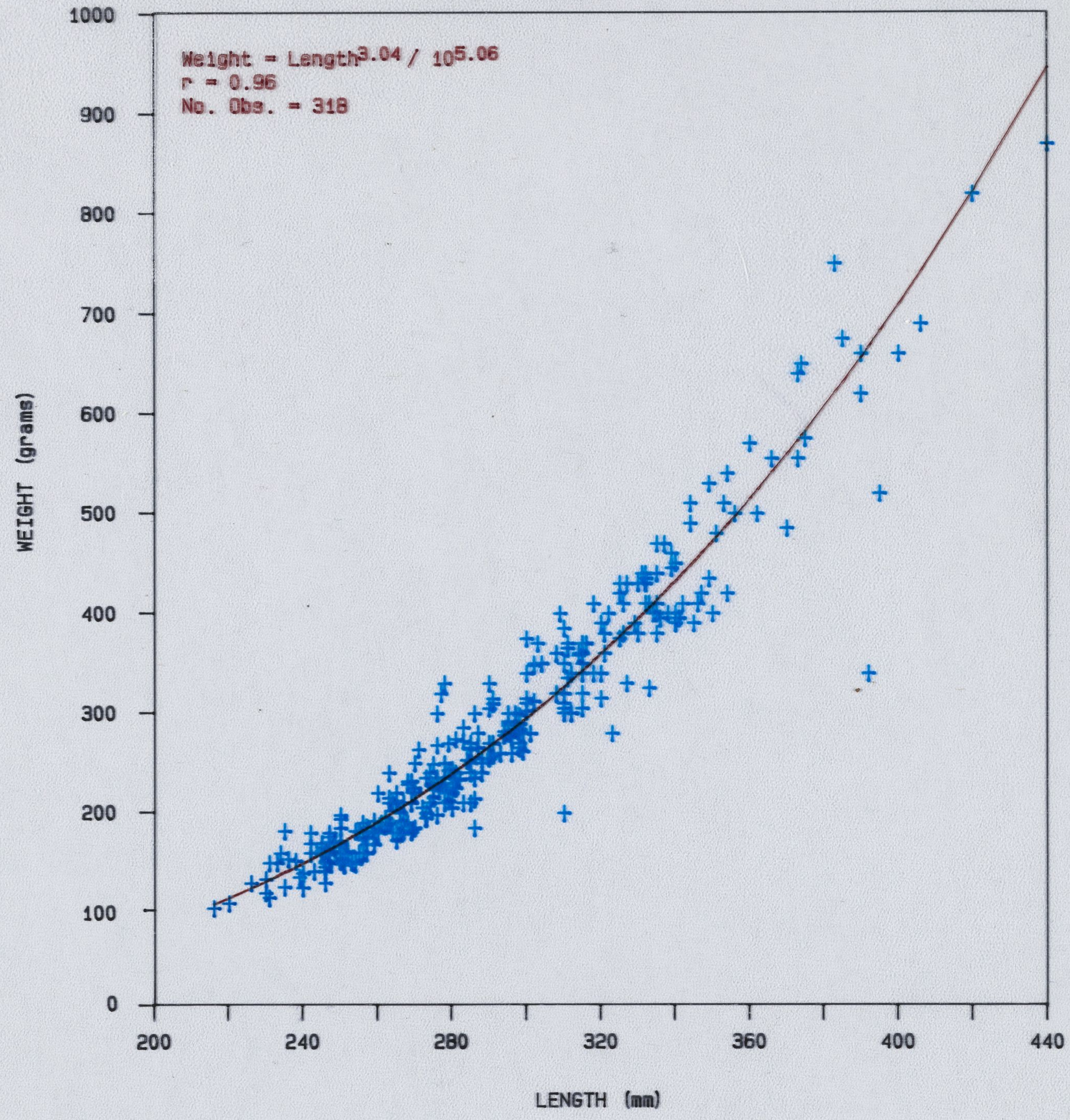
- These problems not associated w/ D.O.

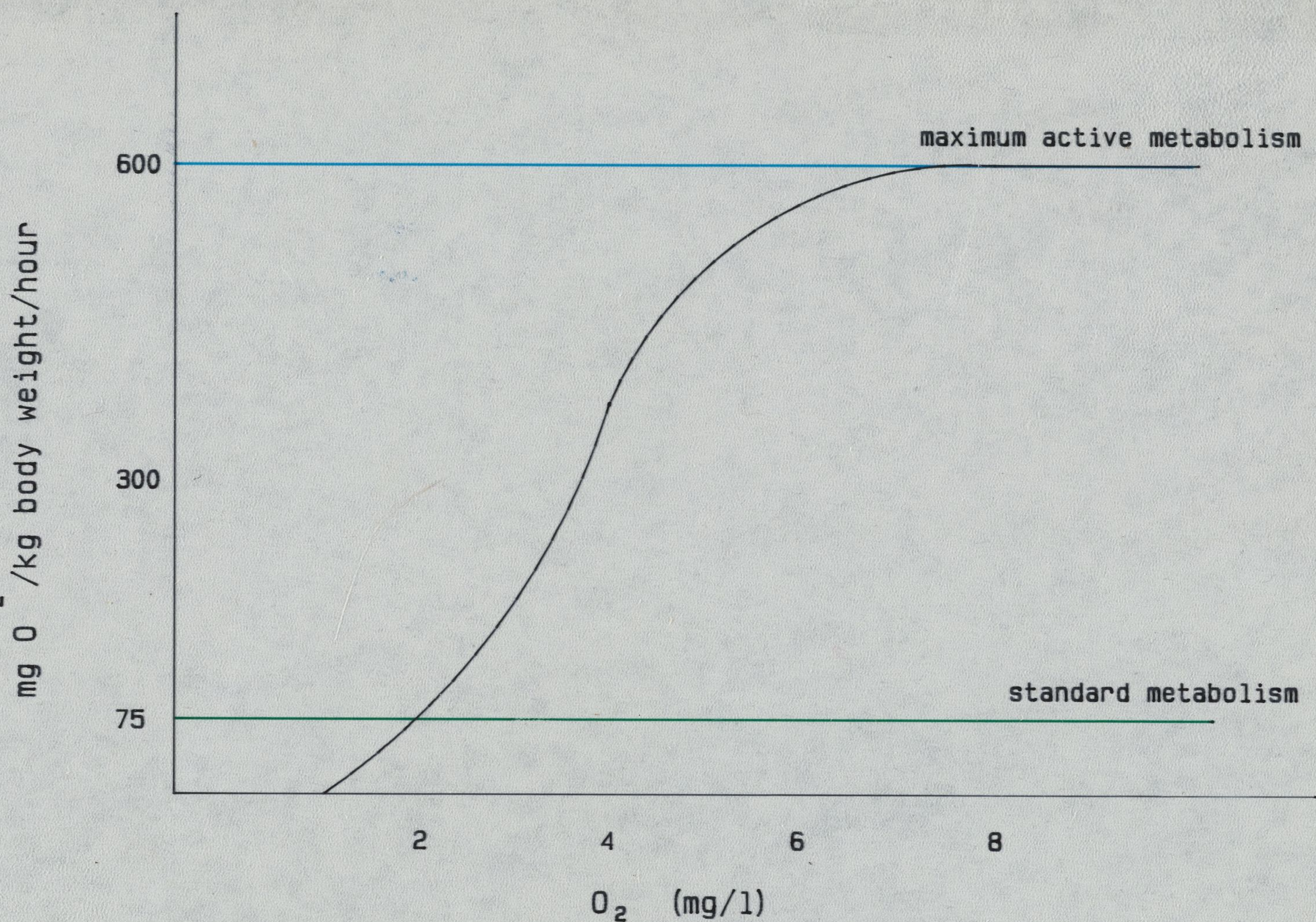
3% anglers fish for bass - 4,744 bass $\bar{x}$ 12.9 in.
9,637 released.

LAKE OGALLALA

LENGTH - WEIGHT RELATIONSHIP OF STOCKED RAINBOW TROUT

TOTAL PLANT - 1987





SCOPE FOR ACTIVITY. ENERGY AVAILABLE AT DIFFERENT O_2 LEVELS AT A CONSTANT TEMPERATURE (ca. 15 °C)

