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Life history, ecology, and low pH tolerance of the freshwater prawn, Palaemonetes kadiakensis Rathbun, in a mitigated wetland of the Green Bottom Wildlife Management Area, West Virginia

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Life History, Ecology, and Low pH Tolerance of the Freshwater Prawn, *Palaemonetes kadiakensis* Rathbun, in a Mitigated Wetland of the Green Bottom Wildlife Management Area, West Virginia

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ABSTRACT

An ecological life history study of the freshwater prawn *Palaemonetes kadiakensis* was conducted at the mitigated wetland of the Green Bottom Wildlife Management Area (GBWMA). Monthly samples were collected from November 1996 through November 1997. In addition, weekly samples were collected from May through November for growth and reproductive analysis. Monthly samples yielded 520 prawns. *Palaemonetes kadiakensis* had a one-year life cycle, with all adults dying by September. Males averaged 23.82 mm (range = 14.15 to 36.75 mm) and females averaged 26.78mm (range = 15.06 to 38.60 mm) in length. Males averaged 0.087g (range = 0.014to 0.293 g) and females averaged 0.140 g (range = 0.014 to 0.417 g) in weight. There was a significant correlation (r = 0.915) between average body length and weight. For the monthly collections, largest percent growth occurred between August and September (32.59 %), with 21.7^{0}C as the average temperature. For weekly collections, the largest percent growth occurred between 31 July and 7 August (39.83 %), with 26.5 as the average temperature. There was no significant difference in sex ratio (p = 0.448). Ovigerous females were present from 30 April to12 August, carrying an average of 69 eggs. There was a low correlation (r = 0.423) between fecundity and length of female. Plant detritus was the main food item for all four seasons, ranging from 82.2 to 97.9 percent, winter and spring, respectively. The median tolerance limit (TL_m) for low pH was determined to be 5.03 by linear regression, and 4.60 by straight line graphical interpolation method. A laboratory test at theoretical pH value of 5.03 produced a 95 percent survival rate.

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CHAPTER 1

INTRODUCTION

Palaemonetes kadiakensis is a North American freshwater shrimp also known as a prawn. It is one of three members of the genus *Palaemonetes* found in epigean freshwaters of the United States (Strength, 1976). The North American species of *Palaemonetes* represent what are probably the most poorly known of our freshwater decapods, in part due to their limited commercial value, overall morphological similarity, lack of extensive field work, and a poor understanding of taxonomic characters (Strength, 1974). However, prawns are of great indirect value because they are an important link in the food chain supporting commercial and game fishes (Meehean, 1936).

A disjunct population of *P. kadiakensis* was found in the mitigated wetland of Green Bottom Wildlife Management Area (GBWMA), Cabell County, West Virginia. To date, no previous ecological studies on this prawn have been reported in West Virginia. This prawn was first introduced in West Virginia in 1977 at Edwards Run Public Hunting and Fishing Area, having been shipped from Missouri (Dayfield, 1981). Prawns were selected for stocking because they: (1) contribute significantly to bluegill growth, (2) facilitate a more efficient energy transfer from producer to consumer by shortening the food chain, (3) can tolerate a variety of water quality conditions, (4) are easily established in ponds containing suitable habitat, (5) tolerate high levels of predation, and (6) have not been reported as a vector of fish disease or parasites (Dayfield, 1981).

In 1978 more prawns were stocked at McClintic Wildlife Station ponds and Warden Lake (Dayfield, 1981). It is speculated that prawns from McClintic ponds were introduced to GBWMA by flooding of McClintic ponds into the Ohio River, and then the

Ohio River flooding into GBWMA; therefore, it is not likely that this is a natural range extension of this species.

The objectives of this study were to determine: (1) population density, growth rate and life cycle, (2) sex ratio, (3) breeding season and fecundity of reproductive females and correlate fecundity with prawn length, (4) seasonal trends in diet, and (5) low pH tolerance of *Palaemonetes kadiakensis*.

CHAPTER II

REVIEW OF THE LITERATURE

Most species comprising the order Decapoda are marine. In the United States, only the Astacidae, Cambaridae (crayfishes), about 12 species of Palaemonidae (freshwater prawns and river shrimps), and four species of Atyidae are found in fresh waters (Pennak, 1989). Eleven species of *Palaemonetes* are known from America, only two of which are western species (Holthius, 1952). Five species of the caridian shrimp genus of *Palaemonetes* inhabit surface waters of eastern North America: *P. vulgaris, P. intermedius,* and *P. pugio* are marine or brackish water forms, while *P. paludosus* and *P. kadiakensis* are freshwater species (Hubschman, 1975).

Rathbun (1902) was the first to describe *Palaemonetes kadiakensis* specimens collected from the coast of Alaska southward to San Diego, California. The species was morphologically described, with the length of the only female collected found to be 39mm. The type locality is Kodiak Island, Alaska.

The decapod crustaceans of Wisconsin were described by Creaser (1932). Holthius (1949) described species of *Palaemonetes* in the United States, stating that *P. paludosus* found east of the Alleghenies is identical to *P. kadiakensis* found west of the Alleghenies. He also questioned the probability of the species originating in Alaska, and believed the prawns were incorrectly labelled. Holthius (1952) made a general revision of the Palaemonidae of the Americas. Hobbs and Hart (1959) published an illustrated key, ecological data, and ranges for freshwater decapod crustaceans of the Apalachicola Drainage System in Florida, southern Alabama, and Georgia.

Broad and Hubschman (1963) studied the larval development of *P. kadiakensis*. Upon hatching, prawns passed through six larval forms, and the complete larval phase lasted about three weeks. Dobkin (1963) found that *P. paludosus* passed through three larval stages. Hubschman and Rose (1969) studied post embryonic growth of *P. kadiakensis* in the laboratory. They found that the duration of larval life was 16 to 24 days, and also generated growth data for each larval stage. Hubschman (1975) studied the larval development of *P. kadiakensis* under osmotic stress, testing larvae survival in various salinities. Fleming (1969) found that the second pleopod of male prawns may be used in taxonomic evaluation of epigean species of *Palaemonetes.*

Nielsen (1974) did an extensive life history study on *P. kadiakensis* in central Missouri, and documented its potential use as fish forage. Prawn reproduction was found to occur in the spring, with juveniles occurring from June through August. Eggs per female ranged from 20-76, and was a linear function of total length. The potential of females to produce multiple broods during the same season was also mentioned. Length and weight data were also recorded. Rapid growth was found to coincide with the approach of the breeding season. Prawn populations in experimental ponds without bluegill were approximately four times more dense than prawn populations in ponds with bluegill, supporting the premise that bluegill preyed extensively on shrimp populations. Growth of bluegill in ponds containing shrimp was significantly greater than growth of bluegill in ponds not containing prawns.

Strength (1974) reported an extensive study on the systematics and zoogeography of freshwater species of *Palaemonetes.* Three new species from Texas and Mexico were also described. A key to the known North American species was included in the

publication . Larval studies indicated North American freshwater shrimp are of monophyletic origin separate from marine species. Laboratory studies of *P. kadiakensis* indicated the inability of this species to disperse across wide oceanic stretches. Beck and Cowell (1976) published a paper on habitat, seasonal abundance, age and growth, reproduction and feeding of *P. paludosus*, and compared the data with that of other *Palaemonetes* species.

Nielsen and Reynolds (1977) documented population characters of *P. kadiakensis* in Missouri. This study encompassed reproduction, fecundity, growth, density, life cycle, and predation. Hobbs and Jass (1988) studied the crayfishes and shrimp of Wisconsin. Identification, ecology, and life history were discussed in the publication.

Several studies on prawn parasites have been published. Font and Corkum (1975, 1976) studied trematodes from the genus *Alloglossidium* from the antennary glands of *P. kadiakensis* in Louisiana. Felgenhauer and Ridgeway (1977) examined the peritrich ciliate *Lagenophrys sp.* on *P. kadiakensis* in Illinois. Felgenhauer (1982) described a new species of *Lagenophrys* from *P. kadiakensis*. Felgenhauer and Schram (1978) studied differential epibiont fouling in relation to the grooming behavior in *P. kadiakensis*. Grooming was found to be a functional adaptation to selective pressures which brought about development of elaborate morphological and behavioral changes. Since this prawn inhabits shallow areas where peritrichous ciliates cohabit, it was concluded that selective pressures brought about elaborate grooming behavior by the prawns.

Nelson and Hooper (1982) examined the thermal tolerance of *P. kadiakensis*. Prawns tested to determine the upper temperature survival limits manifested five distinct responses to thermal stress: initial disorientation, complete disorientation, onset of tail

fold, end of tail fold and total loss of movement. The upper temperature survival limit ranged from 37 to 40^{0}C. Prawns tested in a horizontal gradient stayed in water with temperatures that ranged from 28 to 32^{0}C.

Distler and Bleam (1988) collected *P. kadiakensis* from Kansas. An ovigerous female was collected carrying 18 eggs, of which 11 young were successfully reared in the laboratory. Cheper (1988) studied this prawn in Oklahoma. He determined size range, sex ratio, and mean size for all specimens collected. Cheper (1992) published a paper comparing the above criteria from data in 1982 to data collected in 1987.

CHAPTER III

TAXONOMY AND DISTRIBUTION

Taxonomy and Morphology

Kingdom- Animalia

Subkingdom- Eumetazoa

Phylum- Arthropoda

Class- Crustacea

Order- Decapoda

Family- Palaemonidae

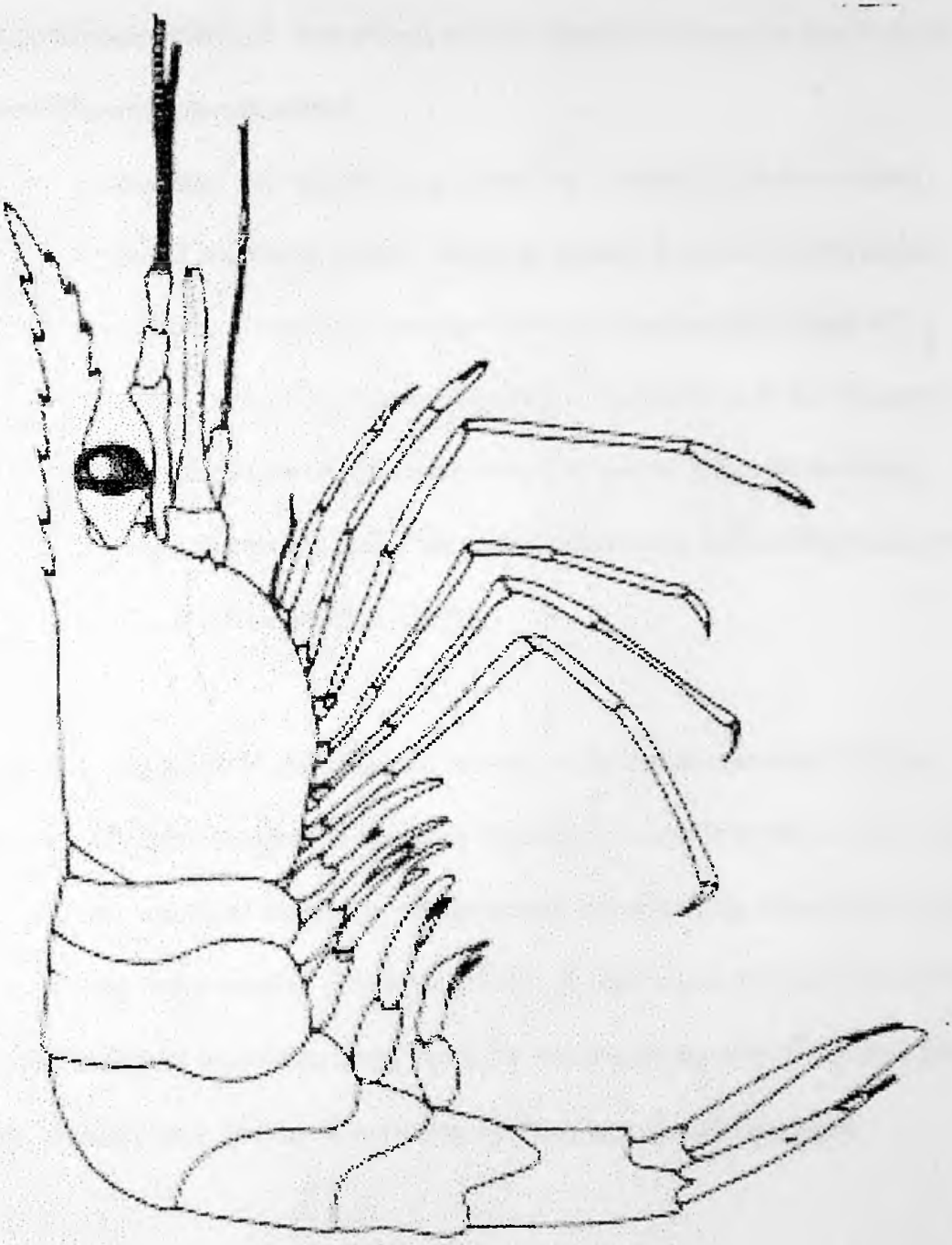
Genus- *Palaemonetes*

Species- *kadiakensis*

This prawn was originally described by Rathbun in 1902 as *Palaemonetes kadiakensis.* Although the type specimen is labeled from Kodiak Island, Alaska, Holthius (1952) considered the correctness of that highly improbable (Nielsen, 1974). This prawn then went through a series of name changes over the years: *Palaemonetes exilipes* (Creaser, 1931, 1932; Creaser and Ortenburger, 1933), *Palaemonetes (Palaemonetes) kadiakensis* (Holthius, 1952), and finally back to *Palaemonetes kadiakensis* (Phillips, 1980).

