COMPARATIVE FEEDING RATES OF CRAYFISH SPECIES *ORCONECTES RUSTICUS*, *O. VIRILIS*, AND *O. PROPINQUUS*

Robert J. Houlihan

Undergraduate Research (UNDERC)

Dr. David Lodge

November 28, 1988

ABSTRACT

The following study compares the feeding rates of three crayfish species, Orconectes rusticus, O. virilis, and O. propinquus. The three species were trapped from northern Wisconsin lakes, maintained in the laboratory in natural photoperiod, and used within three weeks of capture. This was a variation on previous experiments in which crayfish were used that had been kept on midsummer photoperiod in autumn captivity. Each replicate used three equal-weight (+/-1g) crayfish -- one of each species. Each crayfish was tested separately in a 12 gallon tank at natural midsummer photoperiod (16L:8D). 250 Amnicola snails (size range 2.2-5.3 mm) were placed in each tank and consumption monitored over a 24 hour period. Sixteen replicates resulted in mean consumptions of: 57 snails for O. propinquus, 89 snails for O. virilis, and 146 for O. rusticus. There was a significant difference among the means (ANOVA, $p< 0.0001$),with O. rusticus consuming significantly more snails than O. virilis and O. propinquus (Tukey's Test, $p<0.05$).

Key Words

Orconectes rusticus, O. virilis, O. propinquus, Amnicola, consumption, feeding rate.

INTRODUCTION

During the last fifty years, northern Wisconsin has experienced an invasion by two species of crayfish. Fifty years ago, the only species present in northern Wisconsin lakes was Orconectes virilis, which appears to have entered the region through natural migration up the tributaries of the Mississippi River (Lodge et al 1985). O. propinquus, later migrated from the Lake Superior drainage system (Capelli and Magnuson 1983). O. rusticus was introduced to the region within the last thirty years, probably from Illinois or Indiana by vacationing fishermen (Capelli and Magnuson 1983). The spread of O. rusticus may also have been hastened by commercial "crabbers" who purposefully introduced them to remote water bodies to take advantage of the high population densities that they achieve (Lodge and Lorman 1987; Lodge et al 1985).

All three species appear to have over-lapping habitat requirements that fit the northern lake systems. O. virilis and more recently the O. propinquus established themselves as benign members of the ecological community (Lodge et al 1985). O. rusticus, on the contrary, appears to be thriving at the expense of the more docile O. virilis and O. propinquus (Lodge et al 1985). The larger O. rusticus is consistently more aggressive than O. virilis and O. propinquus, and is able to out-compete the other species for limited shelter. In aquarium experiments, involving individuals of equal size, O. rusticus always assumes the dominant position in shelter occupancy and appears to be less vulnerable to predation (Lodge, Kratz, and Capelli, 1986). The greater aggression of O. rusticus is important in defence against predators and interspecific competition, and may therefore increase the probability of survival (Capelli et al 1983). These factors have helped O. rusticus displace the other two species from the water systems it enters.

O. rusticus ^apparently^ is capable of obtaining much higher densities than its fellow species, thus its' occupancy has a greater impact on the benthic community (Lodge et al 1985). Orconectes are opportunistic omnivores which preferentially consume a high protein diet of fish eggs, carrion, insect larvae, and snails, but plant food consisting of periphyton or "scum flora", which is generally more abundant and less nutritious, constitutes the main source of food (Lodge et al 1985). The reduction of macrophyte communities in response to consumption has been linked to recruitment failure in walleye and other game fishes (Lodge, Kratz, and Capelli 1986; Lodge and Lorman 1987).

The purpose of the experiment was to test the relationship between consumption and crayfish biomass. Previous work has not established conclusive differences between the consumption of the three species of crayfish using snails (Zurovchak and Olsen, unpublished work) and macrophytes as a food (Lodge et al 1985). This work would tend to indicate that the characteristic of ~~the~~ O. rusticus that gives it an advantage in the interspecific competition of the three species results from features like its' aggressiveness rather than its' rate of consumption per unit biomass. In laboratory experiments, I tested the null hypothesis that the feeding rates of the three species are the same per unit crayfish biomass.

I don't think so. You controlled for biomass. The goal of your expt was to test interspecific differences in consumption at a single biomass.

Previous work?

I think you're continuing to confuse two questions: 1) what is (are) the mechanism(s) for species replacements? 2) What is the mechanism(s) of the apparently greater impact of O.r.?

see p. 7.

MATERIALS AND METHODS

Crayfish were captured from three sites near the Trout Lake Field Station.at two times during the summer intermolt period ^(Appendix 2)^.