From Davis (1975) and Dickson & Kramer (1971) points to be made 86-87

density

86 - Buoy line-keystone greater use - veg. - [illegible] O2

wind

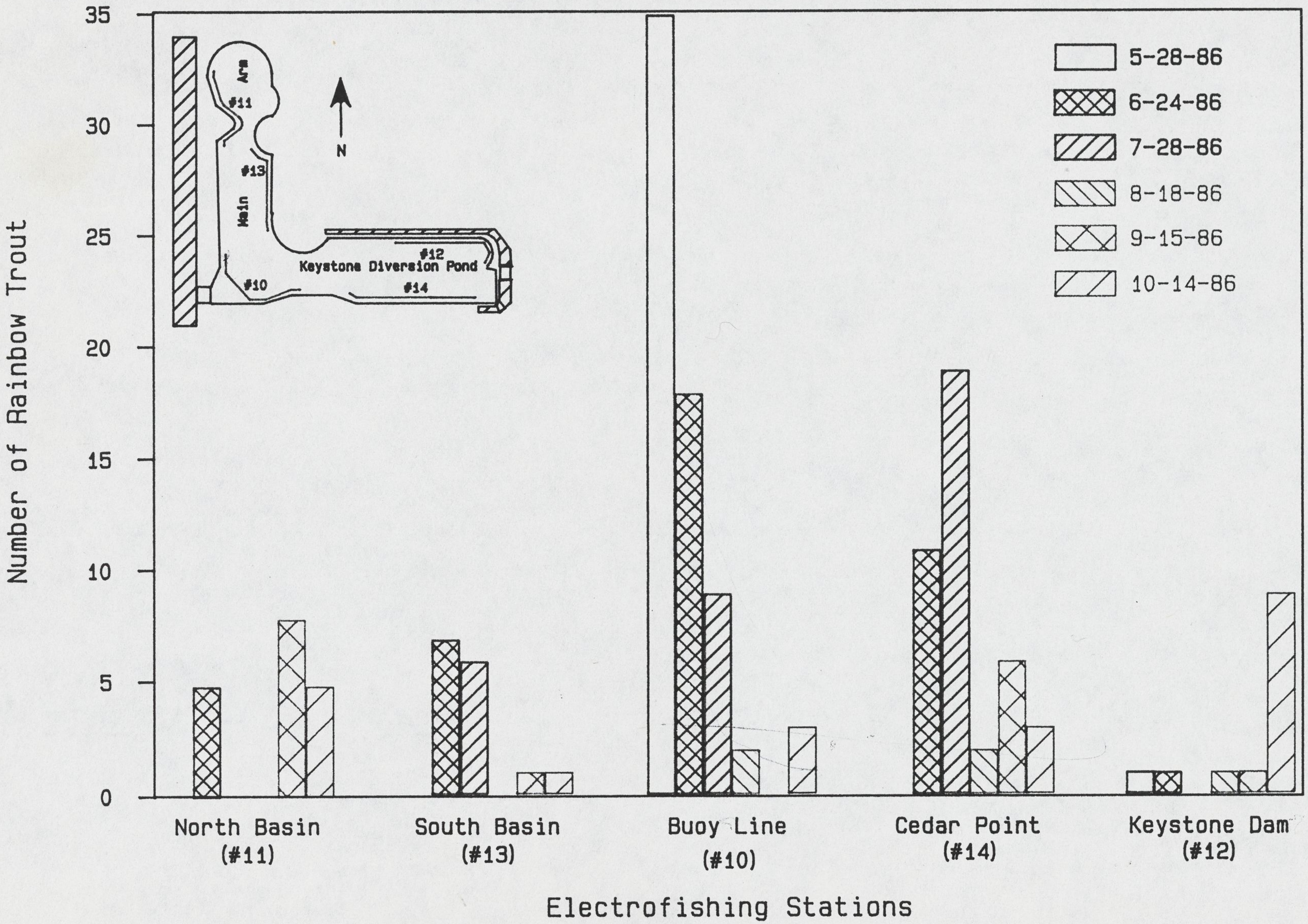
N. basin - low

for outmigration

87 - emphasis on Main #5

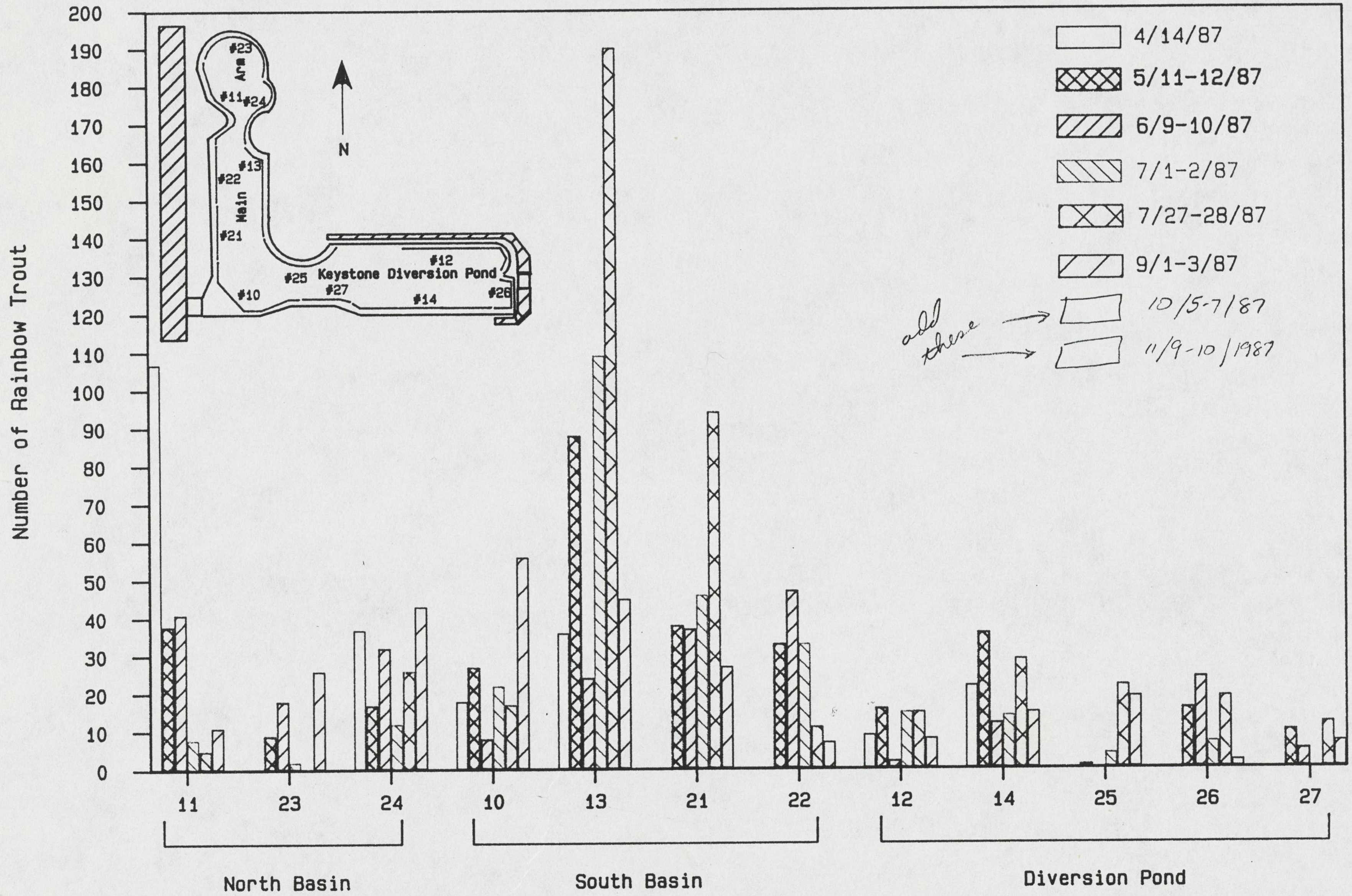
#5 Main low

growth good

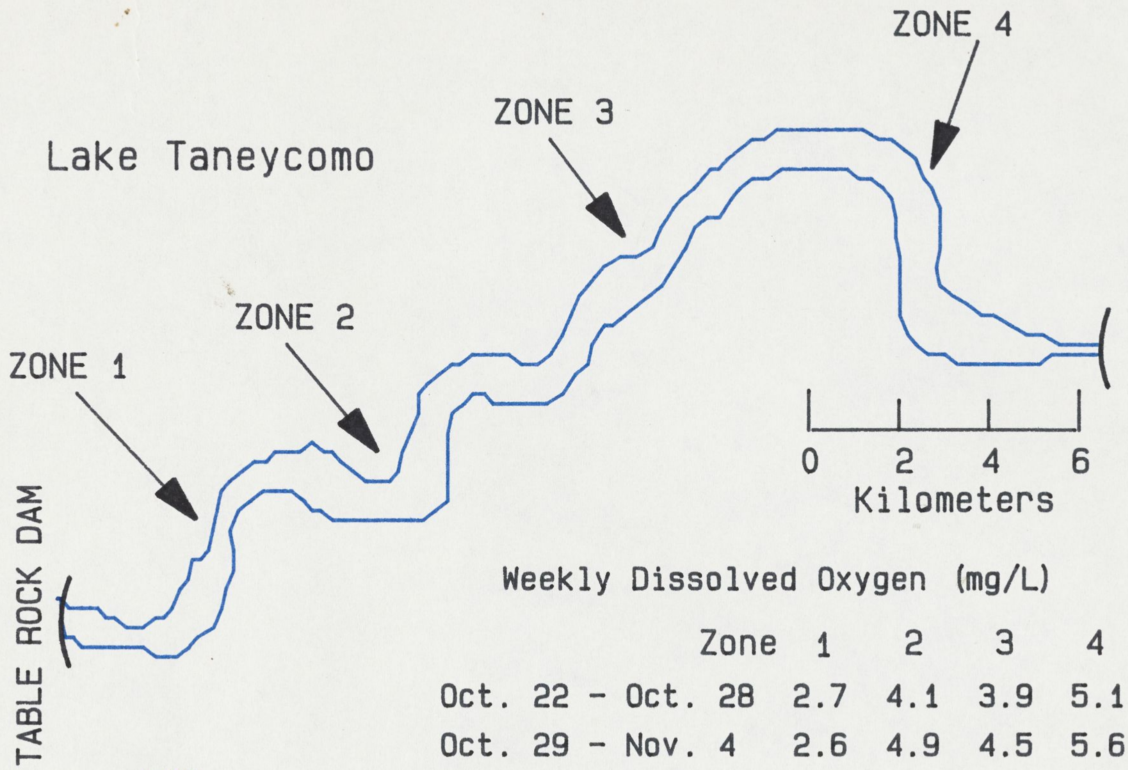


Tortdist.drw

Distribution of all Rainbow Trout captured in Lake Ogallala during 1987



Lake Taneycomo



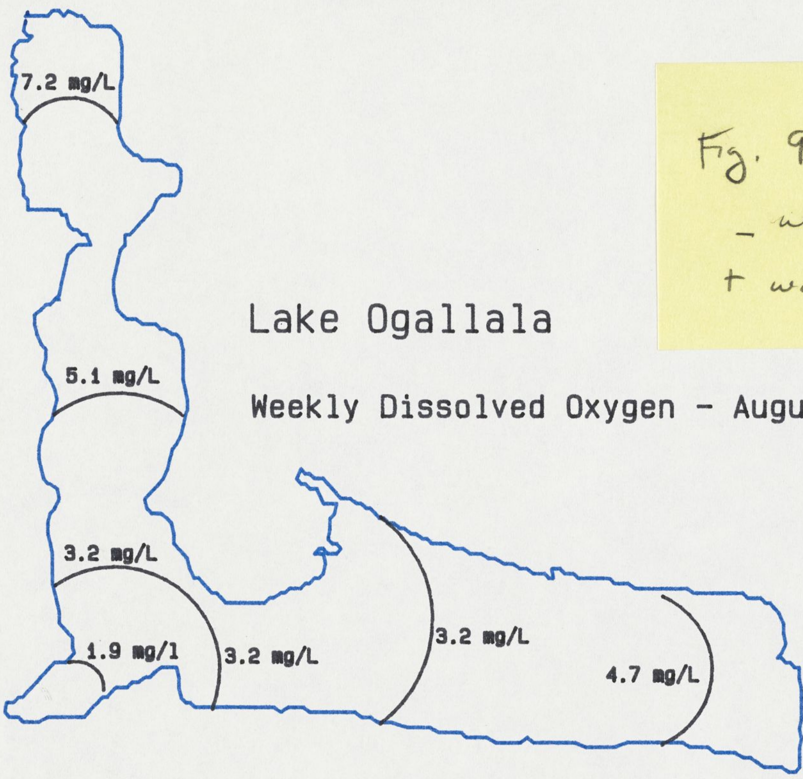
Weekly Dissolved Oxygen (mg/L)

	Zone 1	2	3	4
Oct. 22 - Oct. 28	2.7	4.1	3.9	5.1
Oct. 29 - Nov. 4	2.6	4.9	4.5	5.6

Fig. 9 & 10 legend
- outlet
- worst 86
+ worst 87

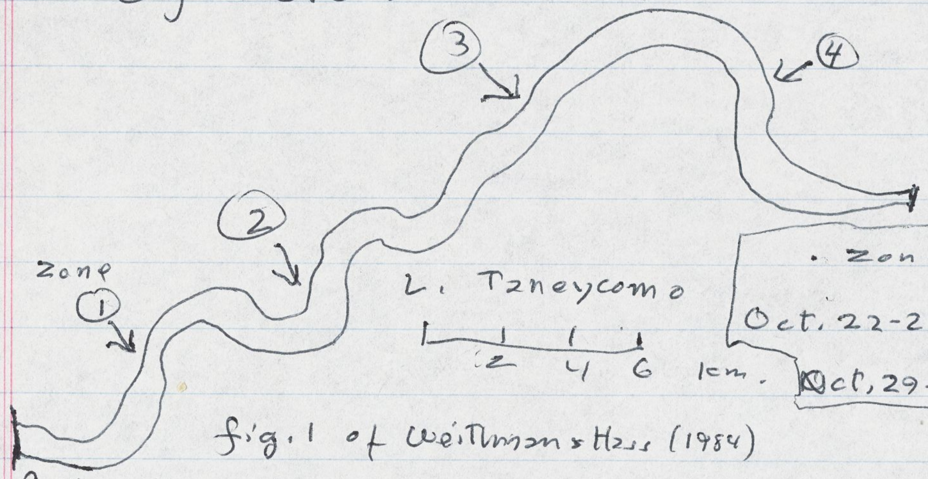
Lake Ogallala

Weekly Dissolved Oxygen - August 28, 1986



Comparing low dissolved oxygen levels by lake area
for Lake Taneycomo, Missouri and Lake Ogallala, Nebraska

Figure 9 Comparing low O_2 levels by lake area for Taneycomo & Ogallala.

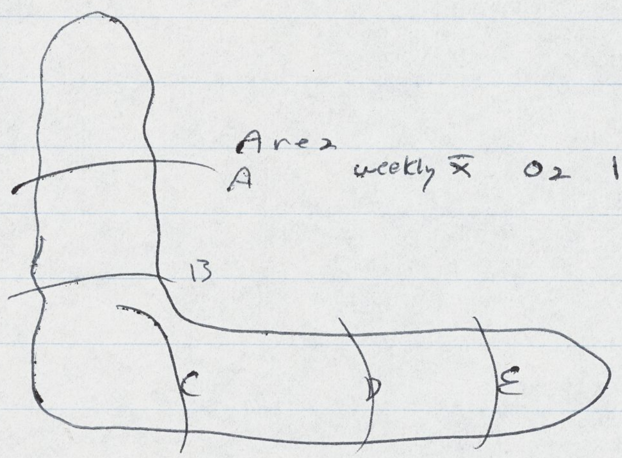


$\bar{x}$ weekly O_2				
Zone	1	2	3	4
Oct. 22-28	2.7	4.1	3.9	5.1
Oct. 29-Nov. 4	2.6	4.9	4.5	5.6

fig. 1 of Weithman & Haas (1984)

– Table 4 of "Lake Taneycomo White Paper", unpublished draft of L. Taneycomo Management Comm. (undated) lists monthly dissolved oxygen concentration in water from Table Rock Dam. The dissolved oxygen levels averaged 0.1 in October and November, 1983, 0.8 and 0.2 in Oct. and Nov. 1984, and 0.5 and 0.3 in Oct. and Nov. 1985.

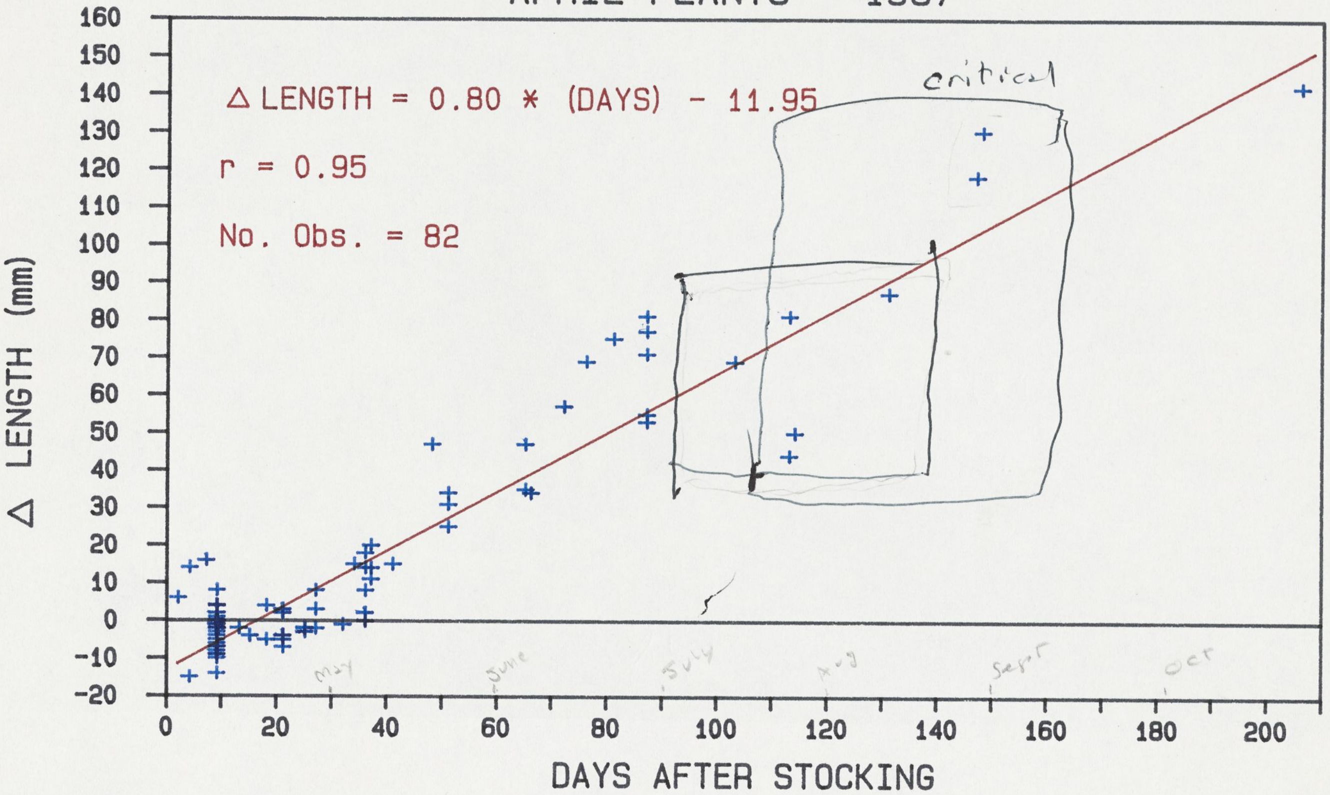
fig 10

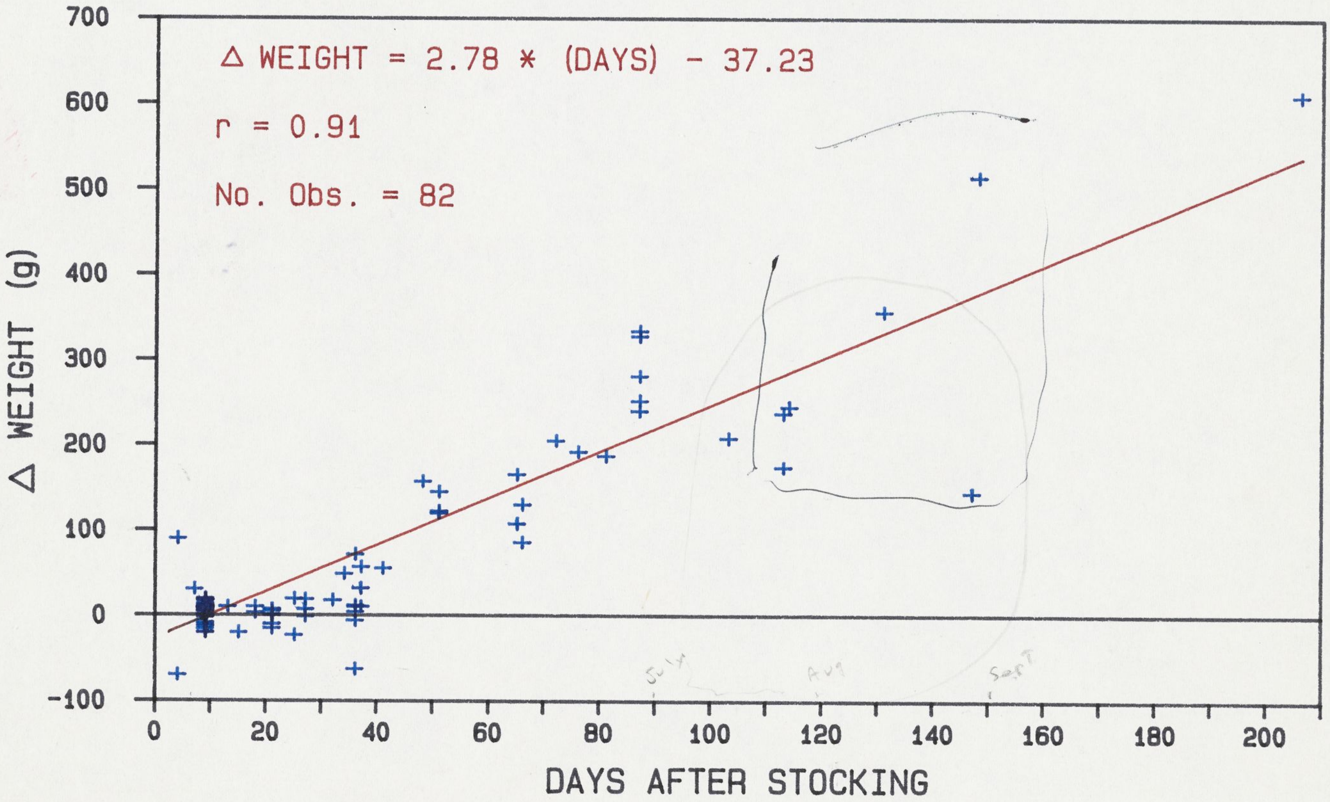


weekly $\bar{x}$ O_2 levels for worst week with outlet water at bouy line of 4 mg/l. O_2