The family Palaemonidae is separated from the other decapods by the following characteristics: first two pairs of legs chelate; cephalothorax and abdomen laterally compressed (Fig. 1); second chelae larger than first, and without terminal hair tufts (Pennak, 1989). The rostrum is well developed, and provided with teeth, while the

Figure 1. *Palaemonetes kadiakensis*



carapace is smooth (Holthius, 1952). The antennal and branchiostegal spines are well developed and a branchiostegal groove is present.

Individuals of this species are translucent to pale yellow in color (Fig. 2). According to Pennak (1989), *P. kadiakensis* may be separated from other species in the genus by the following characteristics:

> Second legs only slightly longer then first. Usually 25 to 45 mm long. Eyes and coloration normal. Epigean species. Rostrum slightly curved downward. Branchiostegal spine removed from anterior margin of carapace, below branchiostegal groove. Posterior pair of dorsal spine of telson placed close to posterior margin of telson. Up to 50 mm long. Sporadic in central third of the United States west of the Alleghenies, and from Canada to the Gulf (Fig.3).

Habitat

This prawn is found in sluggish lotic or lentic environments (Hobbs and Jass, 1988). Prawns are found among the emergent vegetation, on the branches of trees which have fallen into the water, or clinging to the duckweed which entirely covers the surface of some ponds during warm weather (Meehean, 1936). In high water, they are abundant in the inundated terrestrial vegetation along the shore, and especially among the high grass and bushes. Prawns may also be taken among the floating vegetation in lakes.

Figure 2. Photograph of *Palaemonetes kadiakensis*

Figure 3. North American distribution of *Palaemonetes kadiakensis*

CHAPTER IV

DESCRIPTION OF STUDY AREA

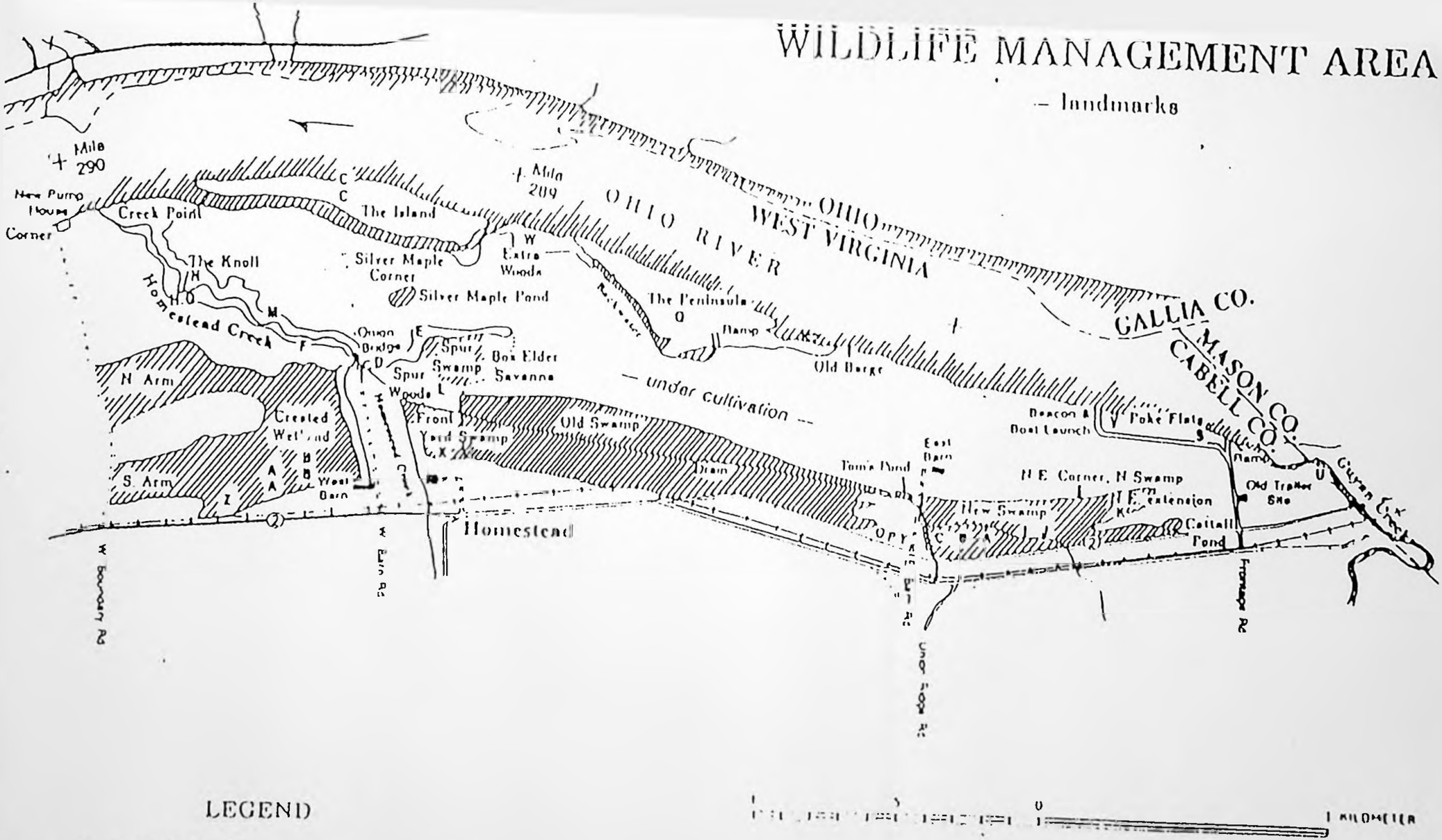
Green Bottom Wildlife Management Area (GBWMA) is a joint effort between the United States Fish and Wildlife Service (USFWS), the United States Army Corp of Engineers (UACOE), and the West Virginia Division of Natural Resources (WVDNR). The GBWMA is located sixteen miles north of Huntington, West Virginia, lying mostly between State Route 2 and the Ohio River in Cabell and Mason counties (Figs. 4,5) (WVDNR, 1991). The GBWMA contains 836 acres in the following classifications: forestlands, 162 acres; wetlands, 140 acres; agricultural land, 518 acres; and open water, 16 acres. It contains four wetland types: seasonally flooded basins or flats, inland open fresh water, shrub-swamp, and wooded swamp; however, a mitigation project has added at least 100 new acres of swamp to replace wetlands destroyed by the implementation of Gallipolis Locks and Dams. GBWMA is managed by the WVDNR as a state hunting and fishing area, and has been an important research, teaching, and recreation resource (Evans and Allen, 1995)

Winter months are cold ($\bar{x} = 12.8^0$C) and have a moderate amount of snowfall ($\bar{x}$ = 66cm/year), while summer months are fairly warm ($\bar{x} = 22.8^0$C) with 55 percent of the average precipitation falling in April through September (Evans and Allen, 1995). The rocks of most of this region are late Pennsylvanian or early Permian systems, dating back to the first coal age when expansive "coal swamps" existed along the eastern and southern edges of the North American inland sea (Evans and Allen, 1995).

Figure 4. Map of Green Bottom Wildlife Management Ares, Cabell Countty, West Virginia (Stark, 1993)

WILDLIFE MANAGEMENT AREA

— landmarks



LEGEND

Shaded areas are inundated.
Capital letters (A) are approximate transect locations.

Landmarks and Transects refer to:

Stark, T. J. 1993. Flora and Vegetation of Green Bottom Wildlife Management Area, W.Va., unpublished master's thesis, Marshall University, Huntington, W Va

Figure 5. Green Bottom Wildlife Management Area mitigated wetland

GBWMA is subject to seasonal flooding. Riverside mudflats and sandbars still experience seasonal inundation within these navigation pools; however, most of the site lies above allowed pool fluctuations (Evans and Allen, 1995). Runoff by terrestrial impacts and drainage controls, such as beaver dams and human construction, influence these latter regions. Soils associated with GBWMA drain poorly, allowing for swamp, and numerous ponds and vernal pools.

GBWMA contains a variety of vegetation and wildlife. Due to beaver activity and levee construction that increases wetland area, the atypical appearance of woody trees such as *Acer negundo, A. saccharinum*, and *A. saccharum* has occurred (Evans and Allen, 1995). Buttonbush (*Cephalanthus occidentalis*) dominates deepest and wettest areas, while *Lemna minor, Spirodela polyrhiza*, and *Wolffia sp.* cover the majority of the surface water. *Carex* species thrive in and around the swamp, while *Hibiscus moscheutos* (marsh mallow) encloses the swamp.

GBWMA provides a wonderful habitat for amphibians, birds, reptiles, aquatic insects, and fish (Evans and Allen, 1995). Some common amphibians found are: Jefferson salamander (*Ambystoma jeffersonianum*), spotted salamander (*Ambystoma maculatum*), red-spotted newt (*Notophthalmus v. viridescens*), wood frog (*Rana sylvatica*), pickerel frog (*Rana palustris*), leopard frog (*Rana pipiens*), bullfrog (*Rana catesbeiana*), and spring peeper (*Pseudacris crucifer*). Many aquatic insects such as mayflies, dragonflies, damselflies, water boatmen and hymenopterons are common among the sedges and rushes. Common fish include: bowfin (*Amia calva*), bluegill (*Lepomis machrochirus*), largemouth bass (*Micropterus salmoides*), green sunfish (*Lepomis cyanellus*), black and white crappie

(*Pomoxis nigromaculatus* and *P. annularis*), central mudminnow (*Umbra limi*), carp (*Cyprinus carpio*) and black and yellow bullhead (*Ictalurus melas and I. natalis*).

CHAPTER V

MATERIALS AND METHODS

Field Studies

Sampling

Palaemonetes kadiakensis specimens were collected monthly from November 1996 through November 1997 from one site in the mitigated area of Green Bottom Swamp. Quantitative collections were made using a modified Gerking sampler (19"x19"x31") (Gerking, 1957) and a standard D-shaped dredge. The dredge was placed into the sampler and pushed along the sides and throughout the middle of the sampler through the substrate and vegetation (Fig. 6). Upon capture, prawns were placed on ice to lower their body temperature and thus prevent regurgitation. They were then transferred into 70 percent ethanol for preservation and transported to the laboratory for analysis. Prawns were also collected weekly from May to November for growth and reproductive analysis. They were collected using a D-shaped dredge, and were placed in 70 percent ethanol and transported to the laboratory for analysis.

Water Quality and Temperature

On each monthly collection date, temperature (°C) was recorded from a maximum-minimum thermometer. Using a Hach chemical kit (Model AL-36-WR), the following water quality parameters were measured: dissolved oxygen (mg/L), alkalinity (mg/L $CaCO_3$), CO_2 (mg/L), total hardness (mg/L $CaCO_3$), total acidity (mg/L) and pH. All data were collected from the same location on each collecting date.

Figure 6. Modified Gerking (Gerking, 1957) sampler and D-shaped dredge

Laboratory Studies

Growth

The blotted wet weight (0.001g) of prawns from monthly collections was recorded using an analytical balance and total length (0.01mm) was measured using a Vernier caliper. Length measurements were made from the tip of the rostrum to the tip of the telson. A correlation coefficient (r) was used to test the strength of the relationship between length and weight by performing linear regression analysis using the SigmaStat program. Size measurements were categorized into one millimeter size classes and data were compiled into length frequency histograms to determine the life cycle. Weekly and monthly growth rates were also calculated.