→ Your experiment was designed to test one possible answer to the second question.

The crayfish were trapped using wire mesh cylindrical minnow traps with openings enlarged to 3.5-4.5 cm in diameter. Traps were set over a 24 hour period using 120 g of beef liver as bait. *O. rusticus* were obtained along the east shore of Trout Lake, *O. virilis* from White Sand Lake, and the majority of *O. propinquus* from Tenderfoot Lake with a small proportion coming from a trapping site by the inlet of Stevenson Creek on Trout Lake. The trappings took place from June 2-8 and from July 5-9. Intermolt, Form II, male crayfish were used in all replicates. All crayfish were weighed, carapace lengths were measured, and they were marked for identification on the underside of the pincers with a permanent marker. The crayfish ranged in size from 8.75 g to 13.15 g. All crayfish had both pincers intact and had no obvious physical defects. Crayfish were maintained in two aerated 12 gallon fish tanks with the species randomly intermixed between the two. Pieces of 3 inch PVC were placed on the bottom of the tanks to provide cover. Crayfish were fed fish pellets, but were starved for a period of 24 to 48 hours prior to their use in a replicate to ensure that all three species would feed during the 24 hour period of the replicate. For any given replicate, the period of starvation was the same for all three species.

Amnicola were obtained from Tenderfoot Lake at three times during the summer. The three collections were made June 6, June 20, and July 29, 1988. A random sample of 50 snails was measured in each sample, obtaining the following means: 3.915 mm (s^2=0.342), 3.778 mm (s^2=0.432), and 3.608 mm (s^2=0.402) with a size range (2.2-5.3 mm).

Two replicates were run at a time, using three 12 gallon fish tanks for each. Each was filled to a level of 3 cm with fresh tap water (to minimize the escape of snails). Each tank received 250 *Amnicola* and one ~~species~~ crayfish. The three crayfish used in each replicate were of similar biomass (+/-1g). Tanks were covered with wire mesh to prevent the escape of any crayfish and were kept in an isolated room to prevent disruption of the nocturnal feeding period. After 24 hours, remaining snails were counted and crayfish specimens frozen.

The first six replicates were performed in tanks with water temperatures ranging from 17 to 26 °C, varying in accordance with the daily fluctuations in ambient temperature (See Appendix 1). The actual temperature variation during each of the replicates was not recorded, but two test runs were run to establish the pattern of temperature fluctuation. Replicates seven through sixteen were run within a temperature range of one degree between 17.5-18.5 °C.

in teaching lab.

in basement of new dorm

The data, which included replicates 1-16, were then tested using an ANOVA to determine if there was a significant difference among the three means. Tukey's Test was used to indicate which of the pairs of means were significantly different once the existence of a difference was established using an ANOVA. Tukey's Test calculations were performed by hand. Model II ANOVA's were run using the STATVIEW program on a Macintosh Plus.

RESULTS

The date that replicates were run, the weight, the carapace length, number of snails eaten, and the site of capture of the three species were recorded for future reference (Appendix 2).

In the first six replicates the temperature in the experimental tanks varied with outside conditions. The temperature fluctuation pattern during a typical 24 hour test period was established by recording temperature changes during two representative days. The temperature in the tanks during the two recording days ranged from 17 to 27 °C, while the outside temperature ranged from 23-30 °C. These ranges and the pattern of fluctuation were representative of the six replicates. An ANOVA was used to establish that there was no significant difference between the consumption with variable temperature compared to the results received when the temperature was held between 17.5-18.5°C (Figure 1). Mean number of snails eaten in the variable replicates (1-6) were:148 for *O. rusticus*, 59 for *O. propinquus*, and 113 for *O. virilis*. Means for the replicates (7-16) run with constant temperature were:145 for *O. rusticus*, 42 for *O. propinquus*, and 74 for *O. virilis.*

Mean number of snails eaten when all sixteen replicates (1-16) were compared together were: 145 for *O. rusticus*, 57 for *O. propinquus*, and 89 for *O. virilis*. An ANOVA indicated that there was a significant difference among the mean feeding rates of the three species (ANOVA, $p<0.0001$), with *O. rusticus* greater than *O. virilis* and *O. propinquus* (Tukey's Test, $p<0.05$) (Figure 2).