need (1) condition factors
(2) CPH

LAKE OGALLALA
GROWTH OF STOCKED RAINBOW TROUT
APRIL PLANTS - 1987

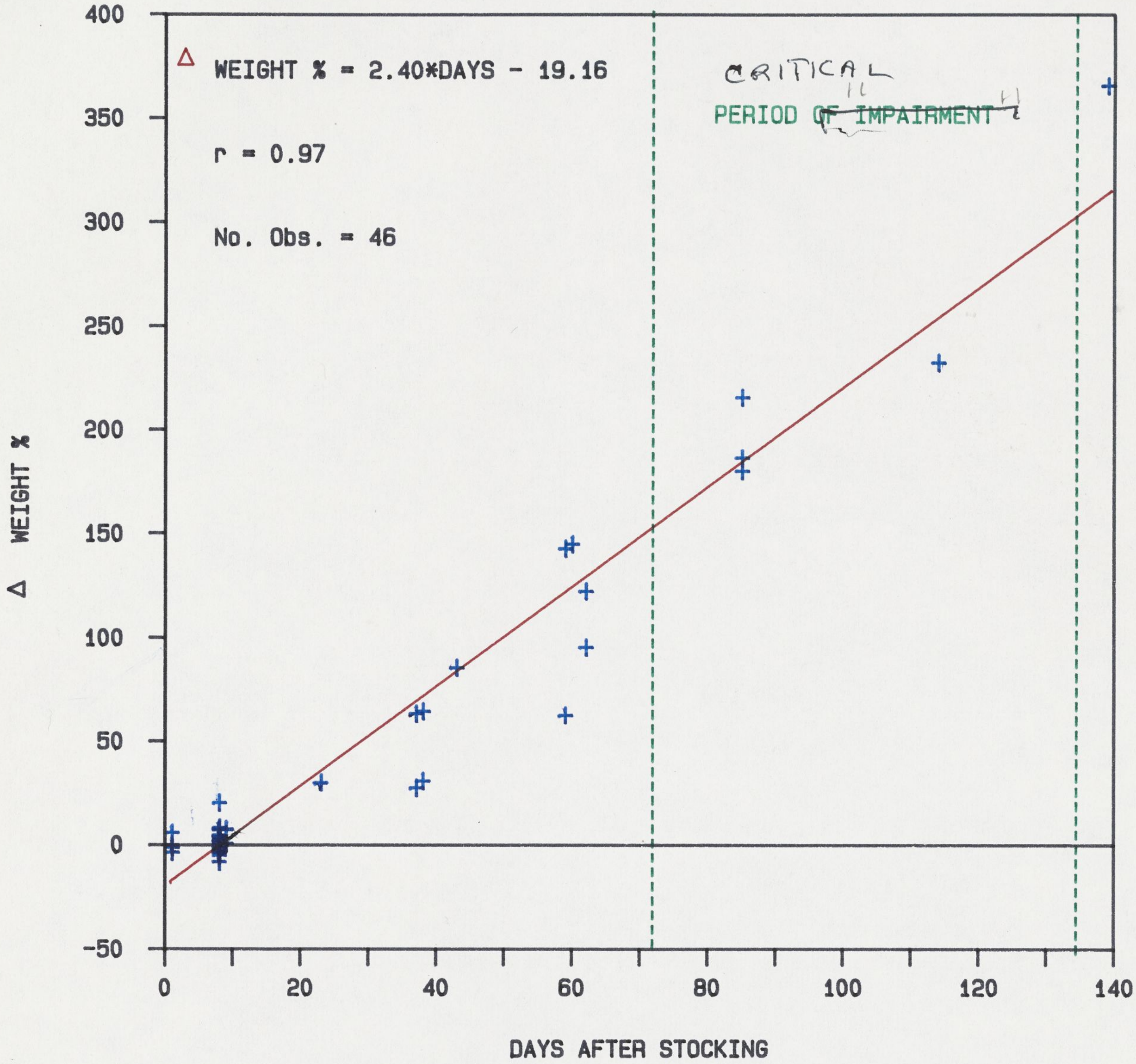




Lake Ogallala

GROWTH OF STOCKED RAINBOW TROUT

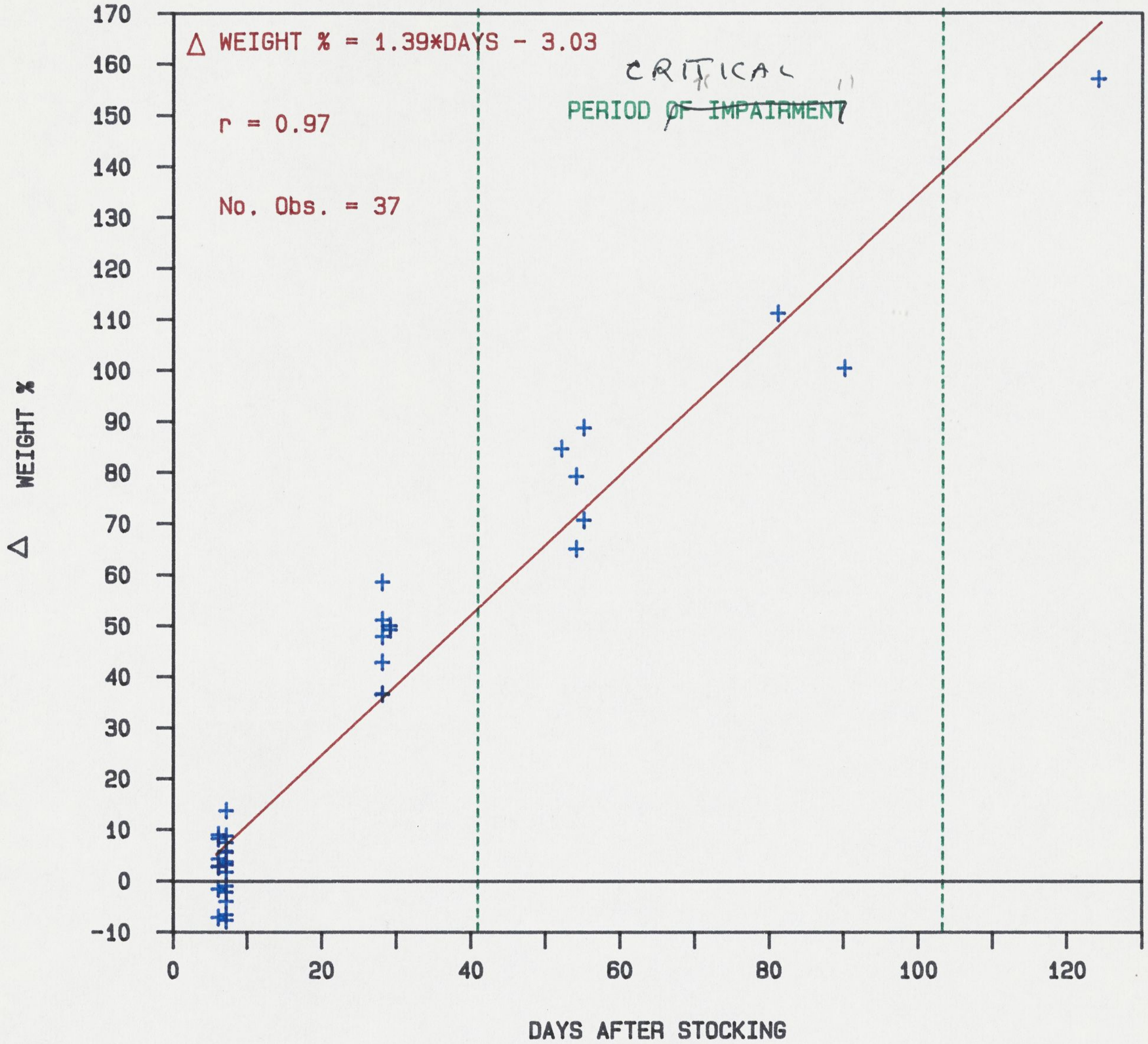
MAY PLANT - 1987



Lake Ogallala

GROWTH OF STOCKED RAINBOW TROUT

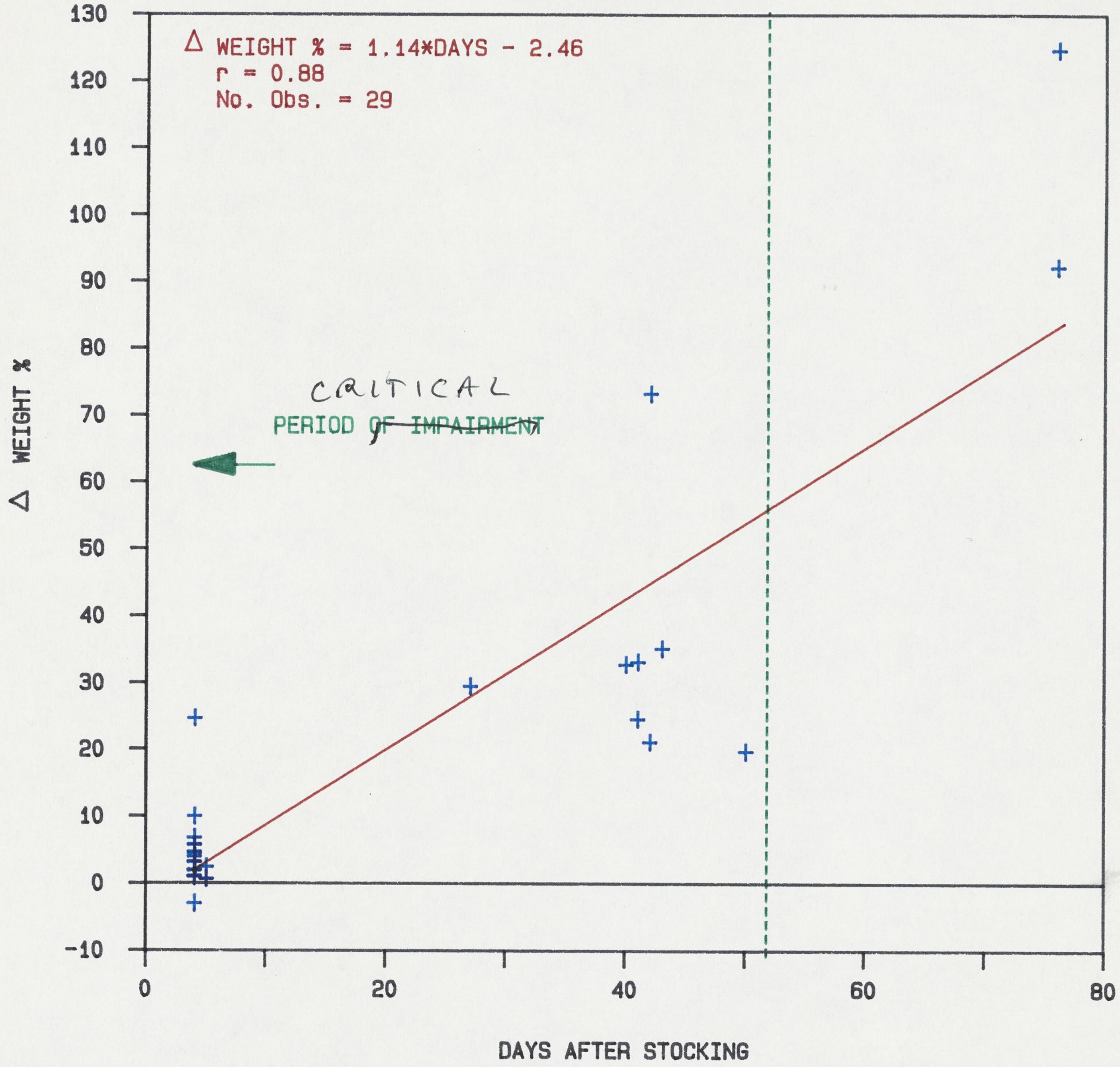
JUNE PLANT -1987



Lake Ogallala