Sex Determination and Reproduction

Egg counts were performed on 30 ovigerous prawns. Eggs were removed from the pleopods and counted. A correlation coefficient (r) was used to test the strength of the relationship between the number of eggs versus female length by performing linear regression analysis using the SigmaStat program. All prawns from the monthly samples were sexed by determining the presence of an appendix masculina on the second pleopod (male) or its absence (female). A chi-square test was used to determine variation in sex ratio (0.05 confidence level).

Gut Analysis

Thirteen prawns were taken from each season (spring = April, summer = July, fall = October, winter = January) for gut analysis. Microdissection scissors were used to remove the stomach from the rest of the body, which was then placed in a watchglass

containing water. The stomach lining was cut to empty the contents, which were then transferred by pipette to a vial containing formalin for preservation. Contents of stomachs were placed in the same vial. This process was followed for all four seasons. To quantify the samples, three drops of iodine were added to three mL of the stomach mixture. One mL of the homogenate was then transferred to a Sedgewick-Rafter cell by a pipette and examined under a compound microscope containing a Whipple Grid in the eye piece. Ten grids were chosen at random for each mL sample, and three mL were examined for each season, for 30 grids per season. Food items were then divided into the following categories: plant detritus, filamentous algae, diatoms, animal detritus and mineral. Seasonal trends were determined by comparing each food item for each season.

Low pH Tolerance

To determine the low pH tolerance of *Palaemonetes kadiakensis*, an acute static bioassay was performed. One-hundred prawns were collected from the mitigated area of Green Bottom Swamp using a standard D-shaped dredge. They were transported to the laboratory and acclimated for 24 hours in an environmental chamber maintained at 10°C with a 12 hour light and 12 hour dark photoperiod. Ten prawns were placed in each bowl, with two bowls having the same pH (1.5, 3.0, 4.5, 6.0, and control of 7.0). The pH value was adjusted approximately every 3-4 hours from 8:00am to 11:00pm using sulfuric acid (12N). Mortalities were removed every 24 hours, and the experiment was terminated after 96 hours. Linear regression analysis was performed by SigmaStat to determine the median tolerance limit (TL_m) and test the strength of the relationship between pH and percent survivorship. The TL_m was also calculated by the straight line graphical

interpolation method. Twenty more prawns were then collected for theoretical TL_m and the experiment was repeated.

CHAPTER VI

RESULTS AND DISCUSSION

Field Studies

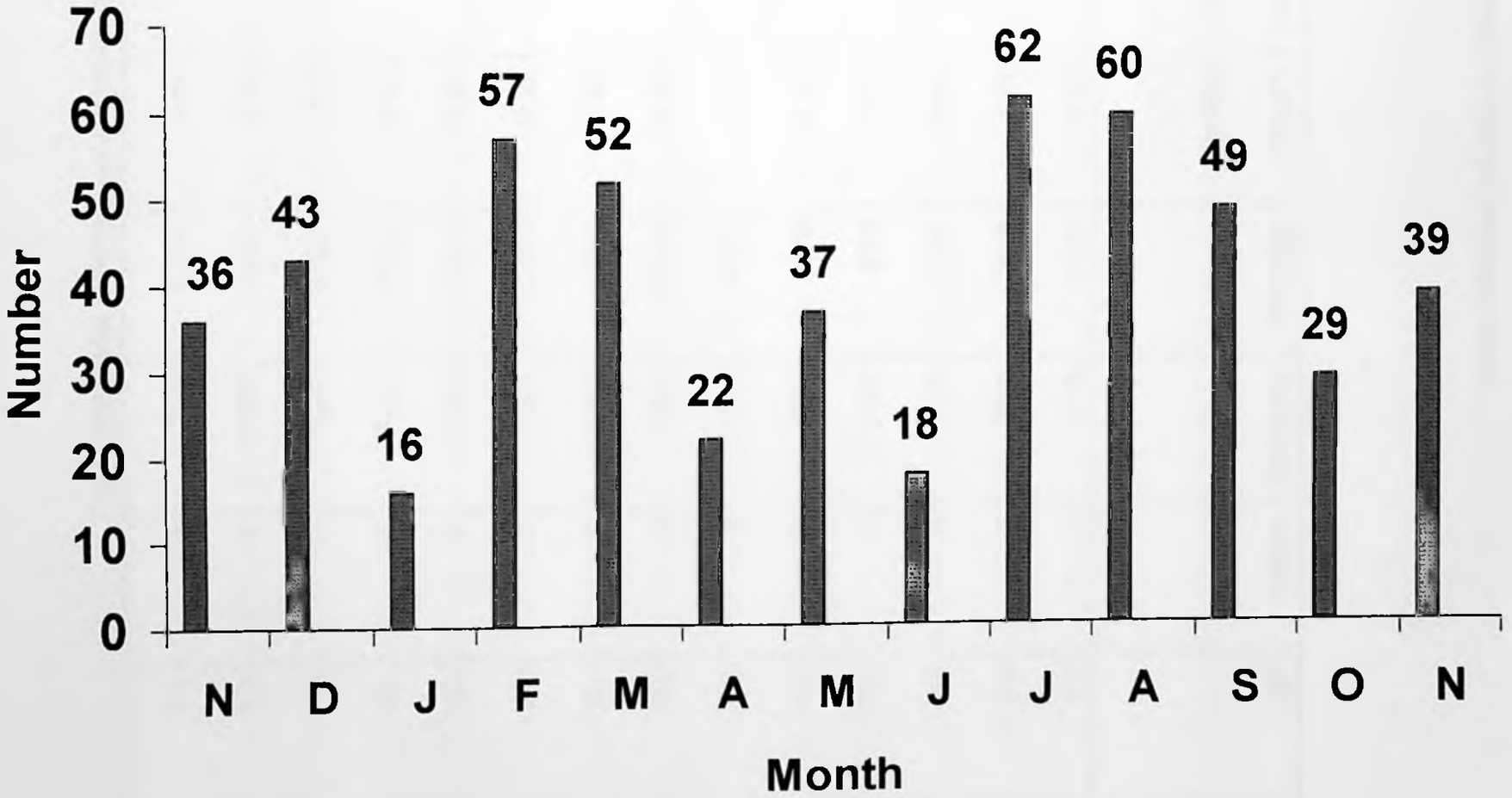
Sampling

Five hundred and twenty prawns were collected during monthly sampling from November 1996 through November 1997. Due to decaying vegetation and muddy water conditions, a qualitative sample was taken in October. Prawns had migrated to a different area. The maximum number of prawns collected from a monthly sample was in July (n = 62), while the minimum number was collected in January (n = 16) (Fig. 7). In addition, 454 prawns were collected from weekly samples taken from late April through November for growth and fecundity studies.

Water Quality and Temperature

Monthly water quality parameters are shown in Table 1. Data were taken from November 1996 through November 1997; however, data from November 1996 through April 1997 were inaccurate due to faulty chemicals in the Hach kit. To compensate for this gap in data, data from previous theses at GBWMA were compiled from December 1977 through November 1997. Averages from these months for each parameter are inserted into the table. Dissolved oxygen ranged from 4 (July, August, September) to 10.6 mg/L (February). Seasonal changes in temperature probably accounted for these differences. Carbon dioxide ranged from 5 (October) to 23 mg/L (May). Total and free acidities remained at zero for the duration of the study. The pH values ranged from 7.1 to 8.0, slightly alkaline. Average monthly temperatures ranged from 2-25.7^{0}C . Highest

Figure 7. Number of Palaemonetes kadiakensis collected from monthly samples


70
60
50
40
30
20
10
0
Number
36
43
16
57
52
22
37
18
62
60
49
29
39
N
D
J
F
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A
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J
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O
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Month

Table 1. Water quality data for Green Bottom Wildlife Management Area (1996-1997).

All units expressed as mg/L except pH and temperature.

DATES	Dissolved Oxygen	Carbon Dioxide	Hardness	Alkalinity	Acidity	pH	Temp-erature (^{0}C)
NOV 96*	6.0	15.0	102.2	85.2	0	7.1	8.8
DEC 96*	7.1	11.3	106.1	68.2	0	7.1	4.2
JAN 97*	9.8	14.0	99.1	63.8	0	7.4	2.5
FEB*	10.6	12.4	95.6	12.4	0	7.2	2.0
MARCH*	8.1	13.6	99.8	90.0	0	7.4	12.9
APRIL*	6.8	16.7	113.9	93.0	0	7.2	17.3
MAY	6.9	23.0	108.5	86.0	0	8.0	24.0
JUNE	5.0	22.0	136.5	109.7	0	7.0	25.6
JULY	4.0	15.0	119.7	102.6	0	7.5	25.7
AUG	4.0	15.0	119.7	119.7	0	7.3	23.3
SEPT	4.0	15.0	126.0	171.0	0	7.0	20.1
OCT	5.3	5.0	119.7	102.6	0	7.3	14.1
NOV	7.0	10.0	119.7	102.6	0	7.2	8.8
MEAN	6.5	14.5	112.8	92.8	0	7.6	21.8

* Compiled data from December 1977 through November 1997

temperature was recorded in July (25.7^{0}C), while the lowest temperature was recorded in February (2.0^{0}C).

Laboratory Studies

Growth Measurements

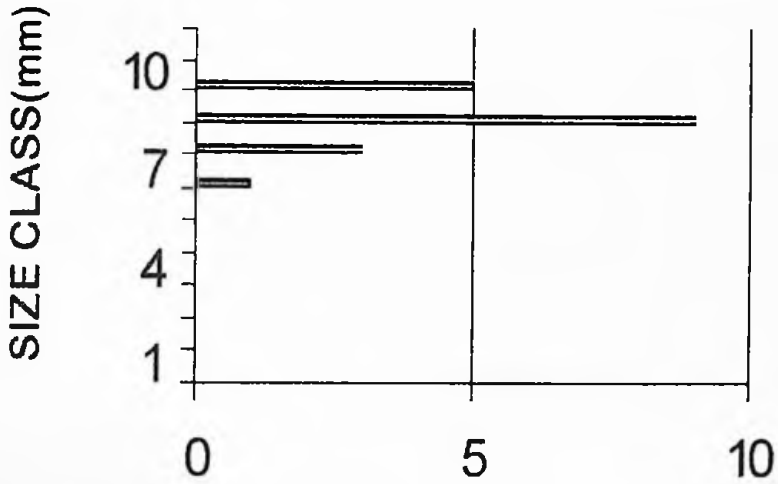
Length-frequency histograms for each month were compiled to determine the life cycle of *Palaemonetes kadiakensis* (Figs. 8-11). There is a univoltine (one-year) life cycle. All adults died by September. Meehean (1936) also found this prawn to have a one-year life cycle. Nielsen and Reynolds (1977) studied a population possessing non-overlapping generations (although a few adults persisted throughout the year). Cheper (1988, 1992) studied a population having a univoltine life cycle.

The average lengths of prawns from the monthly samples were used to calculate the growth rate (Table 2). The largest percent growth occurred between August and September (32.6 %), with 21.7^{0}C as the average temperature. This growth increase probably occurred because juvenile prawns were continuously growing to reach maturity, while the larger adult prawns had completely died. This calculation was also performed on the prawns collected weekly (Table 3). The largest percent growth occurred between 31 July and 7 August (39.8%), with the average temperature of 26.5^{0}C. Figure 12 depicts the average length and temperature for weekly collections. There was a steady increase in average length, while decrease in temperature seemed to have no effect on growth.