Discussion

Results ~~The data received~~ indicated that there was a significant difference in consumption rates between *O. rusticus* and the consumption rates of *O. virilis* and *O. propinquus* per unit biomass. This conclusion helps to clarify the contradictory results received in early studies of consumption (Zurovchak and Olsen, unpublished papers). My results were established using a gastropod food in isolation which facilitated control of the environment and feeding period. Previous experiments indicated that the heavy impact of *O. rusticus* stems from the high densities it achieves as a result of its' highly aggressive nature and resistance to predation. My results indicate that in addition to its' larger size, highly aggressive nature, and resistance to predation, the O. rusticus may possess a higher metabolic rate than the other two species which results in the higher rate of consumption. The destructive effects of O.rusticus on the benthic community may therefore also result from the fact that it consumes more than the O. propinquus and O. virilis per unit biomass.

good - This is much clearer than p3

The major difference between this study and similar previous studies is that crayfish were trapped as they were needed and were quickly used ~~used in replicates~~. Previous experiments comparing consumption rates used crayfish that had been held in captivity for extended periods of time (Zurovchak, unpublished work). These crayfish were no longer exposed to the normal fluctuations in temperature, photoperiod, and were fed the same food for an extended period of time. These changes may have affected the feeding rates of the different species, but not necessarily to the same extent. The fact that Form II male crayfish were used in this experiment, unlike the Form I used during previous experiments, may also have affected the results.

The effects of temperature on consumption are inconclusive. The difference in consumption between the first six trails and the last ten showed no statistically significant difference. The difference of means received for O. virilis (113 snails with variable temperature versus 75 snails with constant temperature) would appear to indicate some trend (Figure 1), but the small sample size prevented the establishment of a significant difference. The pattern of temperature variance established in the two trial runs (Appendix 1) indicates that while the temperature varies throughout the day, the temperature during the nocturnal feeding period was in a range between 20-25 degrees Celsius. While this temperature range is higher than the range of 17.5-18.5 degrees Celsius in the runs 7-16, the temperature elevation may not have been significant enough to cause a change. The results were not significant, but the large difference in means of O. virilis indicates that future research may establish that temperature has an effect.

CONCLUSION

By keeping the crayfish in their normal feeding cycle we were able to establish the comparative feeding rates of the three Orconectes species with improved confidence over the previous experiments of a similar design. The deleterious effects of O. rusticus may result from differential rates of consumption per unit biomass in addition to the established differences in aggression, size, and resistance to predation that result in higher densities of O. rusticus. By following this experimental design, I was able to establish that the higher rate of consumption per unit biomass of O. rusticus, as compared to O. propinquus and O virilis, may contribute to the deleterious effects it has on lake systems.

ACKNOWLEDGEMENTS

I would like to thank David M. Lodge for the valuable advice he gave me during the development and interpretive stages of the experiment. I would like to give thanks to Mark Kershner and Mark Olsen who assisted me in the collection of the crayfish used in the experiment. I would also like to give special thanks to Bernard J. Hank, whose generous contribution funds the UNDERC program for undergraduate students at the University of Notre Dame, under which my project was funded.

LITERATURE CITED

Capelli, G.M. (1975) "Distribution, life history and ecology of crayfish in northern Wisconsin, with emphasis on Orconectes propinquus." Ph. D. Thesis, University of Wisconsin, Madison, WI. 215 p.

Capelli, Gregory M. and Magnuson, John J. (1983). "Morphoedaphic and biogeographic analysis of crayfish distribution in northern Wisconsin." Journal of Crustacean Biology 3(4) :548-564.

Hobbs III, H.H. and Jass, Joan P. (1988) The Crayfishes & Shrimp of Wisconsin. Milwaukee, WI: Milwaukee Public Museum.