GROWTH OF STOCKED RAINBOW TROUT

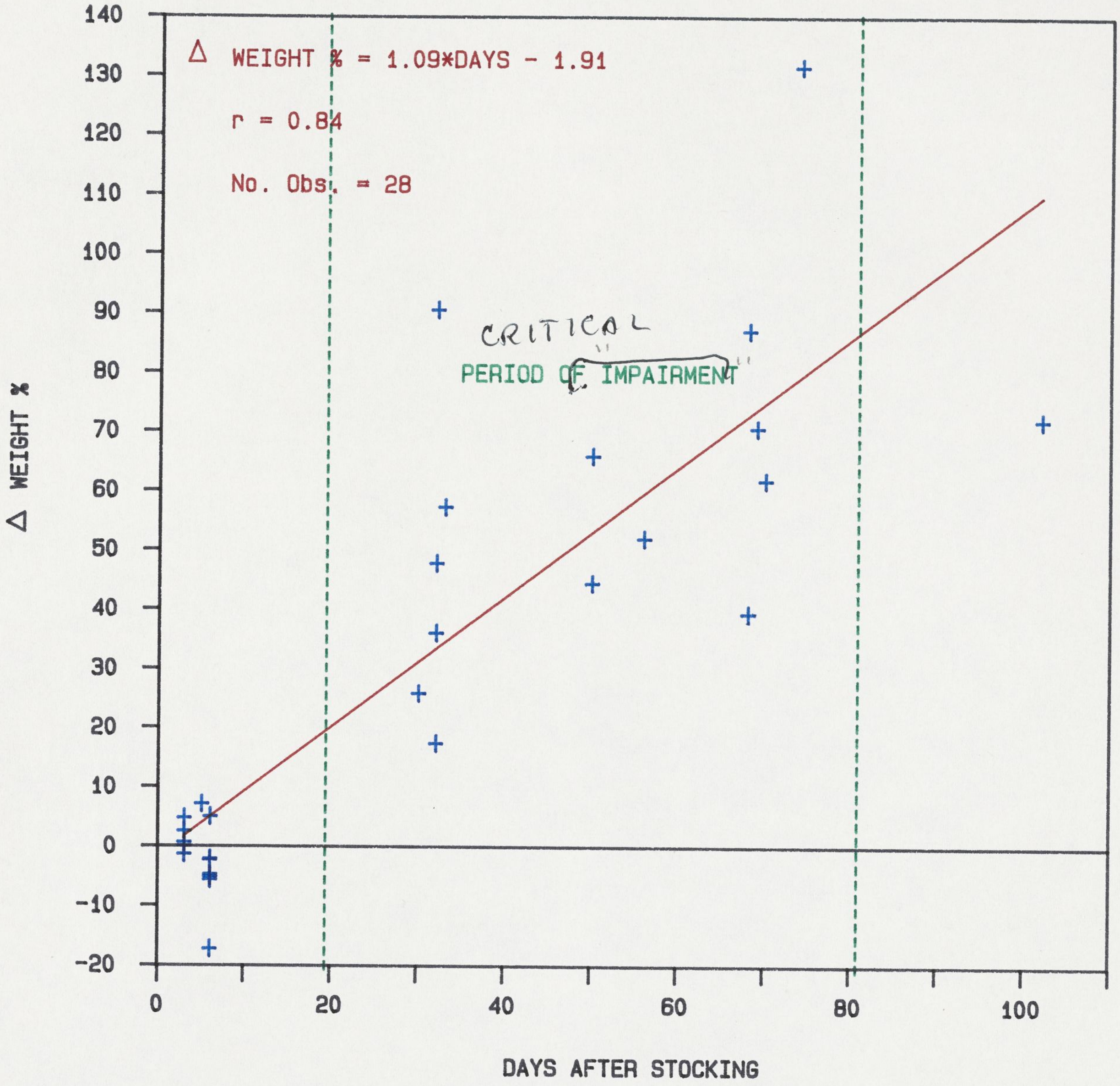
AUGUST PLANT - 1987



Lake Ogallala

GROWTH OF STOCKED RAINBOW TROUT

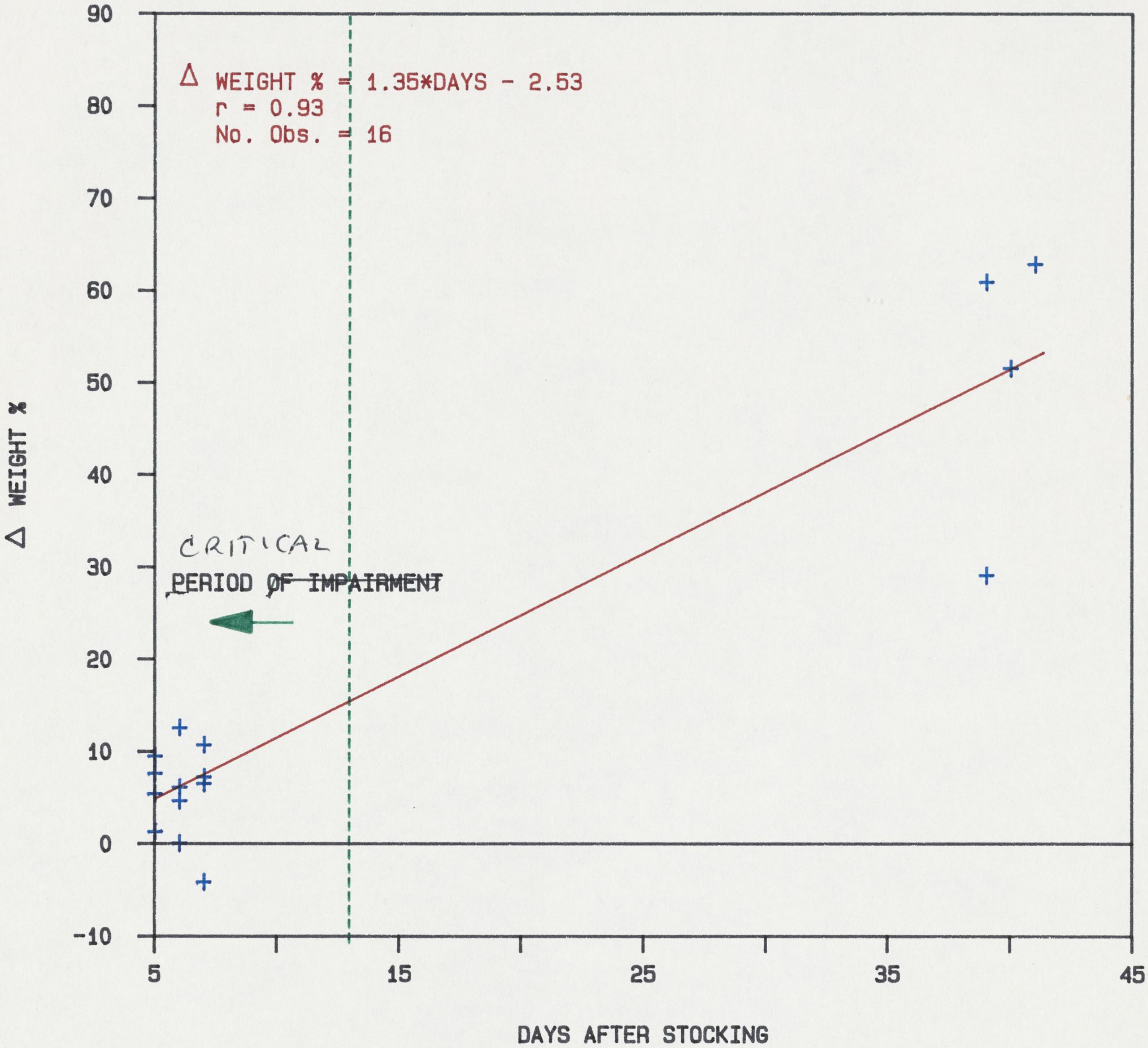
JULY PLANT - 1987



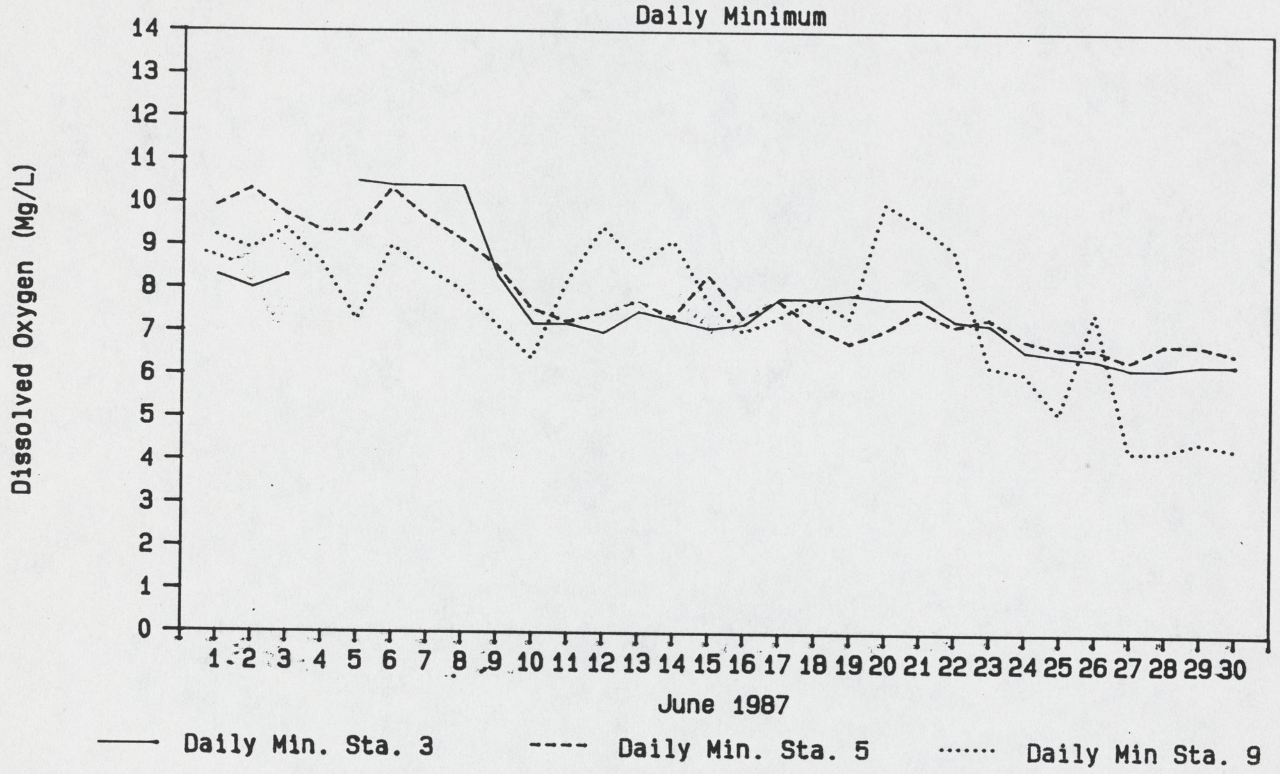
Lake Ogallala

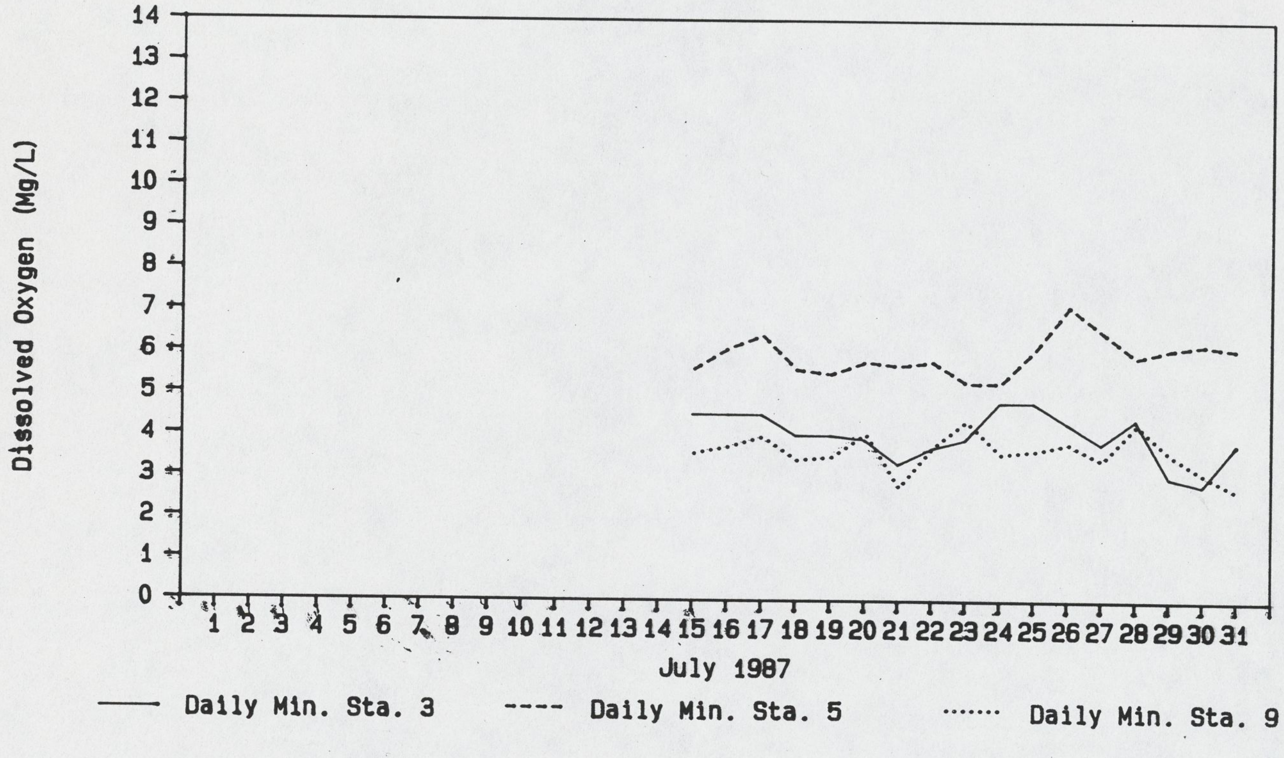
GROWTH OF STOCKED RAINBOW TROUT

SEPTEMBER PLANT - 1987

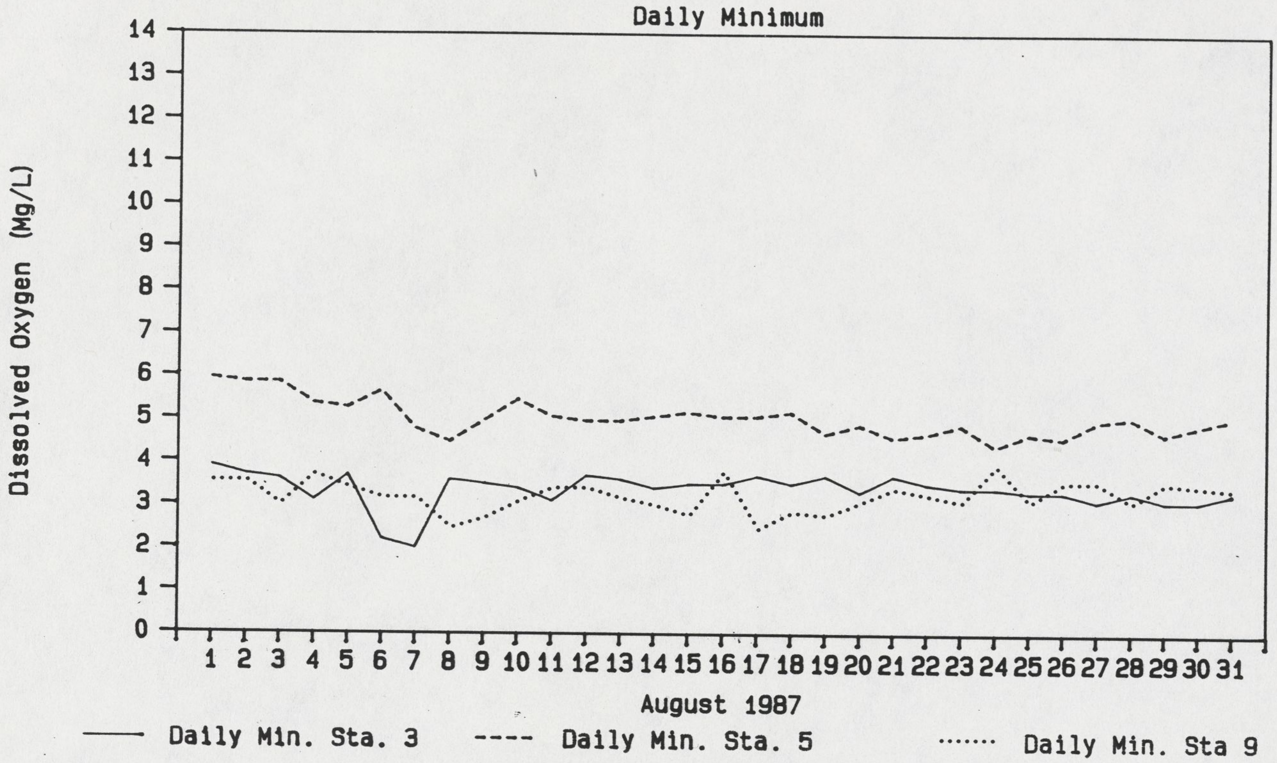