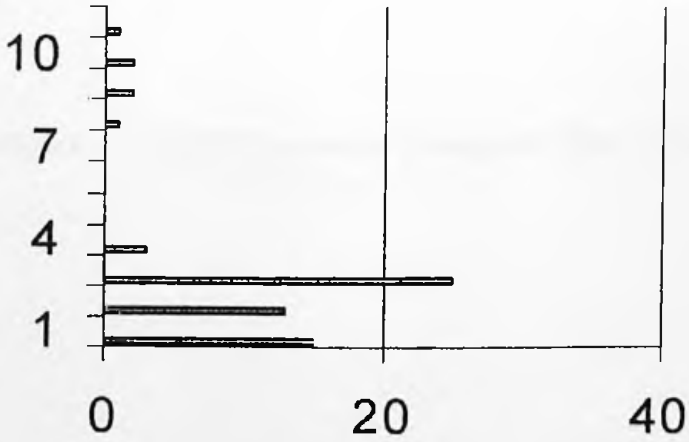
For monthly collections, male prawns averaged 23.82mm (range = 14.15 to 36.75mm) in length while females averaged 26.780mm (range = 15.06 to 38.60mm). The

Figure 8. Length -frequency histogram: June-August

JUNE1997 (n=18)



JULY 1997 (n=62)



AUGUST 1997 (n=60)

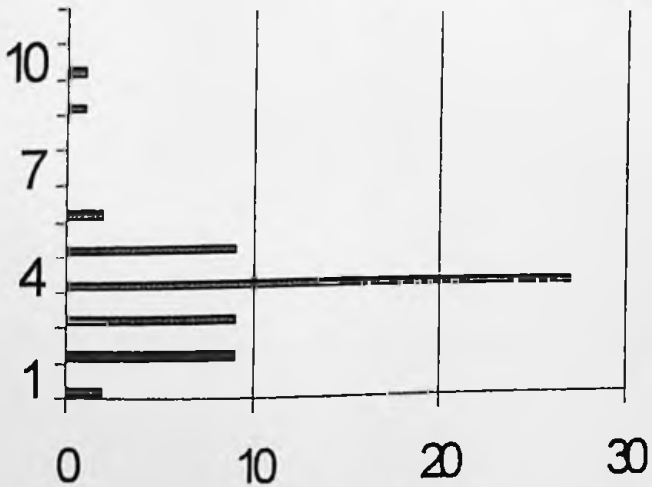
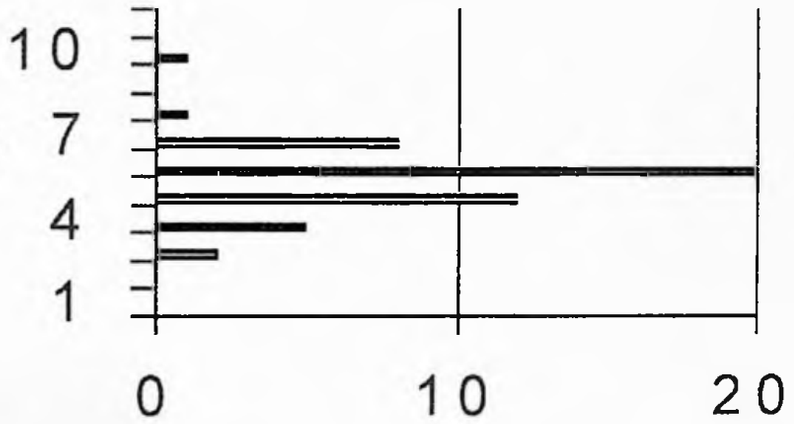
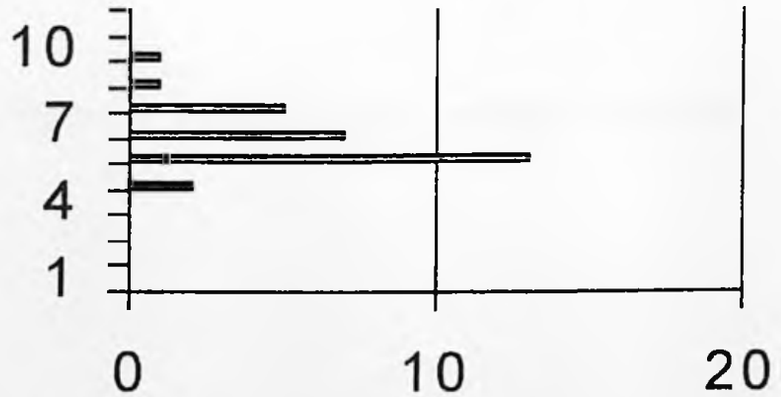


Figure 9. Length-frequency histogram: Sept.-Nov.

SEPTEMBER 1997 (n=49)



OCTOBER 1997 (n=29)



NOVEMBER 1997 (n=39)

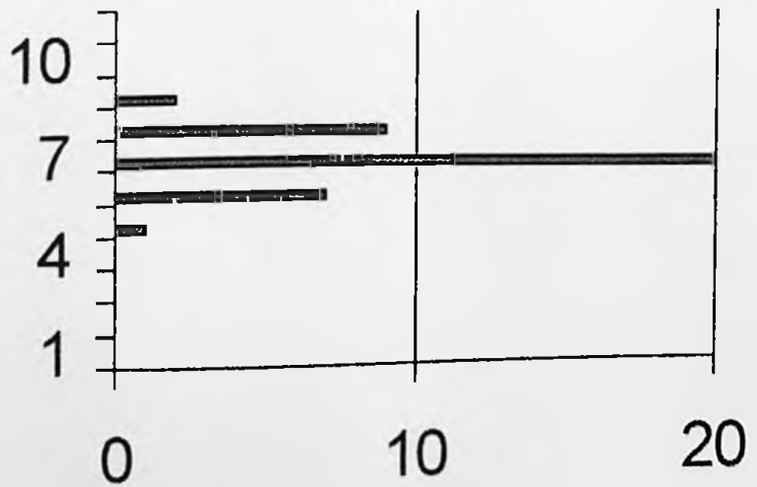
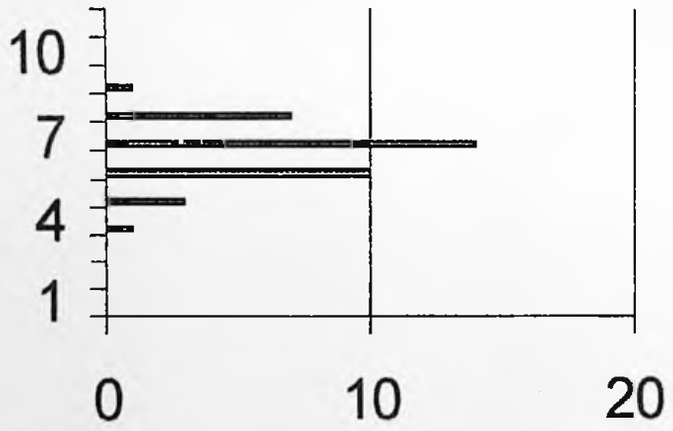
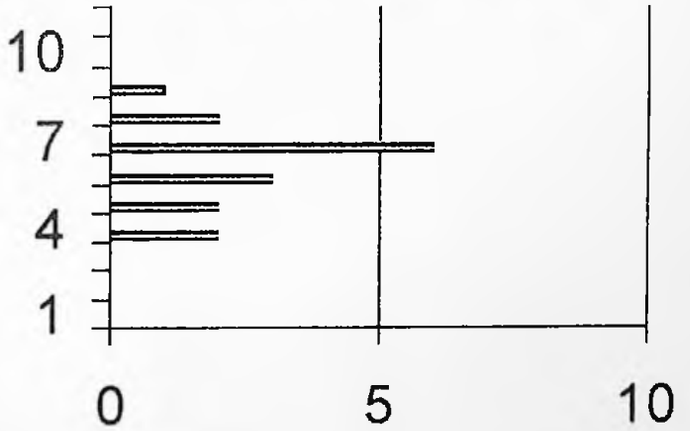


Figure 10. Length-frequency histogram: Nov.-Feb.

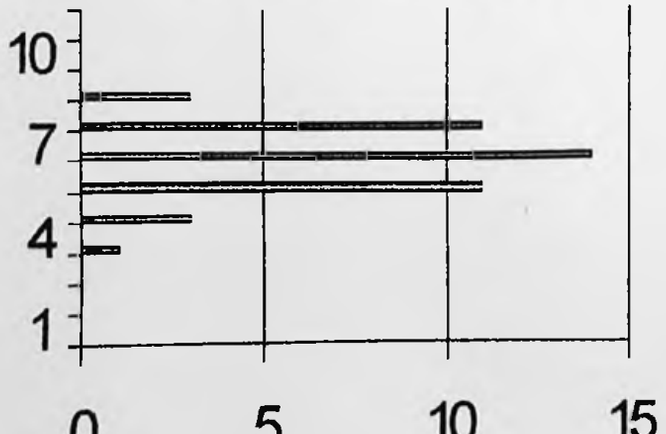
NOVEMBER1996
n=36



JANUARY(n=16)



DECEMBER(n=43)



FEBRUARY(n=57)

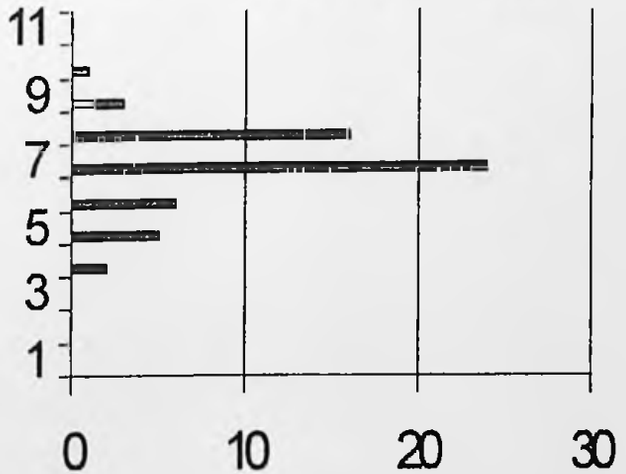
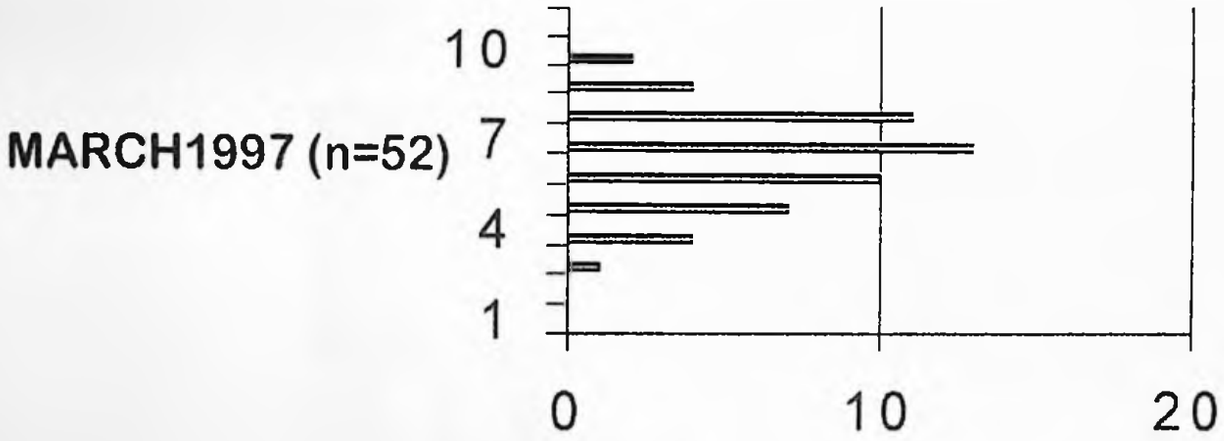
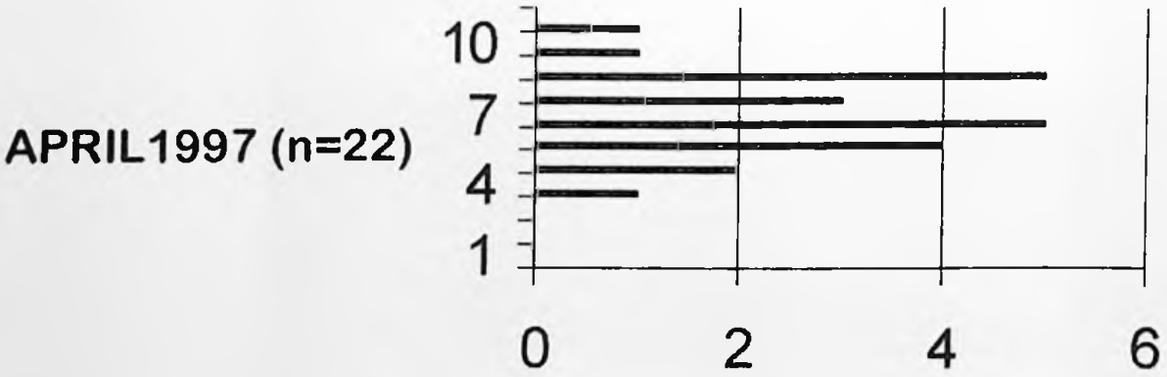