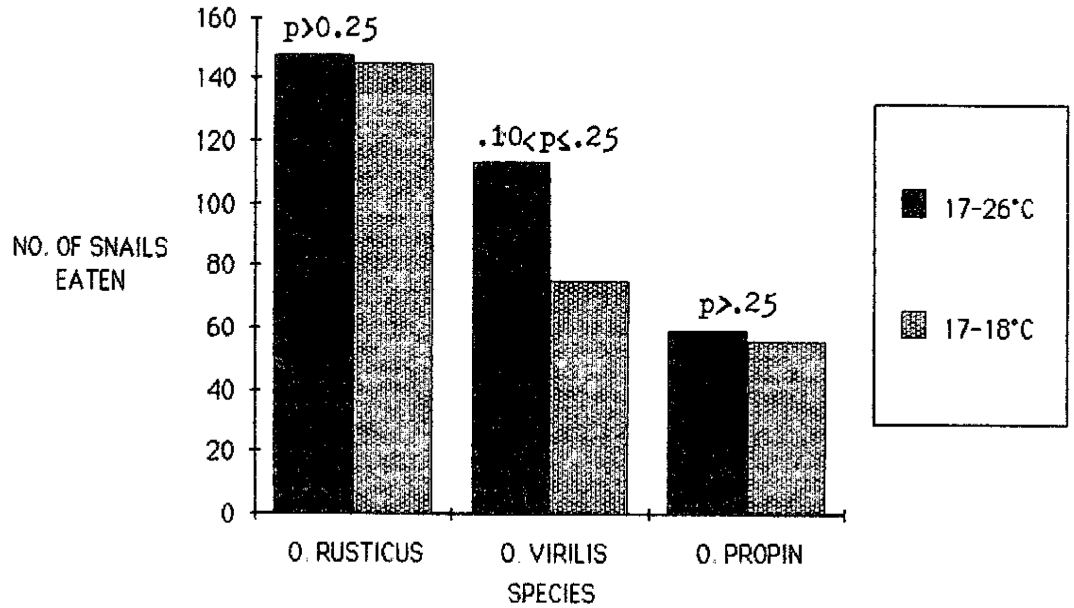
Lodge, David M. and Lorman, James G. (1987). "Reductions in submersed macrophyte biomass and species richness by the crayfish Orconectes rusticus." The Canadian Journal of Fisheries and Aquatic Sciences. 44 :591-597.

Lodge, David M., Beckel, Annamarie L., and Magnuson, John J. (1985). "Lake-bottom tyrant." Natural History 94 :32-37.

Lodge, David M., Kratz, Timothy K., and Capelli, Gregory M. (1986). "Long-term dynamics of three crayfish species in Trout Lake, Wisconsin." The Canadian Journal of Fisheries and Aquatic Sciences. 43 :993-998.

Zurovchak, Joseph G. (1987) "Feeding rates of three Orconectes species of crayfish." Unpublished paper.

FIQUIRE 1

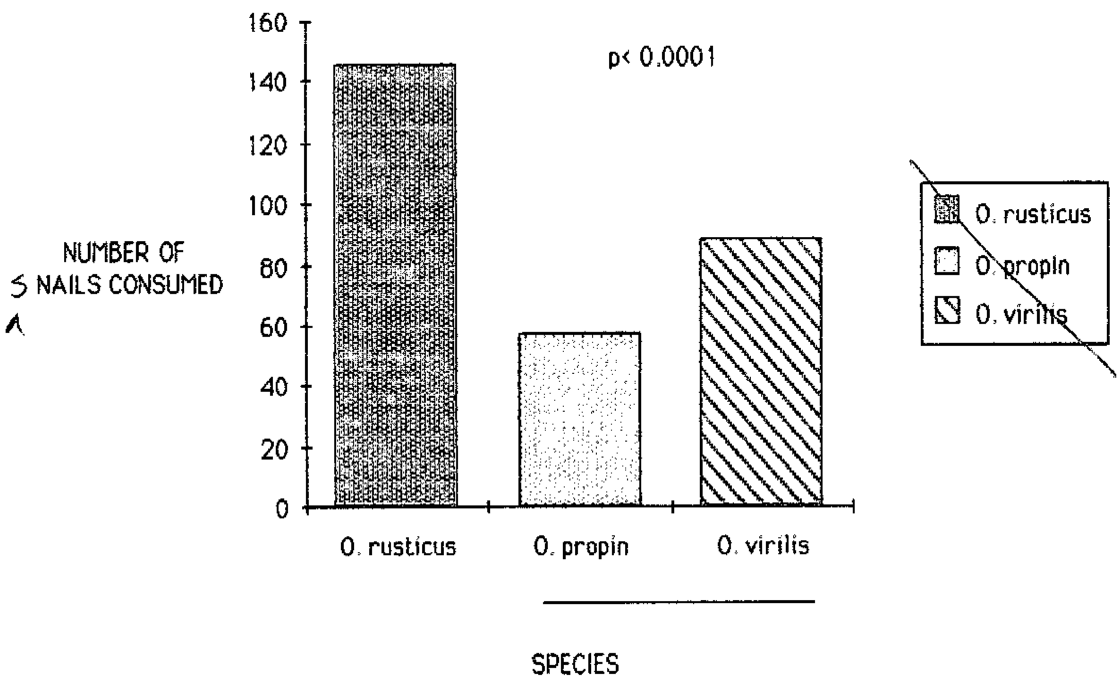


This is a graph comparing the number of snails consumed by each species when temperature was constant in trials (1-6) versus the variable temperature of trials (7-16)

?