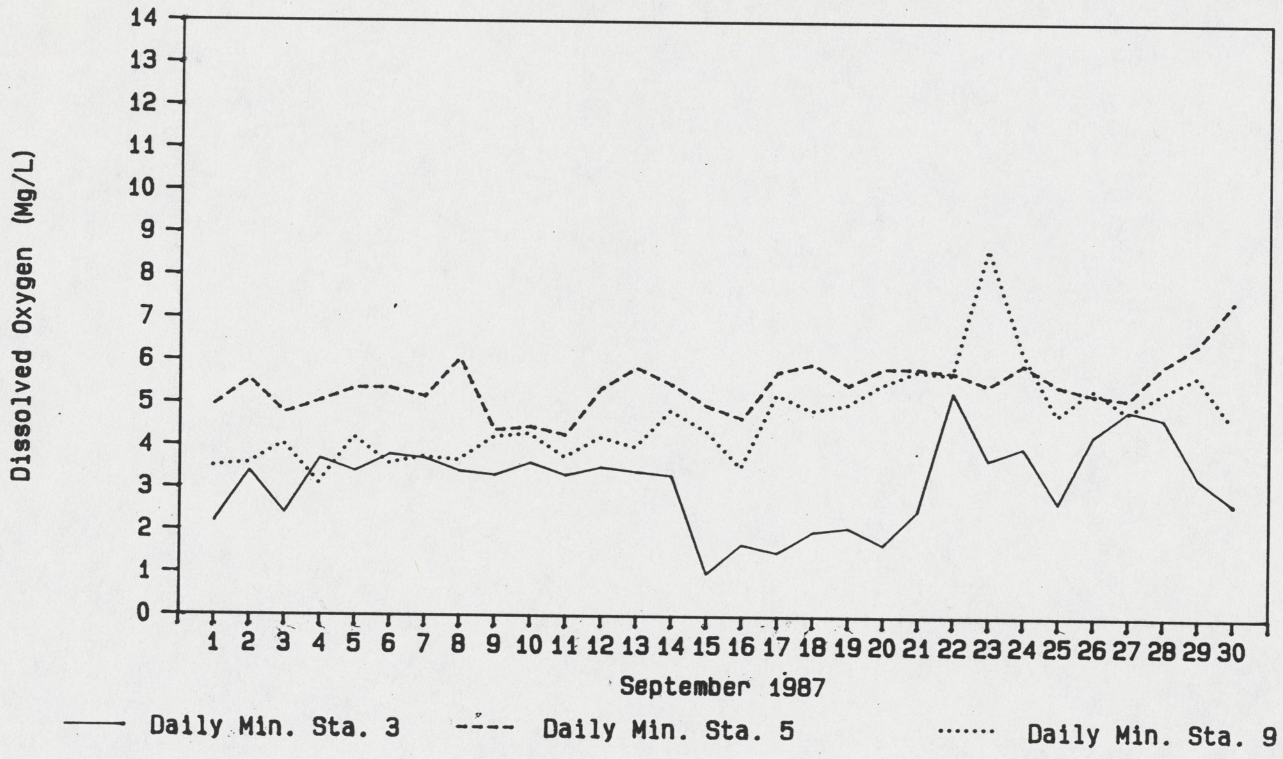
LAKE OGALLALA STA. 3, 5, & 9



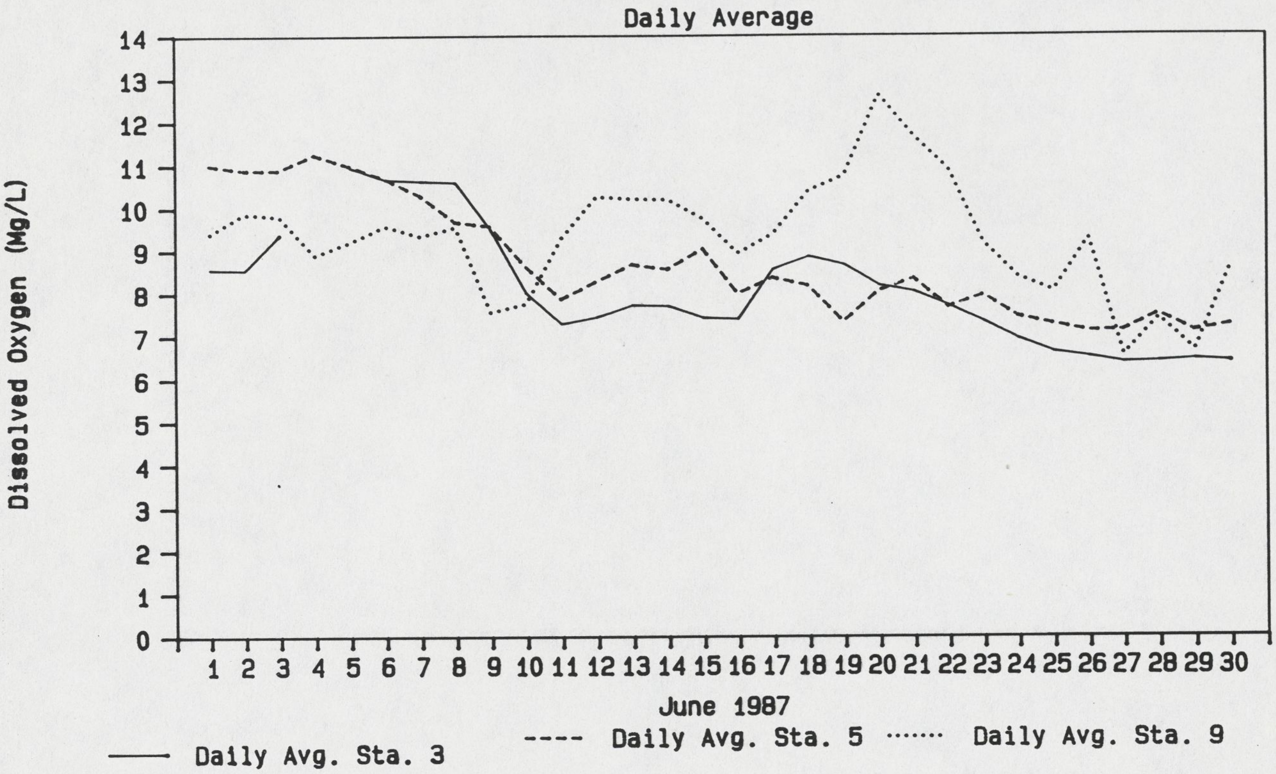


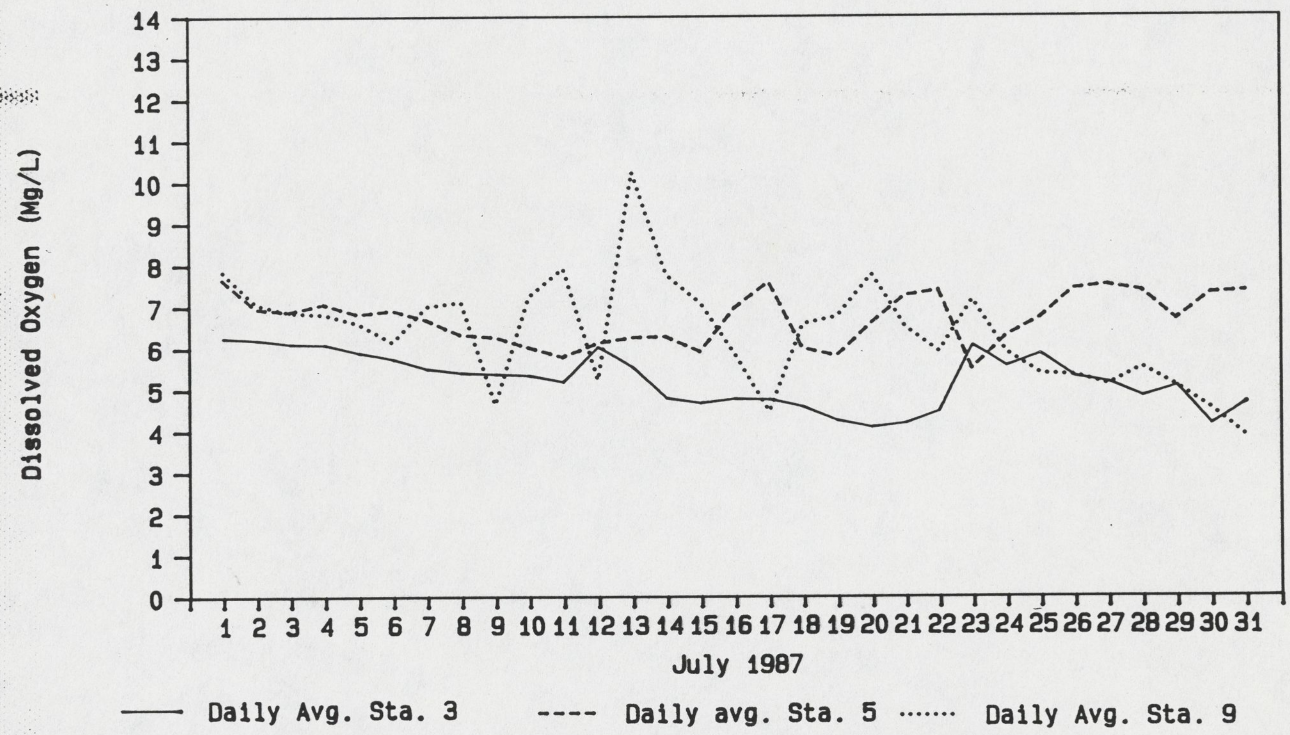
LAKE OGALLALA STA. 3, 5, & 9 D.O.





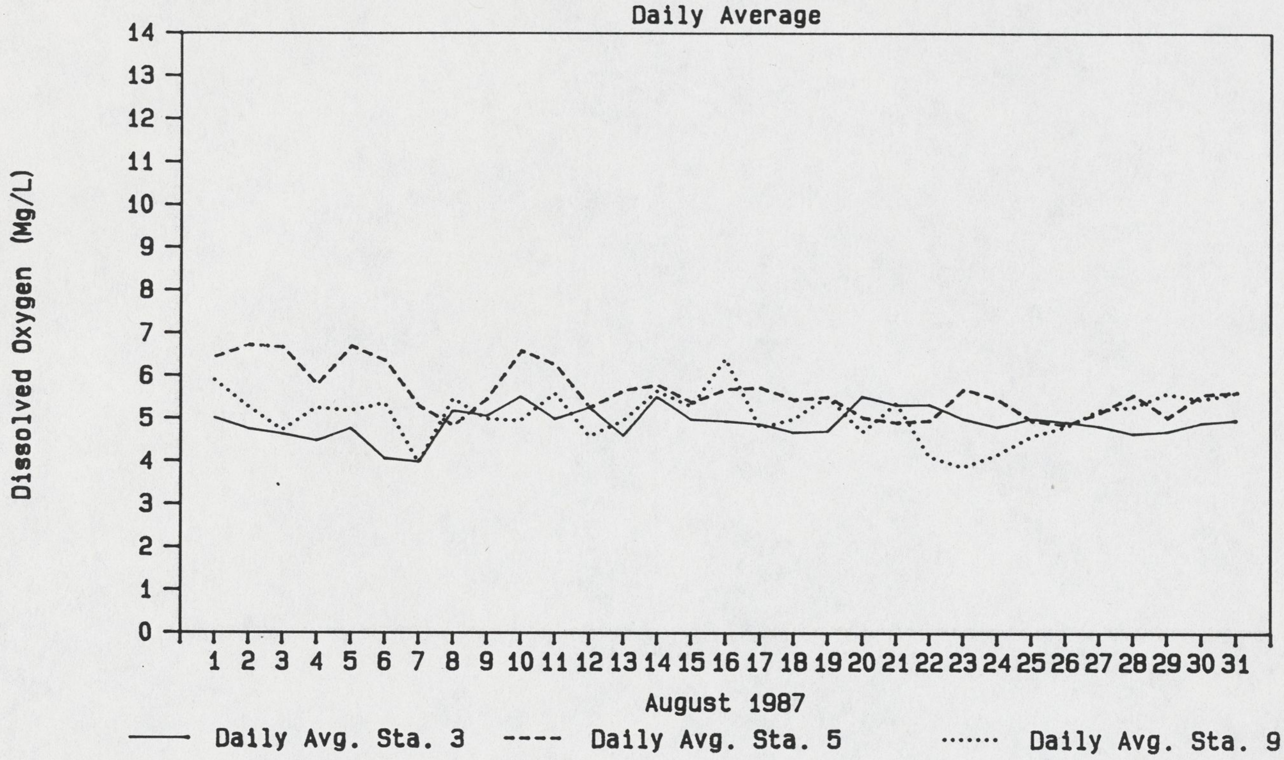
LAKE OGALLALA STA. 3, 5, & 9 D.O.

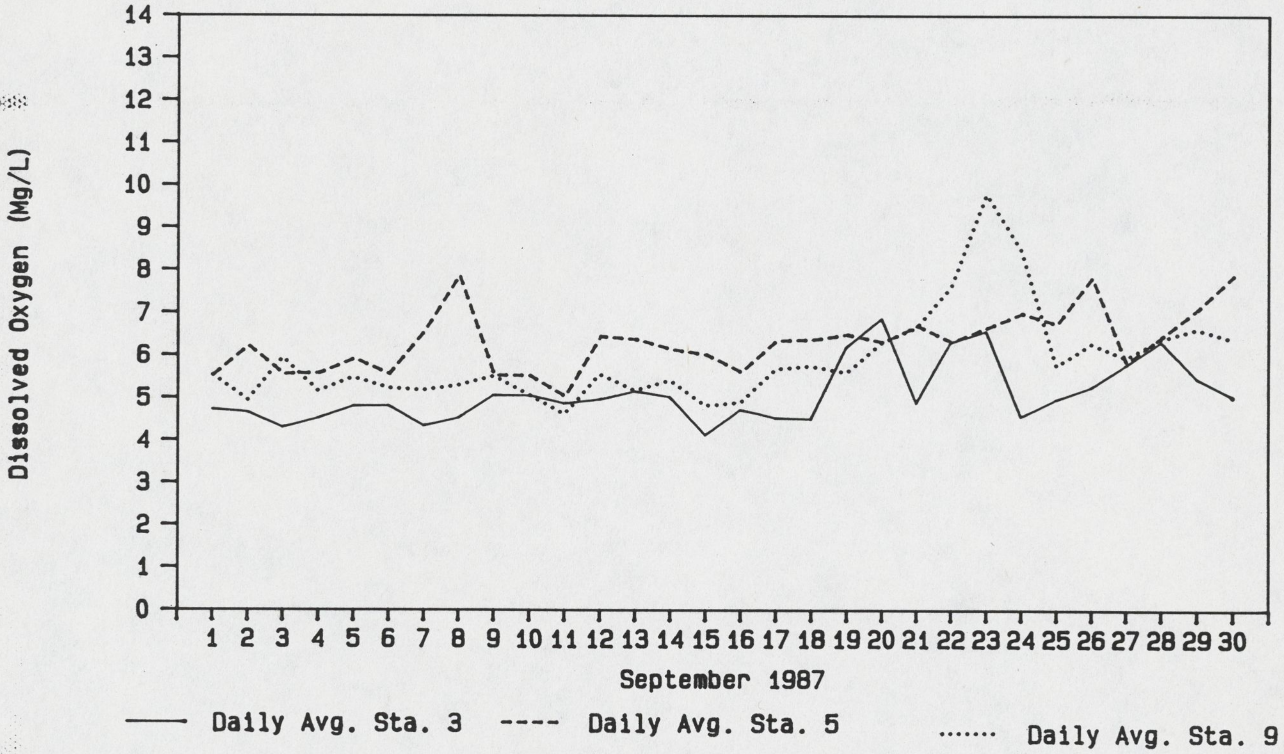




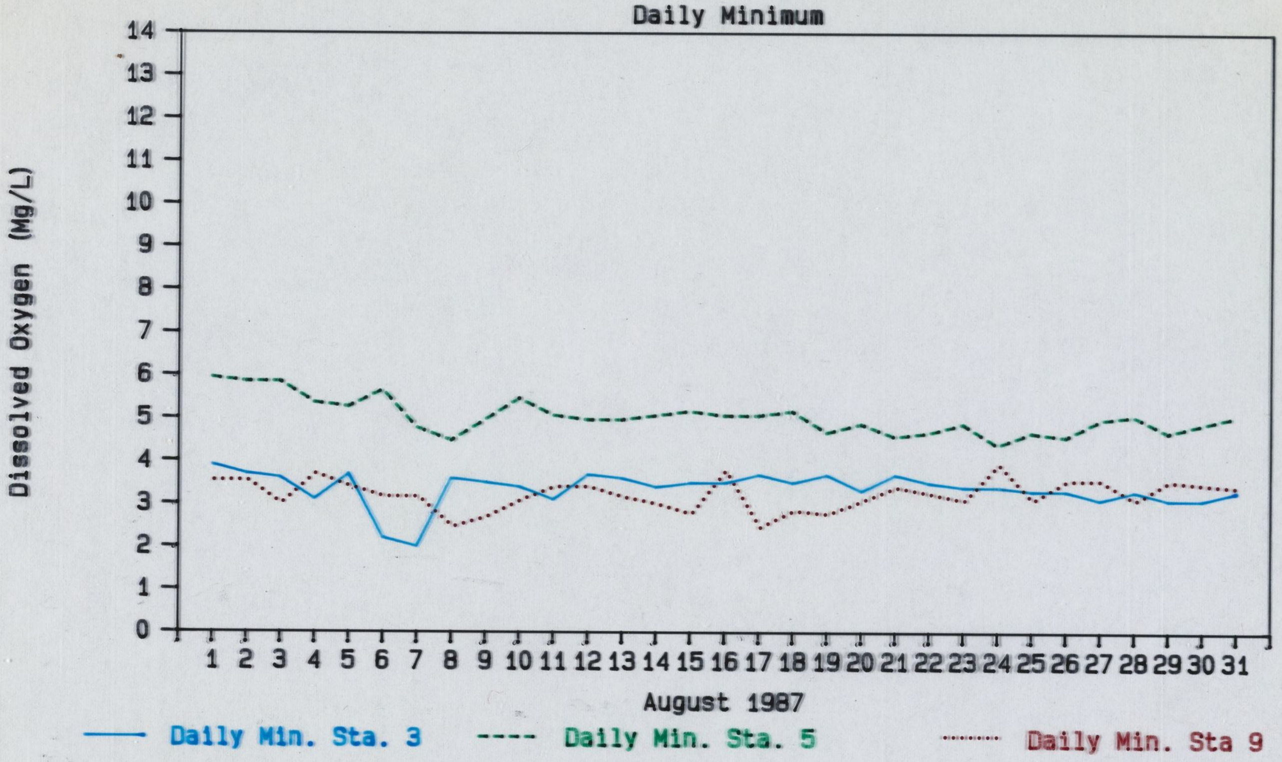
LAKE OGALLALA STA. 3, 5, & 9 D.O.