Figure 11. Length-frequency histogram: March-May


MARCH1997 (n=52)
10
7
4
1
0
10
20


APRIL1997 (n=22)
10
7
4
1
0
2
4
6

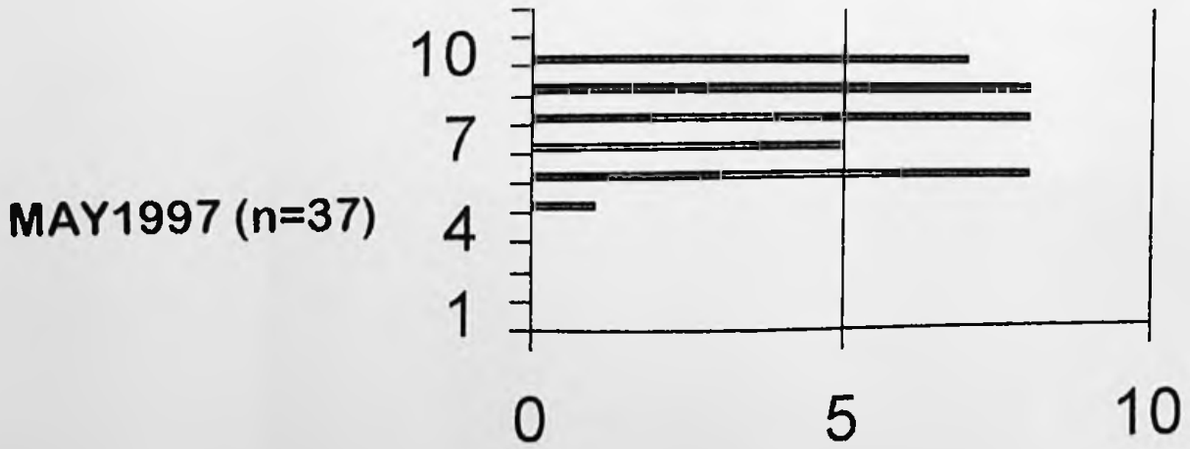

MAY1997 (n=37)
10
7
4
1
0
5
10

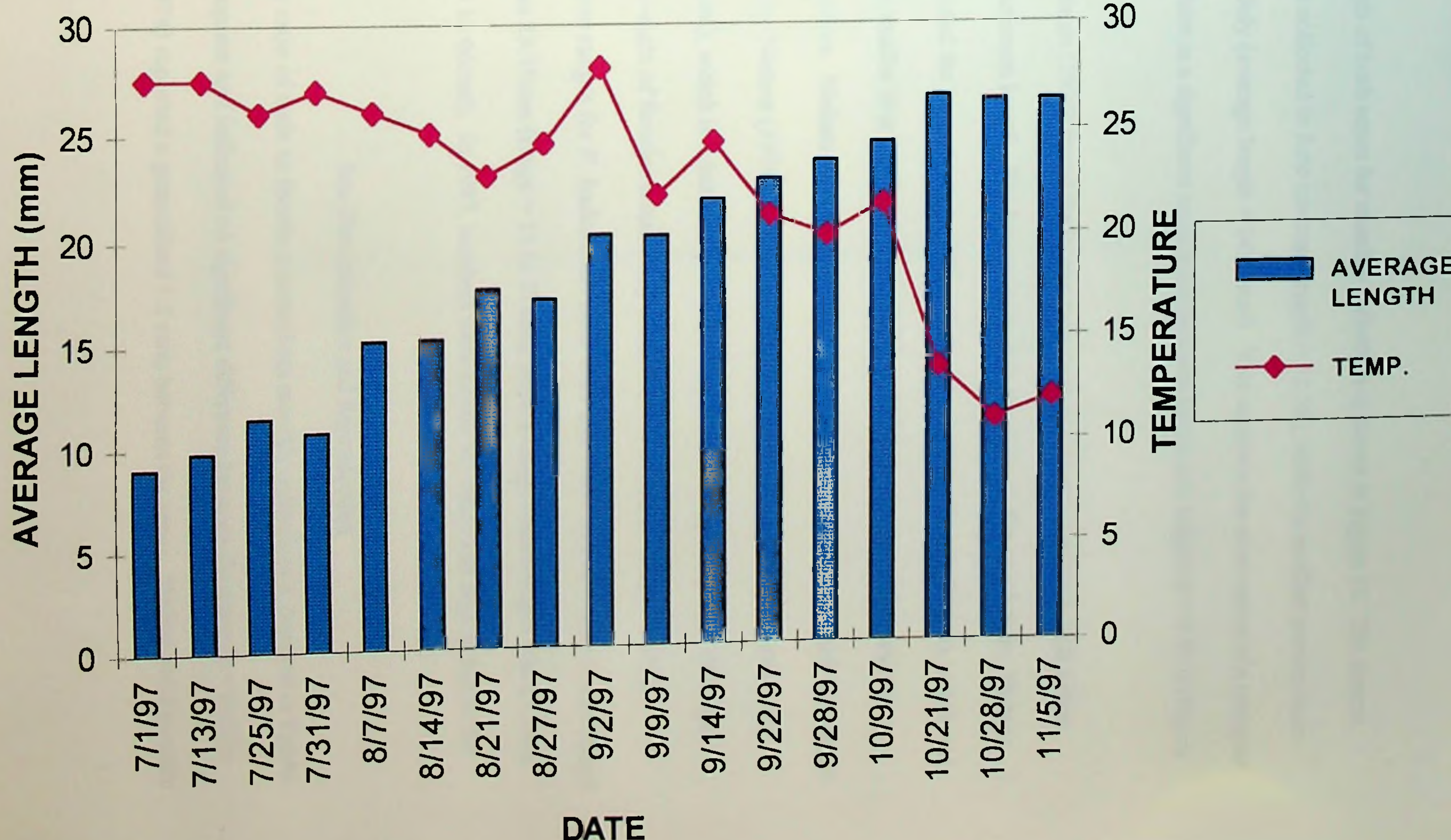
Table 2. Calculated growth rate of *P. kadiakensis* for monthly samples

DATE	AVERAGE LENGTH (mm)	DIFFERENCE (mm)	PERCENT GROWTH (%)	TEMPERATURE (°C)
11-13-96	26.04			8.8
		0.25	1.0	
12-11-96	26.29			4.2
		-1.46	-5.6	
1-22-97	24.84			2.5
		1.59	6.4	
2-19-97	26.43			2.0
		-0.61	-2.3	
3-21-97	25.82			12.9
		2.12	8.2	
4-23-97	27.94			17.3
		1.45	5.2	
5-19-97	29.38			24.0
		3.20	10.9	
6-20-97	32.58			25.6
		-18.0	-55.2	
7-15-97	14.61			25.7
		2.42	16.6	
8-12-97	17.03			23.3
		5.55	32.6	
9-17-97	22.57			20.1
		3.07	13.6	
10-15-97	25.64			14.1
		1.14	4.5	
11-12-97	26.78			8.84

Table 3. Calculated growth of *P. kadiakensis* from weekly collections

DATE	AVERAGE LENGTH (mm)	DIFFERENCE (mm)	PERCENT GROWTH (%)	TEMPERATURE (°C)
7-1-97	9.03			27.5
		0.80	8.8	
7-13-97	9.83			27.5
		1.69	17.2	
7-25-97	11.52			26.0
		-0.71	-6.2	
7-31-97	10.81			27.0
		4.30	39.8	
8-7-97	15.11			26.0
		0.12	0.8	
8-14-97	15.23			25.0
		2.41	15.8	
8-21-97	17.64			23.0
		-0.49	-3.9	
8-27-97	17.15			24.5
		3.04	17.7	
9-2-97	20.19			28.0
		-0.08	-0.4	
9-9-97	20.11			22.0
		1.75	8.7	
9-14-97	21.86			24.5
		1.0	4.4	
9-22-97	22.82			21.0
		0.83	3.6	
9-28-97	23.65			20.0
		0.85	3.6	
10-9-97	24.49			21.5
		2.17	8.9	
10-21-97	26.67			13.5
		-0.24	-0.9	
10-28-97	26.43			11.0
		-0.02	-0.08	
11-5-97	26.41			12.0

Figure 12. Average length and temperature for weekly collections.


30
25
20
15
10
5
0
AVERAGE LENGTH (mm)
TEMPERATURE
7/1/97
7/13/97
7/25/97
7/31/97
8/7/97
8/14/97
8/21/97
8/27/97
9/2/97
9/9/97
9/14/97
9/22/97
9/28/97
10/9/97
10/21/97
10/28/97
11/5/97
DATE
AVERAGE LENGTH
TEMP.

average length of both sexes for monthly collection is shown in Figure 13. The largest prawns were collected in June (average length = 32.58), while the smallest prawns were collected in July (average length = 14.61mm). This supports the observation of a one-year life cycle. There is a significant correlation between length and weight (r = 0.915) (Figure 14).

Meehean (1936) found the largest prawns in late March (>40mm), with 53mm being the maximum length. The largest ovigerous female was 49mm in length. Nielsen (1974) recorded the largest prawn collected was an ovigerous female (36mm), which was substantially smaller that Meehean's reported data. Nielsen also found females to be larger than males. Nielsen and Reynolds (1977) reported *P. kadiakensis* attaining ultimate length in June. Nielsen (1974) recorded the largest prawn collected to be an ovigerous female (36mm), which is substantially smaller that Meehean's reported size. Average length and weight of females consistently exceeded that of males. Cheper (1992) compared size ranges for *P. kadiakensis* from 1982 and 1987. In 1987, the average length of males was 23.10mm (range = 15 to 37mm), while average female length was 23.7mm (range = 15 to 46mm). In 1987, numbers were similar for males and slightly higher for female.

Sex Determination and Reproduction

The ratio of male to female prawns from monthly collections is depicted in Figure 15. A chi-square test indicated no significant difference between the sexes ($p = 0.448$). Nielsen (1974) reported a generalized 1:1 ratio between the sexes. Nielsen and Reynolds

Figure 13. Average length of *Palaemonetes kadiakensis* from monthly collections

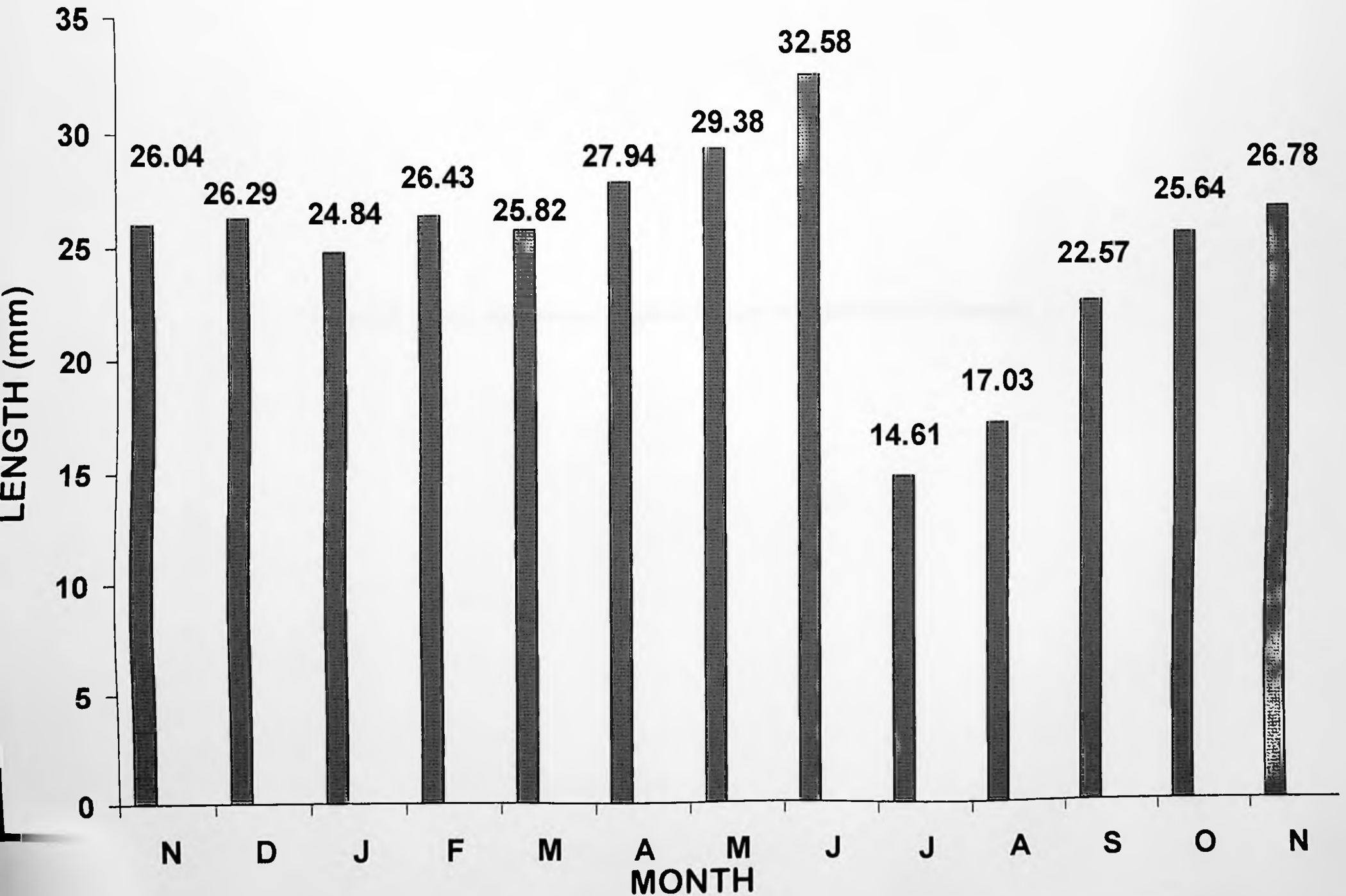

35
30
25
20
15
10
5
0
LENGTH (mm)
26.04
26.29
24.84
26.43
25.82
27.94
29.38
32.58
14.61
17.03
22.57
25.64
26.78
N
D
J
F
M
A
M
J
J
A
S
O
N
MONTH