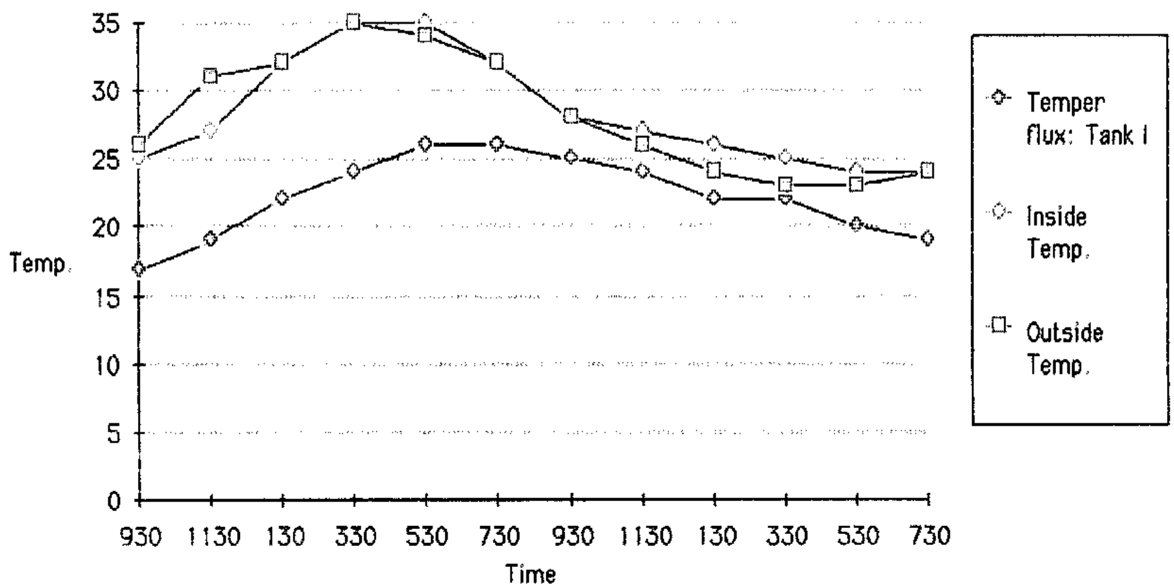
Order of species is reverse of that in Fig 1.

FIGURE 2



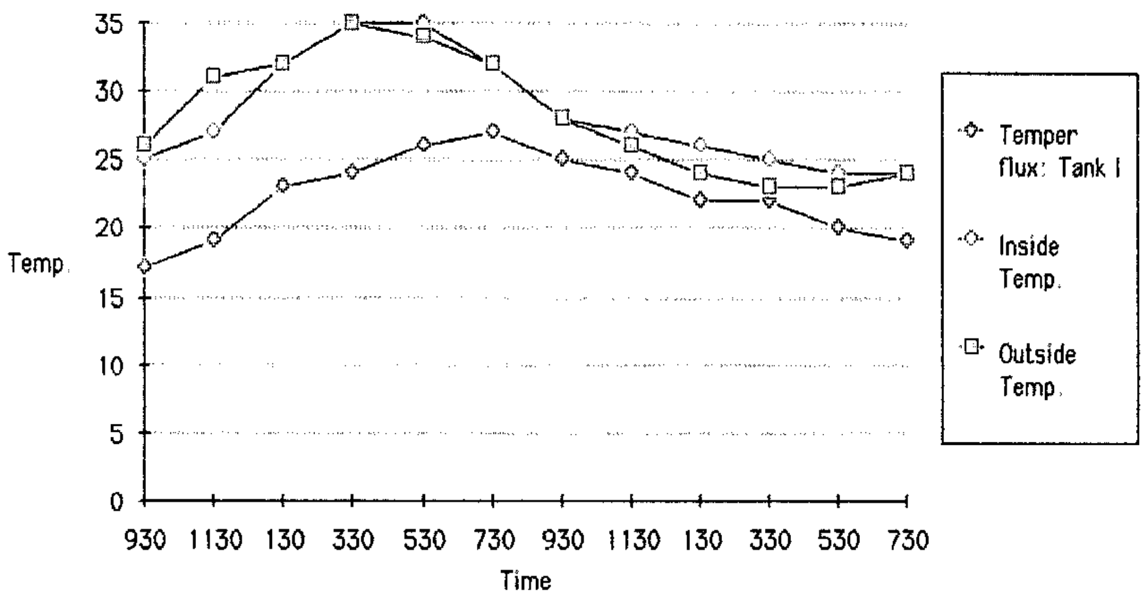
Mean number of snails consumed by O. rust., O. virilis, and O. propinquus.
Horizontal bar connects means that are not different (Tukeys, P >0.05).