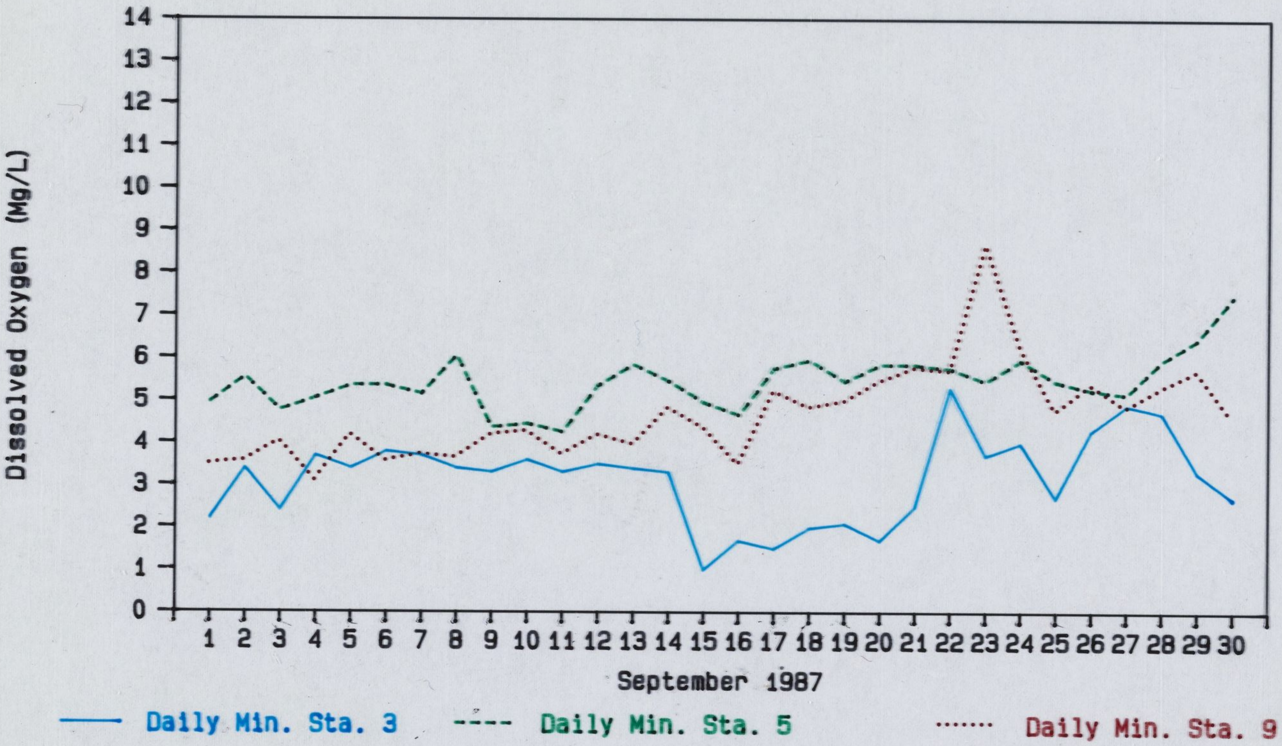
Daily Average





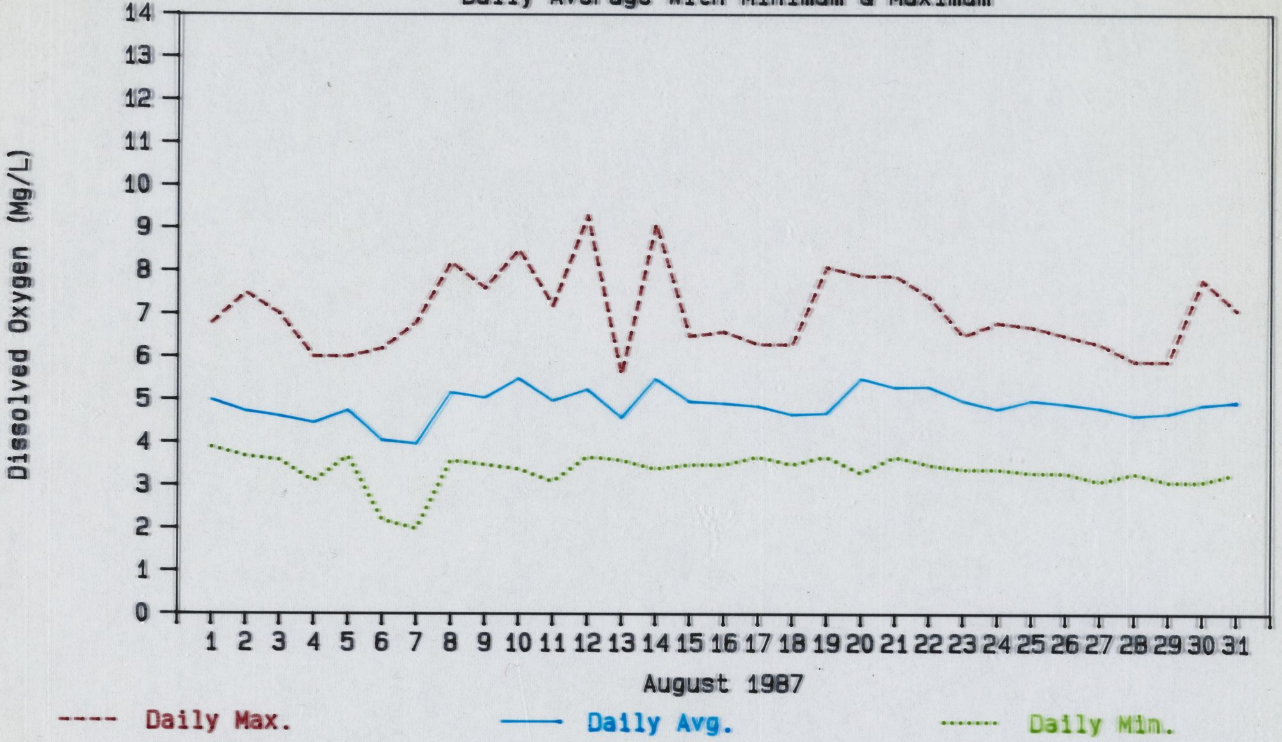
LAKE OGALLALA STA. 3, 5, & 9 D.O.

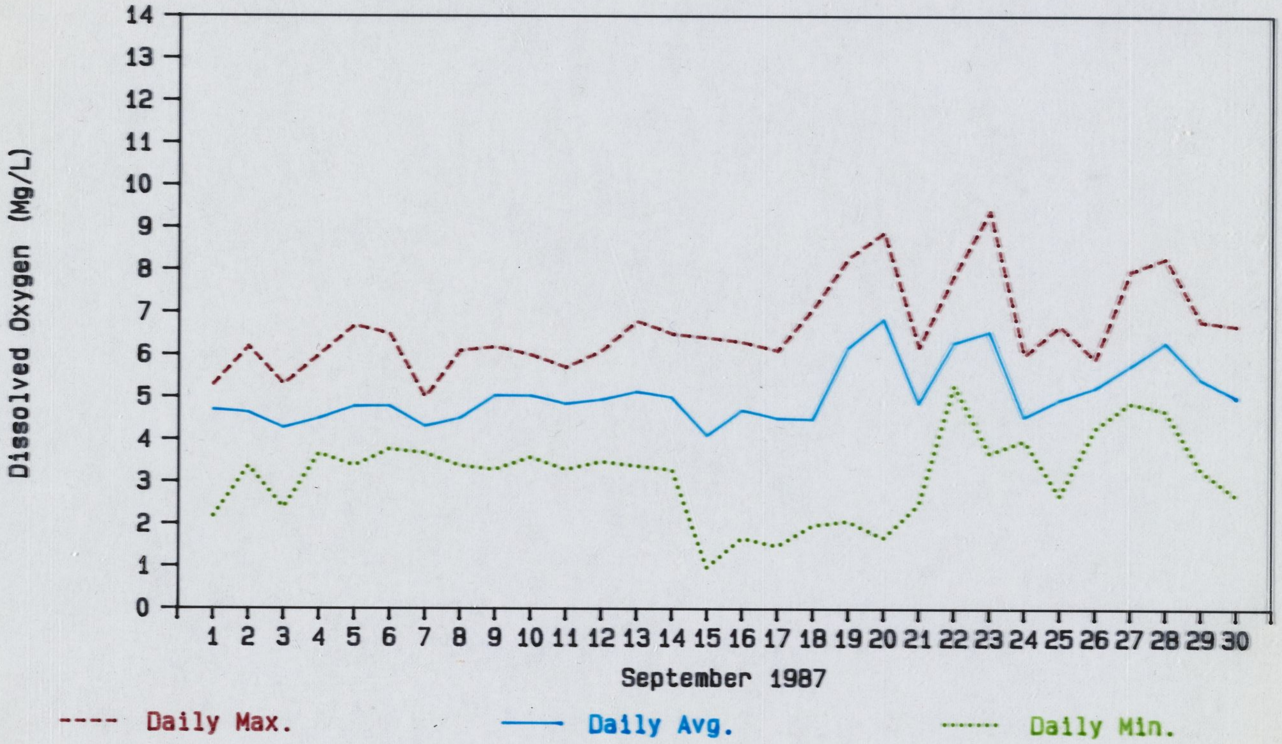




LAKE OGALLALA STA 3 D.O.

Daily Average With Minimum & Maximum





Benthic Invertebrates in Lake Ashtabula Reservoir, North Dakota

JOHN J. PETERKA
Department of Zoology, North Dakota State University, Fargo 58102

ABSTRACT: The kinds and amounts of benthic invertebrates in Lake Ashtabula, a 20-year-old eutrophic reservoir in southeastern North Dakota, were recorded at a single station located 3.2 km N of the dam. The average standing crops of benthic invertebrates in the sampling station collected during April, June and August 1967 were 6.4, 8.2 and 7.1 g m^{-2}, respectively, and 1831, 2622 and 1295 individuals m^{-2}. Organisms in the 0-3 m depth zone accounted for 28% by number and 53% by weight of all organisms present in the study area from April to August; 56% by number and 37% by weight were in the 3-8 m depth zone; and 16% by number and 9% by weight were in the 8-12 m depth zone. The quantity and kinds of its benthic invertebrates indicate Lake Ashtabula is eutrophic when compared with data available from other lakes that are also unstratified during open-water periods.

INTRODUCTION

The kinds and amounts of benthic invertebrates in Lake Ashtabula, a 20-year-old eutrophic reservoir in southeastern North Dakota, were recorded as part of a continuing study designed to characterize the reservoir in terms of its water chemistry and primary productivity.

Lake Ashtabula is to receive waters in the late 1970's from the Garrison Diversion Project, which will provide irrigation water from the Garrison Reservoir to eastern and central North Dakota. As these waters pass through North Dakota farmland and highly saline Devils Lake, they are expected to increase in total dissolved solids which could modify environmental conditions in Lake Ashtabula. Because studies of benthic invertebrates have been useful elsewhere in determining effects of various environmental changes occurring in lakes and streams (*e.g.*, Brinkhurst [1969], Carr and Hiltunen [1965] and others on changing kinds and numbers of benthic invertebrates in Lake Erie associated with organic pollution; Cowell and Hudson [1967] on the effects of variations in morphometry and water level fluctuations on benthic invertebrates in reservoirs on the Missouri River; and Mills, Starrett and Bellrose [1966], who reviewed changes in benthic invertebrates in the Illinois River as affected by activities of man), it is hoped that we will be able to assess any changes in the biota caused by receipt of diversion waters from data collected from Lake Ashtabula. Since there have been no detailed studies of benthic invertebrates from North Dakota reservoirs, it is hoped that information presented here will contribute to the limnology of the Upper Great Plains and, on a broader scope, to knowledge of benthic invertebrates in reservoirs which do not stratify during open-water periods and which do not experience large and rapid changes of water levels.

The lake's limnology, primary productivity and zooplankton standing crops were studied by Peterka and Reid (1968) and Peterka and Knutson (1970). Lake Ashtabula has a surface area at normal pool of 2197.5 ha, a length of 43.5 km, a maximum width of 0.97 km, a mean depth of 4.0 m, a maximum depth slightly over 15 m and drains an area of 10,717.5 km^2 (Peterka and Reid, 1968). The water exchange ratio (volume of water entering the reservoir divided by the volume of the reservoir at normal pool) from March to November 1965, 1966 and 1967 averaged 2.1. Except for periods of a few days when stratification occurred, water temperatures were uniform from top to bottom during ice-free periods. Lake Ashtabula is highly productive with average annual gross primary productivity rates of 4.1 and 6.8 g O_2 m^{-2} day^{-1} for 1967 and 1968, respectively. Heavy blooms of *Aphanizomenon holsaticum* occurred, comprising about 90% of the total algal bloom in numbers and volume during summer and autumn of 1967 and 1968 (Peterka and Knutson, 1970). *Daphnia* comprised 84% of total zooplankton dry weight standing crop in 1967 and 81% in 1968; copepods 14% in 1967 and 17% in 1968. The average dry weight daily standing crop of *Daphnia pulex* was 1110 in 1967 and 2851 mg m^{-2} in 1968; of *Daphnia galeata mendotae*, it was 294 in 1967 and 7.2 mg m^{-2} in 1968.

METHODS

A 15.2-cm-sq Ekman dredge (232 cm^2) was used to sample transects of the reservoir bottom for benthic invertebrates in the spring and summer of 1967. Dredge hauls were taken in three depth zones: the littoral zone (0-3 m), the old river floodplain (3-8 m), and the old river channel (8-12 m).

All sampling was done at a station, which will be referred to as the study area, located 3.2 km (2 miles) N of the dam (Fig. 1). On 26 April 1967, 12 Ekman dredge hauls were made in the 0-3, and six hauls each in the 3-8 and 8-12 m depth zones. From 6-12 June 1967, 60 dredge hauls were made in the 0-3, 64 hauls in the 3-8, and 32 hauls in the 8-12 m depth zones. From 22-30 August 1967, 60 dredge hauls were made in the 0-3, 52 hauls in the 3-8, and 20 hauls in the 8-12 m depth zones. Within each depth zone, sampling was accomplished by anchoring the boat, taking four dredge hauls, and then permitting the boat to drift before taking another series of four hauls. Bottom samples from each four dredge hauls were combined and washed through a sieve with a mesh size of 0.5 mm. Retained organisms were preserved in 5-10% formalin and later counted and weighed to the nearest 0.001 g after being centrifuged in wire-mesh cones to remove surface moisture. Many organisms not easily visible, such as nematodes, Naididae and early stages of organisms retained, were undoubtedly lost during sieving; those retained were not counted.

Results are expressed as numbers and wet weights per m^2. Before weighing, caddis fly larvae were removed from their cases. Only living molluscs with their shells were counted and weighed. A weighted standing crop value for the entire study area accounts for the contributions made by each of the depth zones, which were 15% by the

Lakes - invert

Benthic Invertebrates in Lake Ashtabula Reservoir, North Dakota

JOHN J. PETERKA

Department of Zoology, North Dakota State University, Fargo 58102

ABSTRACT: The kinds and amounts of benthic invertebrates in Lake Ashtabula, a 20-year-old eutrophic reservoir in southeastern North Dakota, were recorded at a single station located 3.2 km N of the dam. The average standing crops of benthic invertebrates in the sampling station collected during April, June and August 1967 were 6.4, 8.2 and 7.1 g m^{-2}, respectively, and 1831, 2622 and 1295 individuals m^{-2}. Organisms in the 0-3 m depth zone accounted for 28% by number and 53% by weight of all organisms present in the study area from April to August; 56% by number and 37% by weight were in the 3-8 m depth zone; and 16% by number and 9% by weight were in the 8-12 m depth zone. The quantity and kinds of its benthic invertebrates indicate Lake Ashtabula is eutrophic when compared with data available from other lakes that are also unstratified during open-water periods.