Figure 14. Linear regression of length and weight of *Palaemonetes kadiakensis*

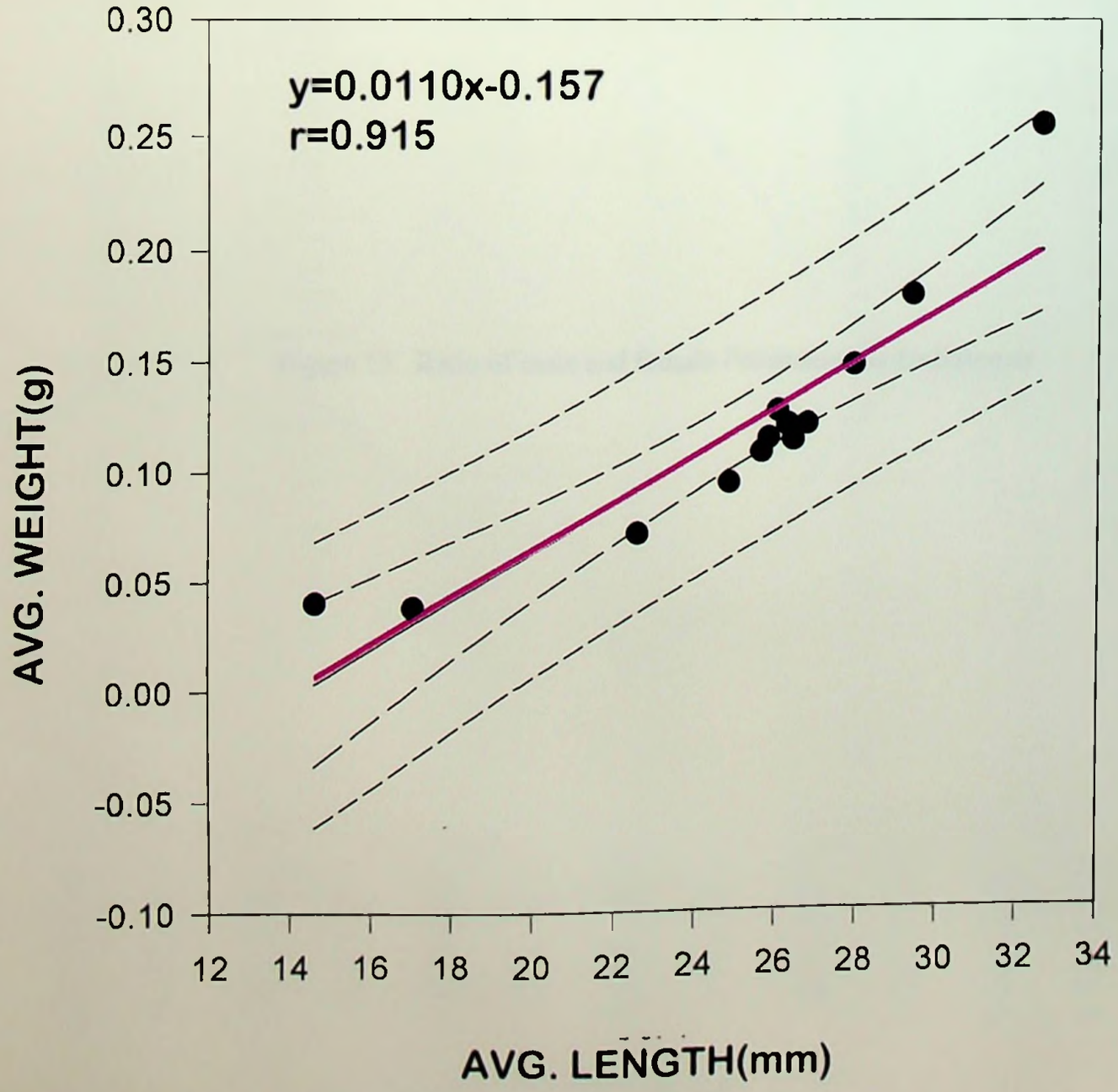
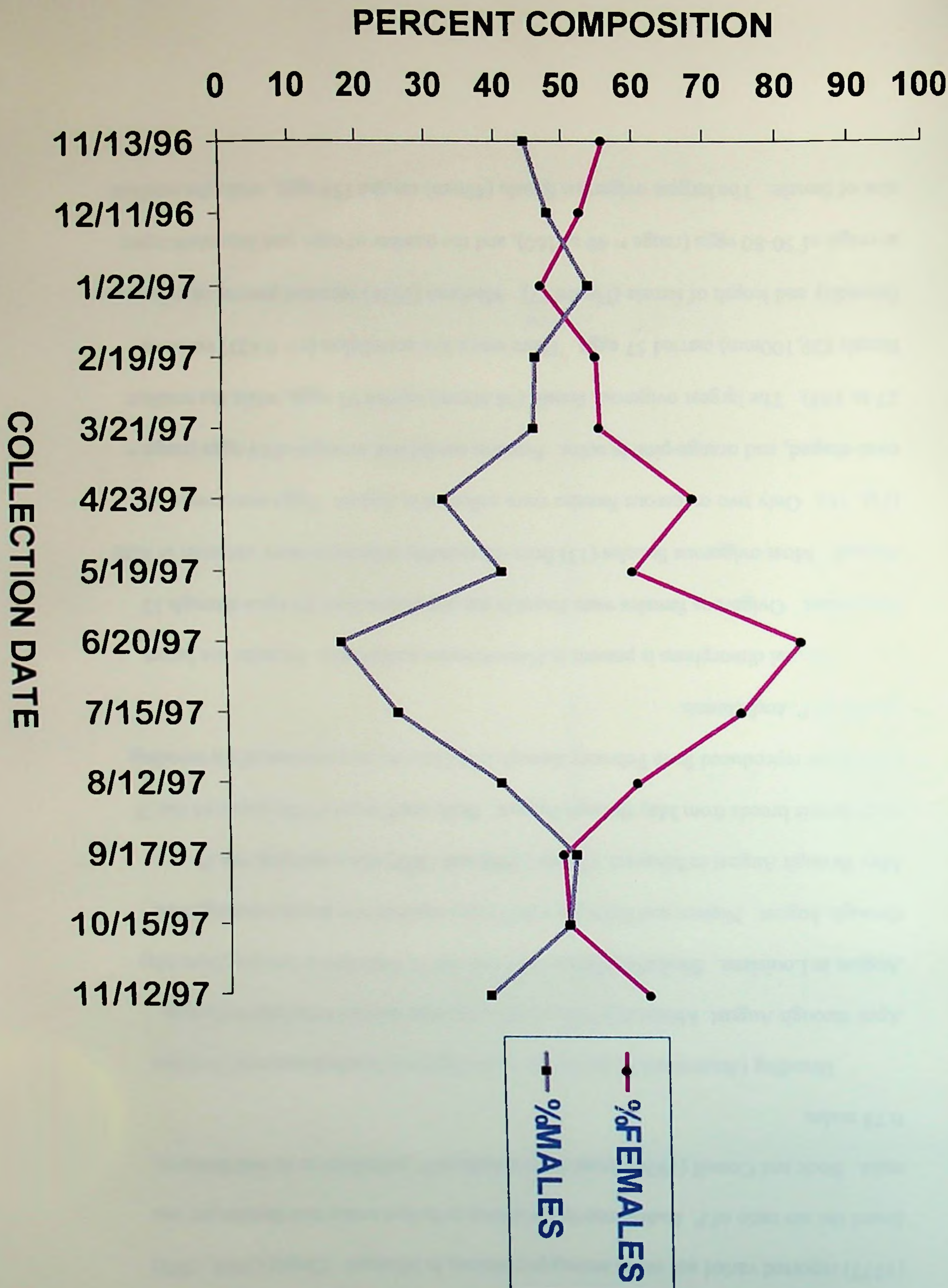

y=0.0110x-0.157
r=0.915
AVG. WEIGHT(g)
AVG. LENGTH(mm)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
12
14
16
18
20
22
24
26
28
30
32
34

Figure 15. Ratio of male and female *Palaemonetes kadiakensis*



PERCENT COMPOSITION
0
10
20
30
40
50
60
70
80
90
100
11/13/96
12/11/96
1/22/97
2/19/97
3/21/97
4/23/97
5/19/97
6/20/97
7/15/97
8/12/97
9/17/97
10/15/97
11/12/97
COLLECTION DATE
%FEMALES
%MALES

(1977) reported varied sex ratios among populations in Missouri. Cheper (1988, 1992) found the sex ratio of *P. kadiakensis* in Oklahoma to be just under two females per one male. Beck and Cowell (1976) found the sex ratio of *P. paludosus* to be one female to 0.78 males.

Breeding (determined by the presence of ovigerous females) occurred from late April through August. Meehean (1936) found ovigerous females from March through August in Louisiana. Similarly, Nielsen (1974) found *P. kadiakensis* breeding from May through August. Nielsen and Reynolds (1977) also reported this prawn breeding from May through August in Missouri. Cheper (1988 and 1992) also concluded that *P. kadiakensis* breeds from May through August. Beck and Cowell (1976) reported that *P. paludosus* reproduced from February through mid-October, an extension of the breeding period of *P. kadiakensis*.

Sexual dimorphism is present in *Palaemonetes kadiakensis*. Females are larger than males. Ovigerous females were found in the population from 30 April through 12 August. Most ovigerous females (13) from the monthly collections were obtained in June (Fig. 16). Only two ovigerous females were collected in August. Eggs were round to oval-shaped, and orange-pink in color. Females carried and average of 69 eggs (range = 27 to 102). The largest ovigerous female (38.60mm) carried 91 eggs, while the smallest female (29.100mm) carried 57 eggs. There was a low correlation ($r = 0.423$) between fecundity and length of female (Figure 17). Meehean (1936) reported prawns carrying an average of 50-80 eggs (range = 40 to 160), and the number of eggs was dependent upon size of female. The largest ovigerous female (49mm) carried 154 eggs, while the smallest