APPENDIX 1 A



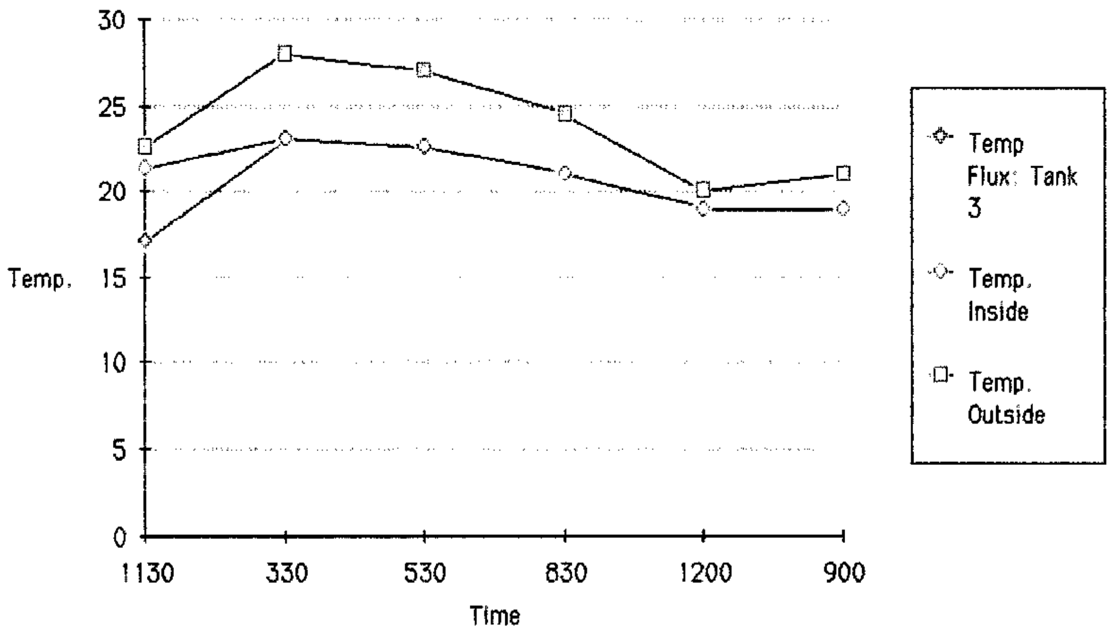
This graph decribes the pattern of temperature fluctuation in tank 1 on a day with a temp. range of 26-35°C.

APPENDIX 1 B



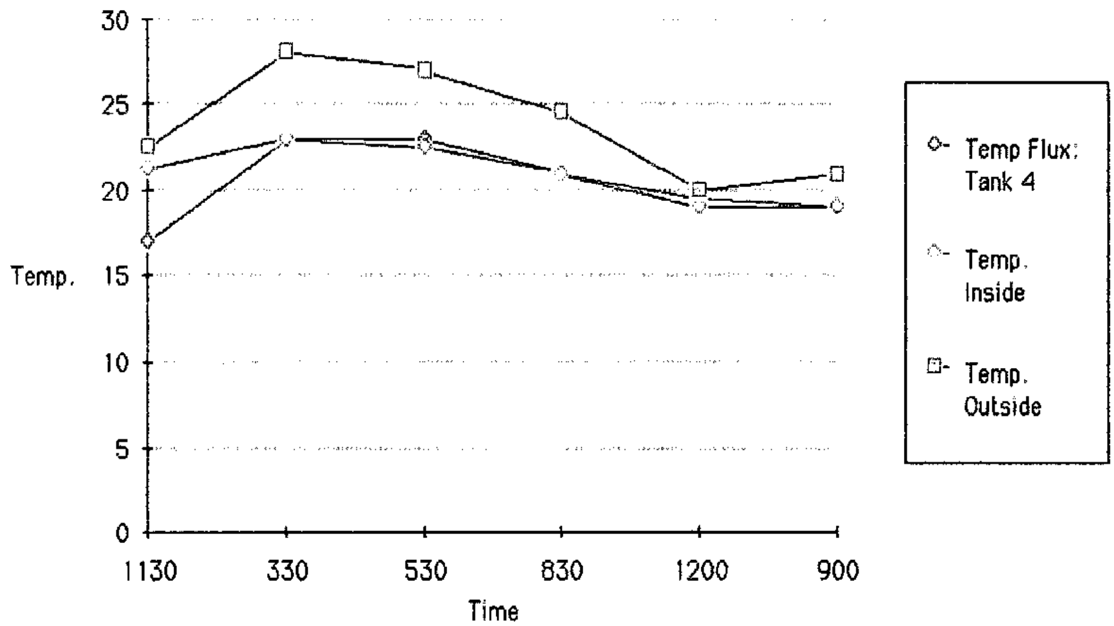
This graph decribes the pattern of temperature fluctuation in tank 2 on a day with a temp. range of 26-35°C.