INTRODUCTION

The kinds and amounts of benthic invertebrates in Lake Ashtabula, a 20-year-old eutrophic reservoir in southeastern North Dakota, were recorded as part of a continuing study designed to characterize the reservoir in terms of its water chemistry and primary productivity.

Lake Ashtabula is to receive waters in the late 1970's from the Garrison Diversion Project, which will provide irrigation water from the Garrison Reservoir to eastern and central North Dakota. As these waters pass through North Dakota farmland and highly saline Devils Lake, they are expected to increase in total dissolved solids which could modify environmental conditions in Lake Ashtabula. Because studies of benthic invertebrates have been useful elsewhere in determining effects of various environmental changes occurring in lakes and streams (*e.g.*, Brinkhurst [1969], Carr and Hiltunen [1965] and others on changing kinds and numbers of benthic invertebrates in Lake Erie associated with organic pollution; Cowell and Hudson [1967] on the effects of variations in morphometry and water level fluctuations on benthic invertebrates in reservoirs on the Missouri River; and Mills, Starrett and Bellrose [1966], who reviewed changes in benthic invertebrates in the Illinois River as affected by activities of man), it is hoped that we will be able to assess any changes in the biota caused by receipt of diversion waters from data collected from Lake Ashtabula. Since there have been no detailed studies of benthic invertebrates from North Dakota reservoirs, it is hoped that information presented here will contribute to the limnology of the Upper Great Plains and, on a broader scope, to knowledge of benthic invertebrates in reservoirs which do not stratify during open-water periods and which do not experience large and rapid changes of water levels.

The lake's limnology, primary productivity and zooplankton standing crops were studied by Peterka and Reid (1968) and Peterka and

Knutson (1970). Lake Ashtabula has a surface area at normal pool of 2197.5 ha, a length of 43.5 km, a maximum width of 0.97 km, a mean depth of 4.0 m, a maximum depth slightly over 15 m and drains an area of 10,717.5 km^2 (Peterka and Reid, 1968). The water exchange ratio (volume of water entering the reservoir divided by the volume of the reservoir at normal pool) from March to November 1965, 1966 and 1967 averaged 2.1. Except for periods of a few days when stratification occurred, water temperatures were uniform from top to bottom during ice-free periods. Lake Ashtabula is highly productive with average annual gross primary productivity rates of 4.1 and 6.8 g O_2 m^{-2} day^{-1} for 1967 and 1968, respectively. Heavy blooms of *Aphanizomenon holsaticum* occurred, comprising about 90% of the total algal bloom in numbers and volume during summer and autumn of 1967 and 1968 (Peterka and Knutson, 1970). *Daphnia* comprised 84% of total zooplankton dry weight standing crop in 1967 and 81% in 1968; copepods 14% in 1967 and 17% in 1968. The average dry weight daily standing crop of *Daphnia pulex* was 1110 in 1967 and 2851 mg m^{-2} in 1968; of *Daphnia galeata mendotae*, it was 294 in 1967 and 7.2 mg m^{-2} in 1968.

METHODS

A 15.2-cm-sq Ekman dredge (232 cm^2) was used to sample transects of the reservoir bottom for benthic invertebrates in the spring and summer of 1967. Dredge hauls were taken in three depth zones: the littoral zone (0-3 m), the old river floodplain (3-8 m), and the old river channel (8-12 m).

All sampling was done at a station, which will be referred to as the study area, located 3.2 km (2 miles) N of the dam (Fig. 1). On 26 April 1967, 12 Ekman dredge hauls were made in the 0-3, and six hauls each in the 3-8 and 8-12 m depth zones. From 6-12 June 1967, 60 dredge hauls were made in the 0-3, 64 hauls in the 3-8, and 32 hauls in the 8-12 m depth zones. From 22-30 August 1967, 60 dredge hauls were made in the 0-3, 52 hauls in the 3-8, and 20 hauls in the 8-12 m depth zones. Within each depth zone, sampling was accomplished by anchoring the boat, taking four dredge hauls, and then permitting the boat to drift before taking another series of four hauls. Bottom samples from each four dredge hauls were combined and washed through a sieve with a mesh size of 0.5 mm. Retained organisms were preserved in 5-10% formalin and later counted and weighed to the nearest 0.001 g after being centrifuged in wire-mesh cones to remove surface moisture. Many organisms not easily visible, such as nematodes, Naididae and early stages of organisms retained, were undoubtedly lost during sieving; those retained were not counted.

Results are expressed as numbers and wet weights per m^2. Before weighing, caddis fly larvae were removed from their cases. Only living molluscs with their shells were counted and weighed. A weighted standing crop value for the entire study area accounts for the contributions made by each of the depth zones, which were 15% by the littoral zone, 70% by the old river floodplain and 15% by the old river channel. Standard errors of the weighted mean wet weights of organisms in the study area for July and August were computed after the methods of Snedecor and Cochran (1967) for randomly stratified samples.

Invertebrates located on submergent vegetation were not included in samples taken in the littoral zone. A rough estimate of organisms present in and on rooted vegetation, however, was obtained from seven samples made on 27 June and 14-15 July 1967, using a 0.1 m^2 sampler constructed of a cylindrical net bag 3 m long with a mesh size of 0.4 mm, attached to a heavy cutting rim. This sampler was dropped over the vegetation and forced to the lake bottom. Plants within the bag were then uprooted by hand and the entire contents brought to the surface where the organisms were separated and preserved as described for Ekman dredge samples. Plants were dried to a constant weight at 100 C. The data from the plant samples are treated in a separate section from samples collected with the Ekman dredge.

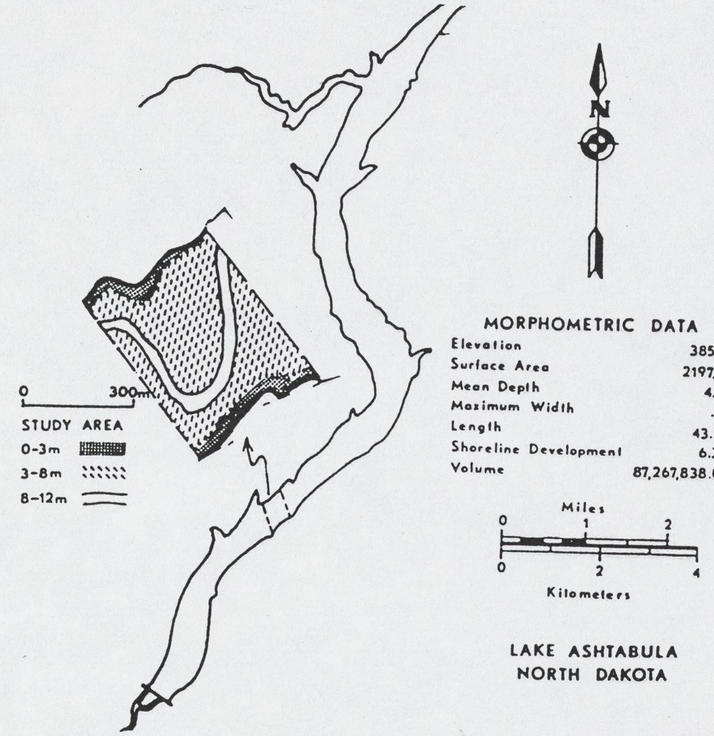


Fig. 1.—Map of Lake Ashtabula, North Dakota, showing the location of the sampling station

RESULTS

Mollusca.—About 46% of the average biomass of all invertebrates collected from the study area from 26 April to 30 August 1967 was comprised of gastropods belonging to the genera *Valvata, Physa, Helisoma* and *Amnicola*. *Amnicola* accounted for about 56% and *Helisoma* and *Valvata* each accounted for 20% of the total biomass of gastropods. Pelecypoda, about 8% of the total average biomass of the study area, were mostly *Pisidium* and a few *Musculium*.

The 0-3 m depth zone contained most of the molluscs (Fig. 2). There were no members of *Musculium, Helisoma* or *Amnicola* collected in the 8-12 m zone and only occasional *Valvata* and *Physa*. In the 3-8 m zone, no *Musculium* were collected, and *Physa* and *Helisoma* never exceeded more than 10 individuals m^{-2}.

The average standing crop of molluscs from April to August 1967 in the study area was 306 individuals weighing 3.93 g m^{-2}. Of these, 212 were gastropods weighing 3.38 g m^{-2}. The maximum biomass of gastropods was reached in August; pelecypods reached their maximum biomass in June (Fig. 3).

Diptera.—About 34% of the total biomass of the study area was comprised of dipterans which included 79% chironomids, 20% ceratopogonids and 1% culicids (mostly *Chaoborus*).

Biomass of dipterans in the 3-8 m depth zone was about three

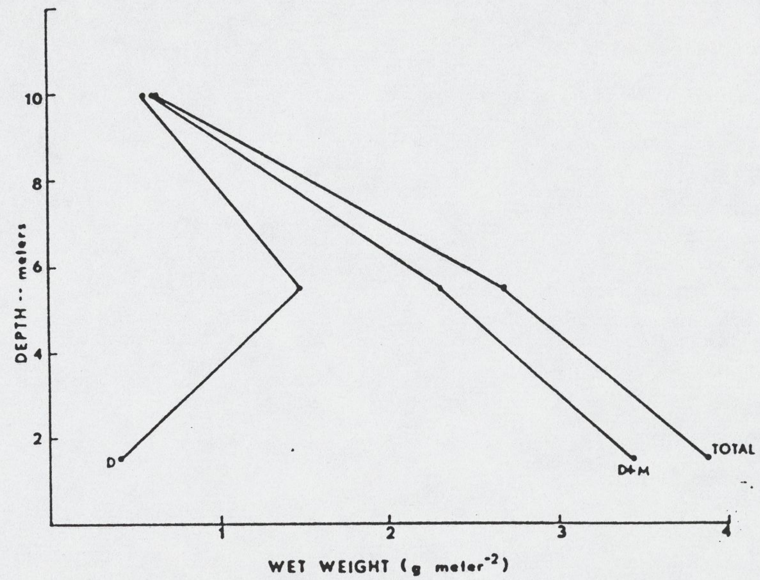


Fig. 2.—Distribution with depth of the mean wet weights of dipterans (D), molluscs (M) and of the total benthic invertebrates from April to August 1967, Lake Ashtabula, North Dakota

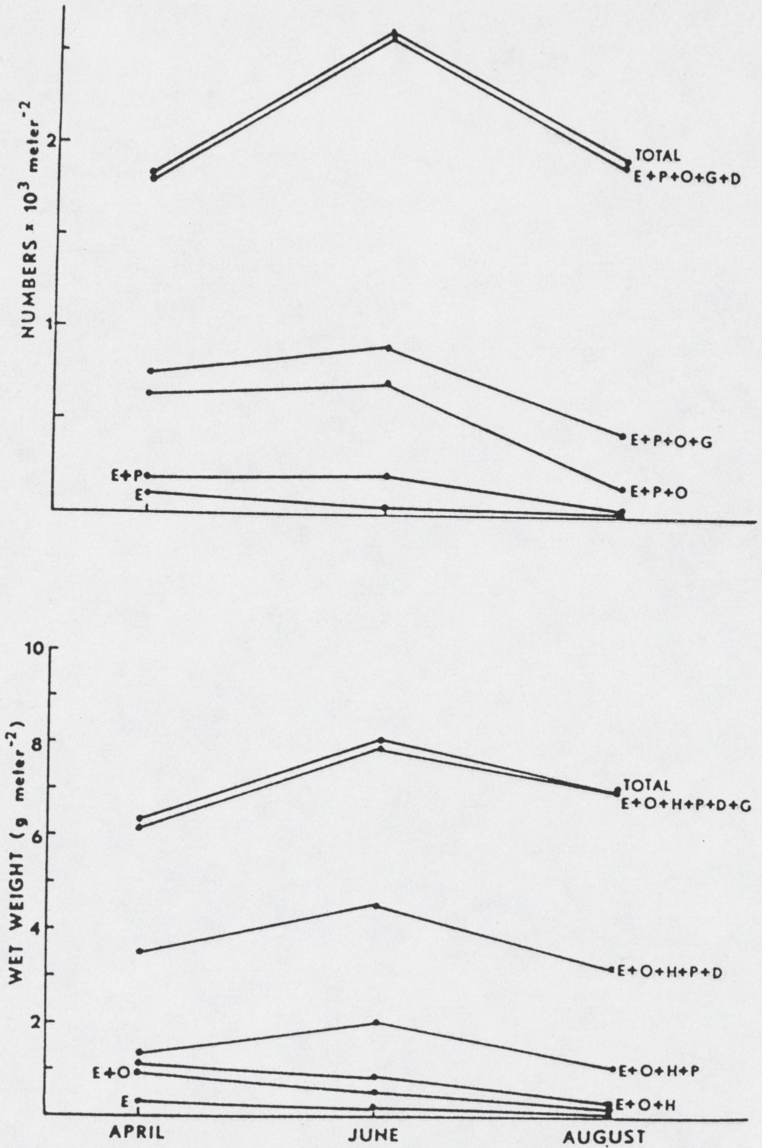


Fig. 3.—Seasonal changes of biomass of ephemeropterans (E), oligochaetes (O), hirudinea (H), pelecypods (P), dipterans (D), gastropods (G) and of the total benthic invertebrates during April, June, August 1967 in Lake Ashtabula. Seasonal changes in numbers of ephemeropterans (E), pelecypods (P), oligochaetes (O), gastropods (G), dipterans (D) and of the total bottom fauna during April, June, August 1967 in Lake Ashtabula, North Dakota

times higher than in the 0-3 m zone and about two times higher than in the 8-12 m zone (Fig. 2). The maximum density of large chironomids, consisting of members of the genus *Cryptochironomus* and the species *Chironomus plumosus,* occurred in August 1967 when there were 103 and 105 individuals weighing 1.58 and 2.94 g m^{-2}, respectively, in the 0-3 and 8-12 m depth zones, and only 27 individuals weighing 0.48 g m^{-2} in the 3-8 m depth zone. Of the small chironomids, the genera *Procladius, Cryptochironomus* and *Tanytarsus* occurred most frequently; *Anatopynia, Einfeldia, Polypedilum* and *Cricotopus* were also present. The maximum density occurred in the 0-3 m depth zone in August 1967 when there were 3592 individuals weighing 3.65 g m^{-2}, in the 3-8 m depth zone in June 1967 when there were 1290 individuals weighing 1.34 g m^{-2}, and in the 8-12 m depth zone in April 1967 when there were 1765 individuals weighing 2.83 g m^{-2}.

The average standing crop of dipterans from April to August 1967 in the study area was 1391 individuals weighing 2.47 g m^{-2}, of which 1093 were chironomids weighing 1.94 g m^{-2}. The biomass of dipterans increased from 2.16 g m^{-2} in April to 2.69 g m^{-2} in August 1967, while numbers were highest in June (Fig. 3). Most of the increase in biomass from April to August was the result of the increase in chironomid standing crop from 1.66 in April to 1.86 and 2.31 g m^{-2}, during June and August 1967.

Annelida.—About 9% of the total biomass of the study area was comprised of annelids of which Hirudinea contributed 40% and oligochaetes (Tubificidae) contributed 60%. The average standing crop of annelids from April to August 1967 in the study area was 358 individuals weighing 0.66 g m^{-2}, of which four were Hirudinea weighing 0.26 g m^{-2}. The biomass of annelids decreased from 0.93 in April, to 0.73 in June, to 0.32 g m^{-2} in August, largely a reflection of an April to August decrease in tubificids (Fig. 3).

Ephemeroptera.—About 2% of the total biomass of the study area was contributed by ephemeropterans, which were mostly found in the 0-3 m depth zone. *Caenis* accounted for 69% of the total biomass of ephemeropterans; the remaining 31% were mostly *Hexagenia.*

The average standing crop of ephemeropterans from April to August 1967 in the study area was 43 individuals weighing 0.14 g m^{-2}, of which 42 were *Caenis* weighing 0.10 g m^{-2} and one was *Hexagenia* weighing 0.04 g m^{-2}.