Figure 16. Ovigerous females from monthly collections

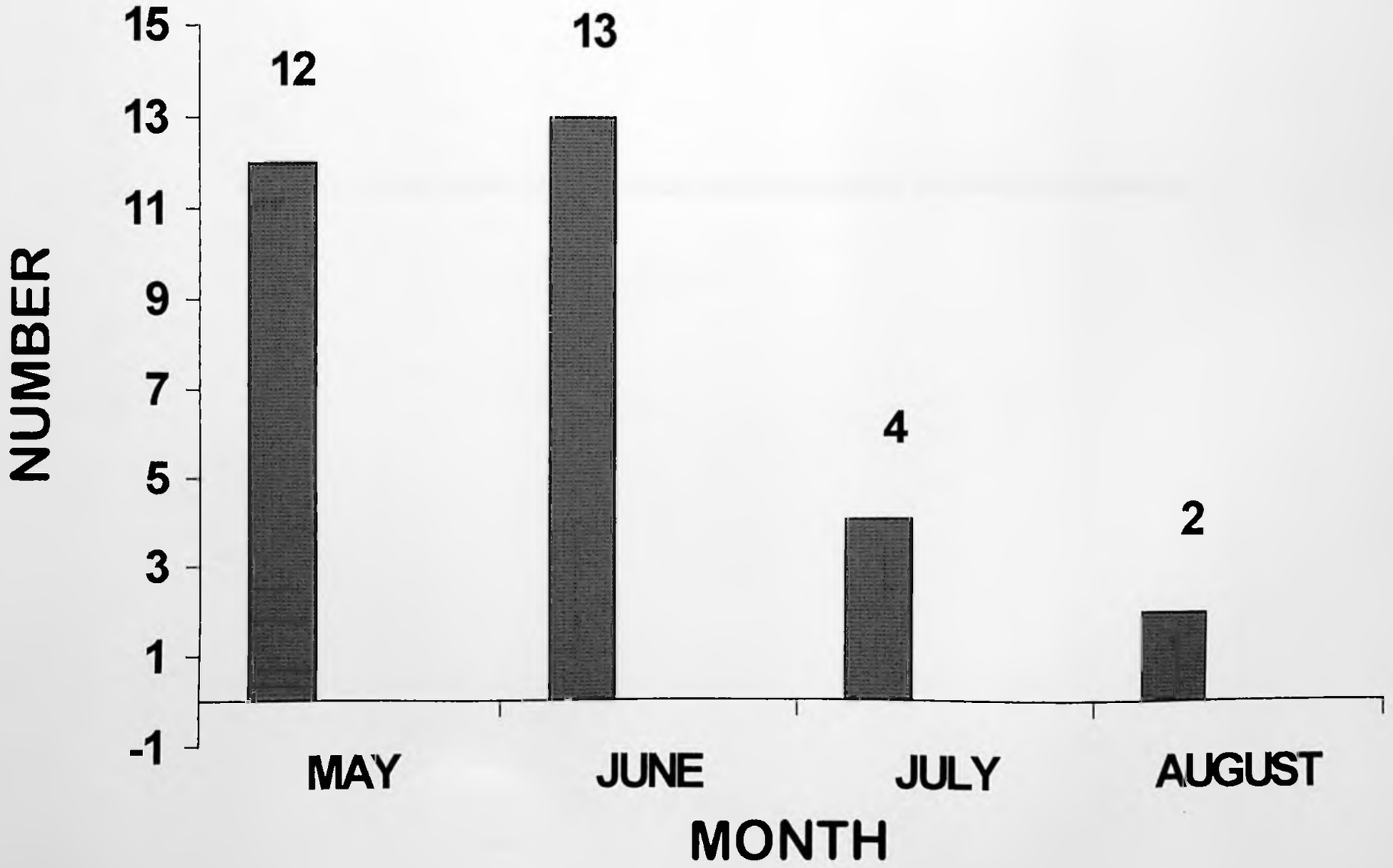
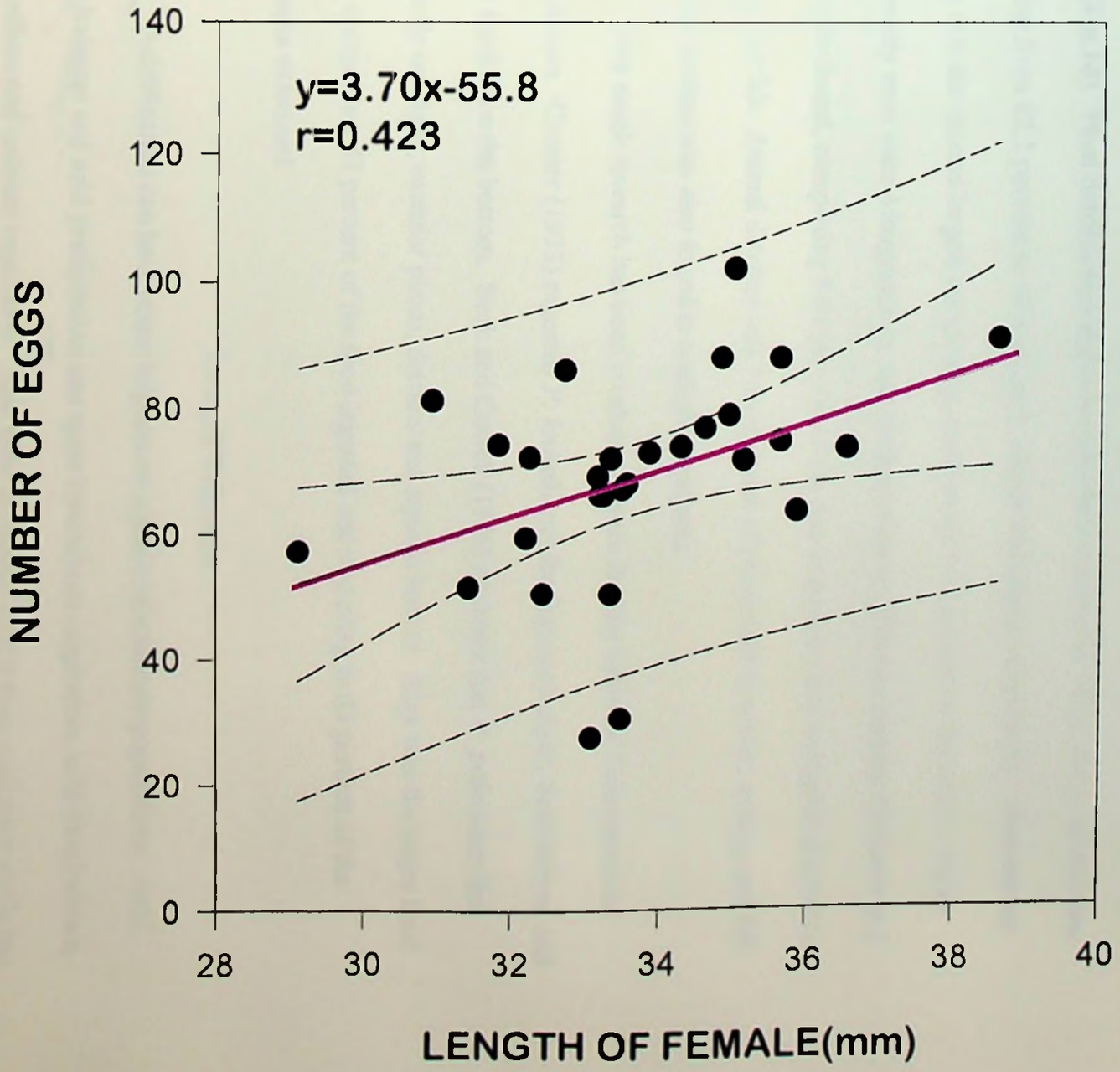

15
13
11
9
7
5
3
1
-1
NUMBER
12
13
4
2
MAY
JUNE
JULY
AUGUST
MONTH

Figure 17. Linear regression for fecundity and body length of *Palaemonetes kadiakensis*


y=3.70x-55.8
r=0.423
NUMBER OF EGGS
LENGTH OF FEMALE(mm)
0
20
40
60
80
100
120
140
28
30
32
34
36
38
40

female (27 mm) carried 43 eggs. Nielsen (1974) found ovigerous females with an average of 40 eggs (range = 20 to 76). Nielsen and Reynolds (1977) found similar results in Missouri. Beck and Cowell (1976) reported females carrying 8-85 eggs, and brood size increased with the length of the female (r = 0.984).

Gut Analysis

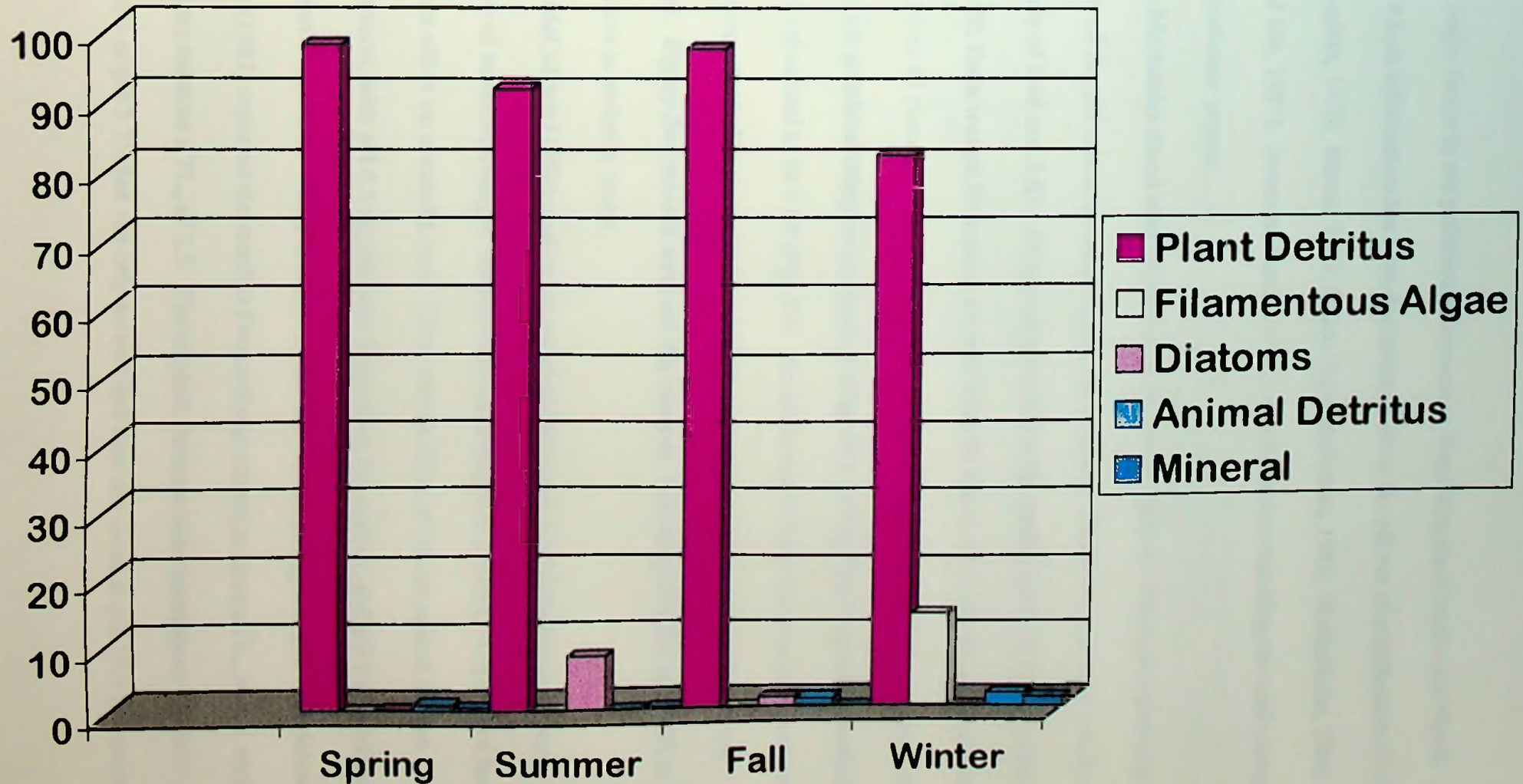
Based on seasonal studies, *Palaemonetes kadiakensis* is mainly detritivorous in its diet (Fig.18). Plant detritus was the most important component of the diet in all seasons, ranging from 82.2 percent to 97.9 percent, winter and spring, respectively. Filamentous algae was the second largest component, comprising 14.2 percent in the winter. Algae commonly seen were *Mougeotia sp.* and *Oedogonium sp.* Diatoms (mainly *Navicula sp.*) were also found, comprising 8.01 percent of the diet in summer, and negligible amounts in spring and fall. Animal detritus was a component of prawn diet in winter, spring, and fall. Mineral detritus was also found in negligible amounts.

Not much research has been conducted on the feeding habits of *Palaemonetes kadiakensis.* Creaser (1933) reported *P. kadiakensis* feeding upon algae, dead leaves, and other food from the bottom. Beck and Cowell (1976) reported that *P. paludosus* fed primarily on algae, vascular plants, detritus and aquatic insects. Alga was the major food item, comprising 47 percent of the food ingested and occurring in 83 percent of the stomachs examined.

Low pH Tolerance

Acidification can have major impacts on aquatic invertebrate populations. Acid mine drainage and acid precipitation can upset invertebrate respiration, acid-base balance, and sodium and calcium regulation. Acid mine drainage (AMD) from coal mine spoils has

Figure 18. Seasonal percent composition of food items from gut analysis


100
90
80
70
60
50
40
30
20
10
0
Spring
Summer
Fall
Winter
Plant Detritus
Filamentous Algae
Diatoms
Animal Detritus
Mineral

been a major factor in the pollution of streams in West Virginia (Canton and Ward, 1976). Much information has been documented about the effects of acidification (Tolbert and Vaughan, 1979; Havas, 1981; Havas and Hutchinson, 1982; Weiderholm, 1984; Hall and Ide, 1987); however, there is a lack of information regarding the acid tolerance of this particular prawn.