APPENDIX 1



This graph decribes the pattern of temperature fluctuation in tank 1 on a day with a temp. range of 22.5-28°C.

APPENDIX 1



This graph decribes the pattern of temperature fluctuation in tank 2 on a day with a temp. range of 22.5–28°C.

Replicate #

APPENDIX 2

APPENDIX 2	O. rusticus			
#: DATE	WEIGHT g	CARAPACE mm	COLLECTION WEEK	# OF SNAILS EATEN
1 : 6/7/88	10.15	31.25	5/6/88 Trout	205
2 : 6/7/88	10.25	32.3	5/6/88 Trout	112
3 : 6/20/88	8.73	31	6/20/88 Trout	178
4 : 6/20/88	9.05	32.1	6/20/88 Trout	134
5 : 6/21/88	9.33	32.5	6/20/88 Trout	146
6 : 6/21/88	9.51	31.3	6/20/88 Trout	110
7 : 6/25/88	10.14	32.5	6/20/88 Trout	157
8 : 6/25/88	10.68	34	6/20/88 Trout	120
9 : 6/27/88	11.45	35.5	6/20/88 Trout	230
10 : 6/27/88	11.69	34.4	6/20/88 Trout	51
11 : 6/28/88	11.85	34.5	6/20/88 Trout	93
12 : 6/28/88	11.31	33.3	6/20/88 Trout	181
13 : 6/29/88	12.22	34.5	6/20/88 Trout	111
14 : 6/29/88	13.06	35.5	6/20/88 Trout	152
15 : 6/30/88	9.66	31.8	6/20/88 Trout	144
16 : 6/30/88	11.15	34	6/20/88 Trout	160
APPENDIX 2	O. propinquus			
#: DATE	WEIGHT g	CARAPACE mm	COLLECTION WEEK	# OF SNAILS EATEN
1 : 6/7/88	9.8	31	5/6/88 Tenderfoot*	23
2 : 6/7/88	9.83	32.1	5/6/88 Tenderfoot	71
3 : 6/20/88	8.93	31.2	6/20/88 Tenderfoot	16
4 : 6/20/88	9.27	32	6/20/88 Tenderfoot	122
5 : 6/21/88	9.53	30.3	6/20/88 Tenderfoot	116
6 : 6/21/88	9.24	30.6	6/20/88 Tenderfoot	2
7 : 6/25/88	10.27	32.1	6/20/88 Tenderfoot	20
8 : 6/25/88	10.23	32.5	6/20/88 Tenderfoot	154
9 : 6/27/88	11.18	33.1	6/20/88 Tenderfoot	60
10 : 6/27/88	11.1	32.8	6/20/88 Tenderfoot	8
11 : 6/28/88	12.68	33.1	6/20/88 Tenderfoot	76
12 : 6/28/88	10.5	31.6	6/20/88 Tenderfoot	6
13 : 6/29/88	12	33.5	6/20/88 Tenderfoot	112
14 : 6/29/88	13.11	34	6/20/88 Tenderfoot	89
15 : 6/30/88	9.6	30.4	6/20/88 Tenderfoot	88
16 : 6/30/88	9.9	32.7	6/20/88 Tenderfoot	41

Appendix 2 describes and records the date and site of collection of all crayfish used in the experiment.

* In addition to the O. propinquus collected on Tenderfoot Lake, several crayfish were captured at Stevenson Creek, which is a stream that enters into Trout Lake.

APPENDIX 2	O. virilis			
DATE	WEIGHT g	CARAPACE mm	COLLECTION WEEK	# OF SNAILS EATEN
1 : 6/7/88	9.25	33.8	5/6/88 Wh. Sand	134
2 : 6/7/88	9.5	33.4	5/6/88 Wh. Sand	111
3 : 6/20/88	9.2	31.9	6/20/1988 Wh. Sand	34
4 : 6/20/88	9.5	34.8	6/20/1988 Wh. Sand	105
5 : 6/21/88	9.32	32.7	6/20/1988 Wh. Sand	187
6 : 6/21/88	9.53	35.25	6/20/1988 Wh. Sand	104
7 : 6/25/88	10.78	35.9	6/20/1988 Wh. Sand	106
8 : 6/25/88	10.79	35.3	6/20/1988 Wh. Sand	134
9 : 6/27/88	11.53	35.5	6/20/1988 Wh. Sand	117
10 : 6/27/88	11.82	35.1	6/20/1988 Wh. Sand	26
11 : 6/28/88	11.97	36	6/20/1988 Wh. Sand	27
12 : 6/28/88	11.09	35.5	6/20/1988 Wh. Sand	32
13 : 6/29/88	12.25	36.3	6/20/1988 Wh. Sand	48
14 : 6/29/88	13.15	36.2	6/20/1988 Wh. Sand	82
15 : 6/30/88	9.5	33.6	6/20/1988 Wh. Sand	41
16 : 6/30/88	10.81	35.8	6/20/1988 Wh. Sand	133