The standing crop in the study area decreased from 102 individuals weighing 0.23 g m^{-2} in April to 28 individuals weighing 0.17 g m^{-2} in June to one individual weighing 0.02 g m^{-2} in August.

Others.—About 2% of the total biomass of the study area was contributed by trichopterans (mostly *Oecetis*), amphipods (mostly *Hyallela*), haliplids, and zygopterans, all of which occurred largely in the 0-3 m depth zone. Trichopterans accounted for 59%, amphipods 35% and zygopterans and haliplids each 3% of the average biomass of 0.16 g m^{-2} present in the study area from April to August 1967.

Plant and fauna samples.—Most of the submerged macrophytes in the reservoir were *Potamogeton* species. These occurred in a band approximately 10 to 20 m wide throughout the length of the reservoir in water 0.6 to 2.5 m deep. *Potamogeton pectinatus* was the dominant species in the study area with some *P. perfoliatus*. The dry weight of plants collected on 27 June and 14-16 July 1967 was 139 g m^{-2} (range 100-183) near the shore in water 1.2 to 1.5 m deep, 244 g m^{-2} (range 199-286) in the center of the plant band in water 1.5 m deep, and 244 g m^{-2} (range 197-308) near the open-water edge of the plant band in water 2.0 m deep. The corresponding wet weights of invertebrates in the plant samples were 25.4 g m^{-2} (range 21.4-29.5), 40.6 g m^{-2} (range 19.0-62.1) and 30.4 g m^{-2} (range 13.8-47.5). The average standing crop of invertebrates in the plant zone from 27 June to 15 July 1967 of about 32 g m^{-2} was about three times the standing crop of 10 g m^{-2} (range 7.25 to 12.89 g m^{-2}) of two samples of benthic invertebrates collected at a depth of 1.5 m with the Ekman dredge on 15 July.

Gastropods (mostly *Amnicola*) accounted for 88% of the biomass and 64% of the individuals in the plant zone. Ephemeropterans, *Piscidium*, chironomids and Hirudinea each accounted for 2% of the total biomass. Tubificids accounted for 15%, chironomids 12% and *Hyallela* 3% of the total individuals.

DISCUSSION

The standing crop of benthic invertebrates in the study area during April, June and August was 6.4, 8.2 (± 2.5, SE of the mean with 39 samples) and 7.1 (± 8.0, SE of the mean with 33 samples) g m^{-2}, respectively, and 1831, 2622 and 1925 individuals m^{-2} (Table 1). The average standing crop for all organisms for the study area from April to August 1967 was 2126 individuals weighing 7.2 g m^{-2}. Organisms in the 0-3 m depth zone accounted for 28% by number and 53% by weight of all organisms present in the study area from April to August; 56% by number and 37% by weight were in the 3-8 m depth zone; and 16% by number and 9% by weight were in the 8-12 m depth zone.

The quantity and kinds of benthic invertebrates in Lake Ashtabula indicate that it is eutrophic when compared with data available from other lakes that are also unstratified during open-water periods. The standing crop of benthic invertebrates reached 7 g m^{-2} in reservoirs of the Missouri River (Cowell and Hudson, 1967) which is lower than the maximum of 8.2 g m^{-2} recorded for the study area in Lake Ashtabula. The maximum standing crop recorded from Lake Ashtabula was in June at a depth of 2 m when there were 8202 individuals m^{-2} weighing 27.5 g m^{-2}. Webb (1965), using a wire screen having openings of 0.59 mm, reported the mean wet weight of benthic invertebrates in Cedar Lake, Saskatchewan, a natural lake, was 17.6 g m^{-2} from June to August 1962, which is high when compared with an average of 7.6 g m^{-2} during June and August 1967 in Lake Ashtabula. Cedar Lake, reported by Webb to be eutrophic, received large amounts of suspended materials from several large rivers which enter it.

The average per cent composition weighted by contributions made

by each depth zone during June to August 1967 of chironomids, gastropods, oligochaetes, ephemeropterans and fingernail clams (Sphaeriidae) for the study area in Lake Ashtabula was 51, 10, 17, 2 and 4%, respectively, and, except for ephemeropterans, was similar to the average per cent composition of 40, 15, 14, 13 and 4%, respectively, for collections made in the S basin of Lake Winnipeg during March 1962 to September 1969 (Crowe, 1970). Mean benthic standing crop during June, July and August 1967 was 7.2 g m^{-2} in Lake Ashtabula and was 6.6 g m^{-2} in Lake Winnipeg (Crowe, 1970). The kinds and amounts of benthic invertebrates were very similar in the two lakes. Crowe (1970) reports data collected from 1962 to 1969 represent an increase in standing crop, from 4.4 to 6.6 g m^{-2}, and a decrease in per cent composition of ephemeropterans, from 40 to 13%, and an increase in chironomids, from 6 to 40%, when compared with data collected from Lake Winnipeg in 1930. She also reported that amphipods contributed from 44 to 83% of the numbers of benthic invertebrates in 1930 and, apparently, less than 4% in 1962-1969. Crowe attributes pollution as a major factor reducing amphipod and mayfly populations in the S basin of Lake Winnipeg.

According to Carr and Hiltunen (1965), increases in numbers from 1930 to 1961 of oligochaetes, chironomids, gastropods and sphaeriids and decreases in *Hexagenia* in the open lake area of western Lake Erie were indicative of increases in the enrichment of bottom sediments. Damach (1969) and Brinkhurst (1969) have also attributed the

TABLE 1.—Standing crops of all benthic invertebrates in numbers and wet weight, in g m^{-2}, collected at 0-3, 3-8 and 8-12 m depth zones during April, June and August 1967, Lake Ashtabula, North Dakota. Numbers in parentheses are adjusted to the per cent of lake bottom of the study area occupied by each depth zone

Depth zone (m)	April	June	August	Total
		Numbers		
0- 3	2686	3305	6117	12.108
	(403)	(496)	(918)	(1816)
3- 8	1184	2674	1244	5102
	(829)	(1872)	(871)	(3571)
8-12	3993	1698	915	6606
	(599)	(255)	(137)	(991)
Total	7863	7677	8276	23.816
	(1831)	(2622)	(1925)	(6378)
		Weight		
0- 3	23.7	23.6	29.7	77.0
	(3.6)	(3.5)	(4.5)	(11.6)
3- 8	2.7	5.9	2.8	11.4
	(1.9)	(4.2)	(1.9)	(8.0)
8-12	6.2	3.1	4.2	13.5
	(0.9)	(0.5)	(0.6)	(2.0)
Total	32.6	32.6	36.7	101.9
	(6.4)	(8.2)	(7.1)	(21.6)

decline of *Hexagenia* in western Lake Erie to increases in organic matter there. The average number of oligochaetes in the open lake area of western Lake Erie collected from depths ranging from 8-10 m during 31 May to 16 June 1961, as computed from Table 2 of Carr and Hiltunen (1965), was 1133 individuals m^{-2}; for sphaeriids was 891; for chironomids, 337; for gastropods, 261, and for *Hexagenia,* 1.2. The average number of oligochaetes from depths of 3 to 8 m during June 1967 in Lake Ashtabula was 633 individuals m^{-2}; for sphaeriids was 108; for chironomids was 1306; for gastropods was 78 and for *Hexagenia* was 2.7. Chironomids in Lake Ashtabula were the only group that greatly exceeded the numbers in western Lake Erie; *Hexagenia* apparently was more abundant in Lake Ashtabula than in western Lake Erie but was still low in comparison to 394 *Hexagenia* m^{-2} reported in western Lake Erie in 1930.

Apparently, numbers of oligochaetes relative to chironomids increase in lakes as organic enrichment increases, since the organic matter supports the bacteria which are fed upon by the tubificids (oligochaetes) (Brinkhurst, 1969). Judging from the relative numbers of chironomids to oligochaetes in its benthic fauna, Lake Ashtabula is not as organically polluted as western Lake Erie, since chironomids in Lake Ashtabula comprised 56% and oligochaetes 22% of the total number of organisms in the profundal zone whereas chironomids in Lake Erie in 1958 comprised 27% and oligochaetes 60%, a radical shift from 1929-1930 when chironomids comprised 10% and oligochaetes 1% of the total number of organisms in the profundal zone of western Lake Erie (Beeton, 1961).

Lake Ashtabula differs radically in relative numbers of chironomids and oligochaetes from Lake Francis Case, a reservoir on the Missouri River, South Dakota, where chironomids comprised 93% and oligochaetes 6% of the total number of organisms in the profundal zone in 1966 (Cowell and Hudson, 1967). Perhaps some of the explanation for these differences in the two reservoirs lies in the difference in water exchange rates during open-water periods of 4 months for Lake Ashtabula and 3 months for Lake Francis Case (Cowell and Hudson, 1967). The high primary production of phytoplankton coupled with slow exchange rates may permit more accumulation of organic matter in Lake Ashtabula, which may offer better food resources for oligochaetes than Lake Francis Case.

Tanytarsus from various dates collected from Lake Ashtabula comprised 2, 8, 14 and 20% of the total number of chironomids at depths of 9, 5, 4 and 2 m, respectively, and was not present below 10 m. Apparently oxygen was a limiting factor below 10 m, due to high oxygen demand of the reservoir bottom when lake stratification occurred for only an occasional few days during open-water periods and when, during winter, stratification created a rapid oxygen depletion near the bottom. *Tanytarsus* has been reported as characteristic of the profundal waters of more oligotrophic lakes (Brundin, 1958) and was also found in the northern and eastern sections of Lake Erie, where more oligotrophic conditions were present than in its eutrophic western section (Brinkhurst, 1969). The higher occurrence of *Tanytarsus* in shallow depths in Lake Ashtabula may be associated with the continual presence of oxygen in the upper layers of water. *Tanytarsus* may be a good indicator of changing conditions in the reservoir related to organic accumulations and associated oxygen depletion. Chironomids belonging to the genera, *Chironomus,* especially *C. plumosus, Procladius,* and *Cryptochironomus,* in relatively high abundance in Lake Ashtabula, have been listed as tolerant genera to eutrophic conditions in the St. Lawrence Great Lakes (Brinkhurst *et al.,* 1968) and were considered to be good indicators of eutrophic conditions in Lake Ashtabula.

Acknowledgments.—I am grateful to Dr. Keith M. Knutson and Dale Kinzler for assisting in collecting and analyzing the data and to numerous undergraduate students for their help in sorting samples. This work was supported in part by the North Dakota Water Resources Research Institute, with funds provided by the United States Department of the Interior, Office of Water Resources Research, as authorized under the Water Resources Research Act of 1964, Public Law 88-379.

REFERENCES

BEETON, A. M. 1961. Environmental changes in Lake Erie. *Trans. Amer. Fish. Soc.,* **90**:153-159.

BRINKHURST, R. O. 1969. Changes in the benthos of Lakes Erie and Ontario. *In:* Proceedings of the Conference on Changes in the Biota of Lakes Erie and Ontario. *Bull. Buffalo Soc. Natur. Sci.,* **25**:45-71.

———, A. L. HAMILTON AND H. B. HERRINGTON. 1968. Components of the bottom fauna of the St. Lawrence, Great Lakes. Great Lakes Institute. No. PR33. 49 p.

BRUNDIN, L. 1958. The bottom faunistical lake type system and its application to the southern hemisphere. Moreover a theory of glacial erosion as a factor of productivity in lakes and oceans. *Int. Ver. Theor. Angew. Limnol. Verh.,* **13**:288-297.

CARR, J. F. AND J. K. HILTUNEN. 1965. Changes in the bottom fauna of western Lake Erie from 1930 to 1961. *Limnol. Oceanogr.,* **10**:551-569.

COWELL, B. C. AND P. L. HUDSON. 1967. Some environmental factors influencing benthic invertebrates in two Missouri River reservoirs, p. 541-555. *In:* Reservoir Fishery Resources Symposium. Southern Division, Amer. Fish. Soc., Univ. Georgia.

CROWE, J. M. E. 1970. The south basin of Lake Winnipeg—an assessment of pollution. Abstract of paper presented at the 32nd Midwest Fish and Wildlife Conference, Winnipeg. 29-30 p.

DAMACH, C. A. 1969. Changes in the biology of the lower Great Lakes. *In:* Proceedings of the Conference on Changes in the Biota of Lakes Erie and Ontario. *Bull. Buffalo Soc. Natur. Sci.,* **25**:1-17.

MILLS, H. B., W. C. STARRETT AND F. C. BELLROSE. 1966. Man's effect on the fish and wildlife of the Illinois River. *Ill. Natur. Hist. Surv. Biol. Notes No. 57.* 24 p.

Peterka, J. J. and K. M. Knutson. 1970. Productivity of phytoplankton and quantities of zooplankton and bottom fauna in relation to water quality of Lake Ashtabula Reservoir, North Dakota. Research Project Technical Completion Report. North Dakota Water Resources Research Institute, Fargo, N. D. 79 p.

——— and L. A. Reid. 1968. Primary production and chemical and physical characteristics of Lake Ashtabula Reservoir, North Dakota. *Proc. N. Dak. Acad. Sci.*, **22**:136-156.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical methods. Iowa State University Press, Ames. 593 p.

Webb, D. W. 1965. Limnological features of Cedar Lake, Manitoba. *Fish. Res. Board Can. J.*, **22**:1123-1136.

Submitted 8 October 1971 Accepted 13 December 1971

Reproductive Ecology of a West Texas Population of the Greater Earless Lizard, Cophosaurus texanus

ROYCE E. BALLINGER and EARL D. TYLER
Department of Biology, Angelo State University, San Angelo, Texas 76901
and
DONALD W. TINKLE
Museum of Zoology, University of Michigan, Ann Arbor 48104

Abstract: The reproductive cycle of *Cophosaurus texanus*, in the vicinity of San Angelo, Texas, was determined from examination of 220 females and 105 males. Reproduction begins in early April and ceases by mid-August. Females mature in a single year at approximately 50 mm snout-to-vent length. Older females begin reproduction earlier and lay a larger first clutch and produce larger eggs than females just maturing. The smaller eggs of the first clutch of younger females are attributed to the lack of adequate fat storage. Approximately three clutches of six eggs each are laid by each female during 1 reproductive season.

Introduction

Seasonal variation in the reproductive cycle of lizards has been described for relatively few species. The objective of the present paper is to provide such information on the greater earless lizard, *Cophosaurus texanus*, as well as to verify several unusual characteristics attributed to this species in a previous study (Johnson, 1960).

C. texanus is distributed throughout the Chihuahuan Desert and adjacent ecotonal areas E to central Texas and W to eastern Arizona (Smith, 1946), where it prefers rocky habitats (Jameson and Flury, 1949; Peters, 1951). The present distribution is presumably either more restricted or more southern than in the recent geologic past, as Etheridge (1958) allocated fossil material from the Pleistocene of Kansas to *C. texanus*. We follow the recognition of *Cophosaurus* as a genus distinct from *Holbrookia* as suggested by Axtell (1958), Earle (1961) and Clarke (1965), but recognize its close affinities to other "sand lizard" genera as noted by Etheridge (1964).

Studies on the ecology of *C. texanus* have been few. Degenhardt (1966) included *C. texanus* in his studies of density and movement of lizards. Smith (1946) estimated a clutch size of 8 to 12. Cagle (1950) reported that several egg clutches are laid by a female each season and suggested that *C. texanus* matured in 1 year in central Texas. Johnson (1960) described in more detail the reproductive cycle of *C. texanus* in N-central Texas (Tarrant Co.). Excluding geographic locality data and habitat notes, little additional information is available on the ecology of this species.

Materials and Methods

Samples of 10-15 females and 5-10 males were collected each week from mid-March to mid-August 1969 whenever possible. A total of 220 females (Table 1) and 105 males were collected in a 5-mile