Mortalities found after 96 hours are shown on Table 4. These pH values are averages of the pH values recorded during the bioassay. There were no survivors for the pH values of 1.48 and 3.03. All prawns survived in the control (pH = 8.30). For the pH value 6.20, there was an 80 percent survival after 96 hours, while the percent survival for pH 4.62 was 45 percent. The median tolerance limit (TL_m) was determined to be 4.80 by straight line graphical interpolation method (Fig. 19). Using linear regression analysis, the TL_m was calculated to be 5.04 (Fig. 20). An additional 96 hour test was then performed for the theoretical pH value of 5.04 using 20 more prawns (ten test specimens, ten controls). Eighty-five percent survived this bioassay, indicating that the actual TLm for *P. kadiakensis* is probably lower.

McCulloch (1990) studied the metabolic response of *P.kadiakensis* to acute exposure of sublethal changes. He reported that changes in pH (6.5, 9.0) did not have a significant effect on metabolic rate. There was an effect of pH on critical oxygen concentration, with pH 6.5 significantly higher than the control, and pH 9.0 significantly lower than the control. Many crustaceans are sensitive to changes in pH. McMahon and Morgan (1983) reported the crayfish *Procambarus clarkii* to have a TL_m of 2.8, and *Orconectes rusticus* a TL_m of 2.5. The crayfish *Parastacoides tasmanicus* can live indefinitely at pH 2.75, but can only survive less than one week at pH 13.0 (Newcombe,

Table 4. Experimental data from an acute static bioassay for the low pH tolerance of *Palaemonetes kadiakensis*.

pH	24 hours	48 hours	72 hours	96 hours
1.48	0	0	0	0
3.03	0	0	0	0
4.62	90	85	85	45
6.20	85	85	80	80
8.30	100	100	100	100

Figure 19. Straight line graphical interpolation for low pH tolerance

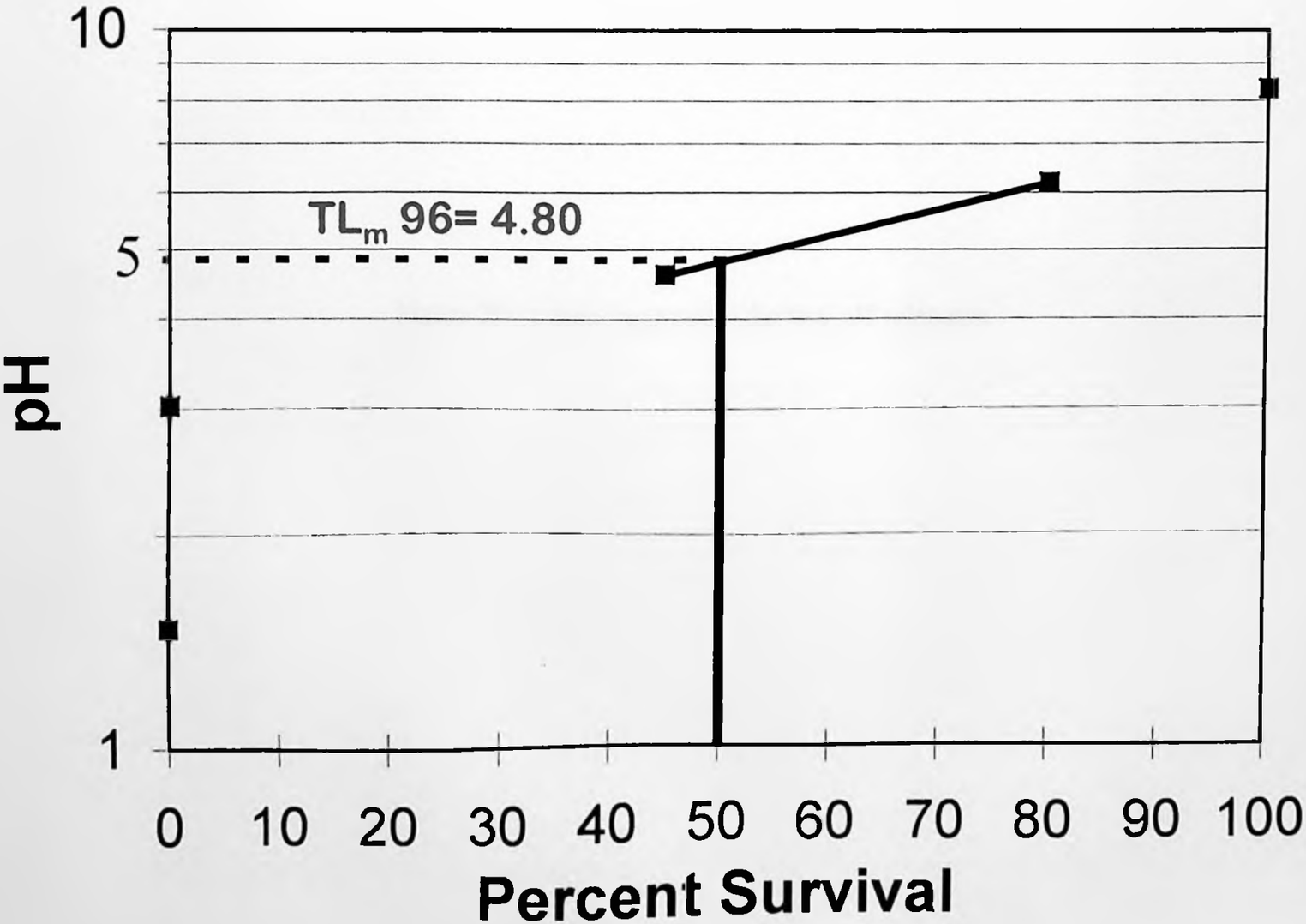
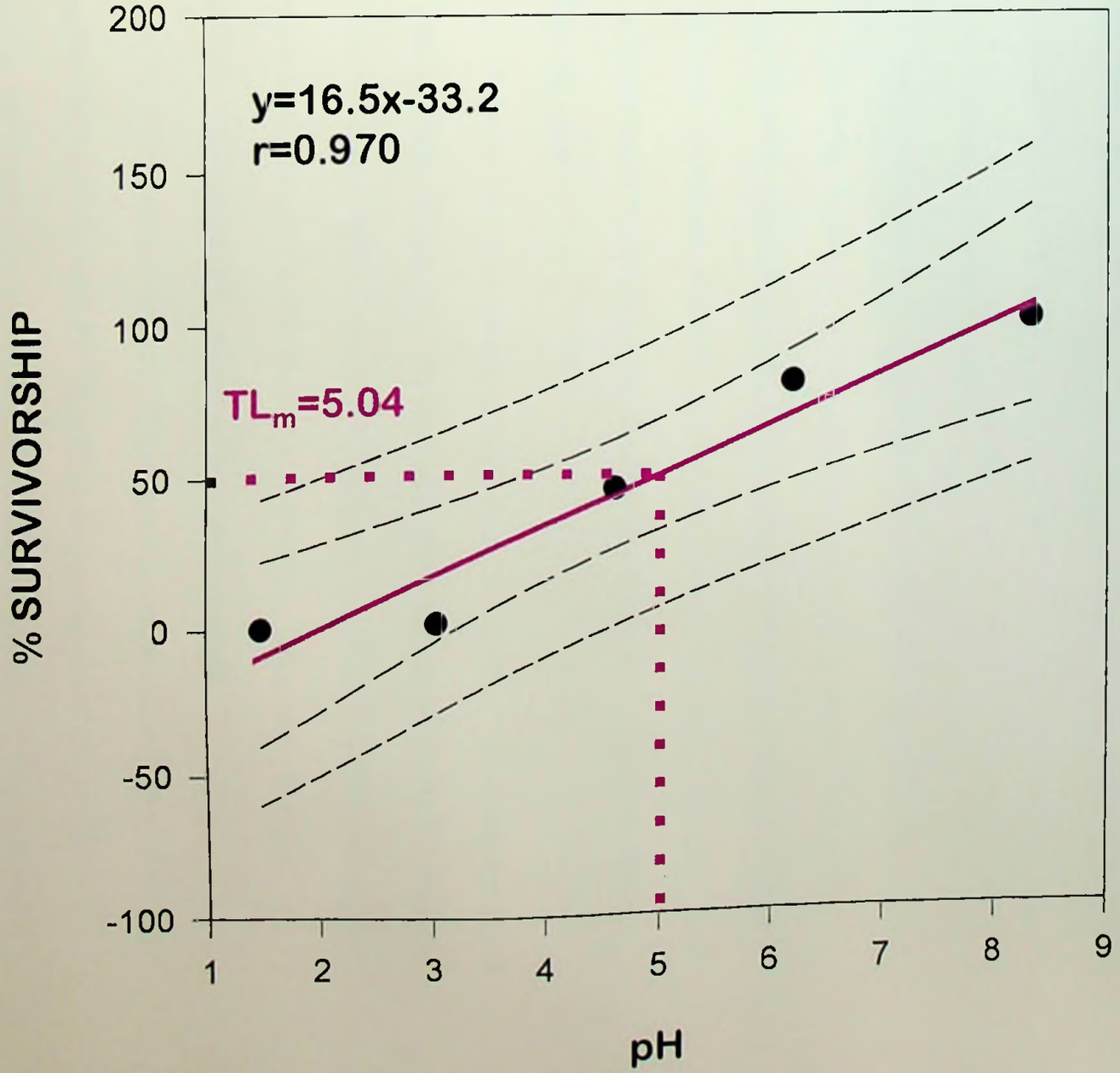

10
5
1
pH
TL_m 96= 4.80
0
10
20
30
40
50
60
70
80
90
100
Percent Survival

Figure 20. Linear regression for low pH tolerance


y=16.5x-33.2
r=0.970
TL$_m$=5.04
% SURVIVORSHIP
pH
200
150
100
50
0
-50
-100
1
2
3
4
5
6
7
8
9

1975). Henry (1997) reported the amphipod *Crangonyx pseudogracilis* having a TL_m of 4.06.

CHAPTER VII

SUMMARY AND CONCLUSIONS

1. A life history study on the freshwater prawn *Palaemonetes kadiakensis* was conducted from November 1996 through November 1997 from a mitigated wetland in the Green Bottom Wildlife Management Area, Cabell County, West Virginia.

2. Water quality at the sample site appeared to be normal throughout the study. The pH ranged from 7.1 to 8.0, and dissolved oxygen varied from 4 mg/L in the summer months to 10.6 mg/L in the winter months.

3. Prawns were abundant in the vegetated area and migrated out from the site in October when dying vegetation overtook the area, making the water extremely muddy.

4. Length frequency histograms indicated that *Palaemonetes kadiakensis* breeds from April through August, with ovigerous females carrying an average of 69 eggs. There is a low correlation ($r = 0.423$) between fecundity and body length. This prawn has a univoltine life cycle.

5. *Palaemonetes kadiakensis* exhibited sexual dimorphism. The average length of males was 23.82mm (range = 14.15 to 36.75mm), and females averaged 26.78mm (range = 15.06 to 38.60mm). Males averaged 0.0872g (range = 0.0142 to 0.2932g) and females averaged 0.1403g (range = 0.0136 to 0.4168g) in weight. There was a significant correlation ($r = 0.915$) between average body length and weight.

6. For the monthly collections, largest percent growth occurred between August and September (32.59 %), with 21.7^{0}C as the average temperature. For weekly collections, the largest percent growth occurred between 31 July and 7 August (39.83 percent), with 26.5^{0}C as the average temperature..

7. There was no significant difference in sex ratio ($p = 0.448$).

8. In the low pH tolerance bioassay, the median tolerance limit (TL_m) was determined to be 5.03 by linear regression, and 4.60 by straight line graphical interpolation method. A 96-hour test at the theoretical pH value of 5.03 produced a 95 percent survival rate, indicating that the actual TL_m value of *Palaemonetes kadiakensis* should be lower.

9. Stomach analysis indicated that *Palaemonetes kadiakensis* preferred plant detritus year round, Ranging from 82.2 and 97.9 percent, winter and spring, respectively. Animal detritus, filamentous algae, diatoms, and minerals were also found in smaller quantities in the prawn stomachs.

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