APPENDIX 3

One Way ANOVA 3 Groups

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	65292.667	32646.333	14.397
Wihin groups	45	102043.25	2267.628	p ≤ .0001
Total	47	167335.917		

Model II estimate of between component variance = 1898.669

1

Group:	Count:	Mean:
CONSUMPTION VIRILUS	16	89.125
CONSUMPTION PROPINQ...	16	56.625
CONSUMPTION RUSTICUS	16	145.875

2

Appendix 3 lists the comparative analysis of the means of the three species. The ANOVA indicated that there was a significant difference between at least one pair of the means analysed ($p<0.0001$)

	CONSUMPTION VIRILUS	CONSUMPTION PROPINQUUS	CONSUMPTION RUSTICUS
1	139	25	205
2	111	71	112
3	34	16	170
4	105	122	134
5	107	116	110
6	104	2	146
7	106	20	120
8	134	154	157
9	117	0	51
10	26	60	230
11	32	6	181
12	27	76	93
13	82	89	111
14	48	12	132
15	41	80	160
16	133	41	194

APPENDIX 4

One Way ANOVA 2 Groups
O. virilis

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	5626.017	5626.017	2.574
Wihin groups	14	30597.733	2185.552	.10 < p ≤ .25
Total	15	36223.75		

Model II estimate of between component variance = 458.729

1

Group:	Count:	Mean:
Virilus Var	6	113.333
Virilus Const	10	74.6

2

Appendix 4 is a listing of the data accumulated from the analysis comparing the consumption rates of each species when the temperature is constant versus when the temperature is variable.

The data above describes the change in consumption by O. virilis when the temperature is constant versus when the temperature varies with the outside temperature. The ANOVA indicates that the difference of means between the two groups of data are not significant ($0.1 < p \leq 0.25$).

	Virilus Var	Virilus Const
	Virilus Var	Virilus Const S
1	139	106
2	111	134
3	34	117
4	105	26
5	107	32
6	104	27
7	•	82
8	•	48
9	•	41
10	•	133

One Way ANOVA 2 Groups

O. rusticus

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	25.35	25.35	.011
Wihin groups	14	31748.4	2267.743	p > .25
Total	15	31773.75		

Model II estimate of between component variance = -298.986

1

Group:	Count:	Mean:
RUSTICUS VAR	6	147.5
RUSTICUS CONST	10	144.9

2

The data above describes the change in consumption by O. rusticus when the temperature is constant versus when the temperature varies with the temperature outside. The ANOVA indicates that the difference of means between the two is not significant ($p > 0.25$).

	RUSTICUS VAR	RUSTICUS CONST
1	205	120
2	112	157
3	170	51
4	134	230
5	110	101
6	146	93
7	•	111
8	•	152
9	•	160
10	•	194

One Way ANOVA 2 Groups

O. propinquus

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	40.017	40.017	.016
Wihin groups	14	34005.733	2428.981	p > .25
Total	15	34045.75		

Model II estimate of between component variance = -318.529

1

Group:	Count:	Mean:
Propin Var	6	58.667
Propin Const	10	55.4

2

The data above describes the change in consumption by O. propinquus when the temperature is constant versus when the temperature varies with the outside temperature. The ANOVA indicates that the difference of means between the two are not significant (p>.25)

	Propin Var	Propin Const
1	25	20
2	71	154
3	16	0
4	122	60
5	116	6
6	2	76
7	∘	09
8	∘	12
9	∘	88
10	∘	41

APPENDIX 5

Tukey's Test (Hand Calculations)

$$S_{\bar{y}} = \sqrt{\frac{MS_{with}}{n}} = \sqrt{\frac{2267.628}{16}} = \sqrt{141.73} = 11.905$$

$$MSD = (\text{Crit. Val}) \times SE$$

$$MSD = 3.42 \times 11.905 = 40.715$$

$$Q = .05[3,45] = 3.442$$

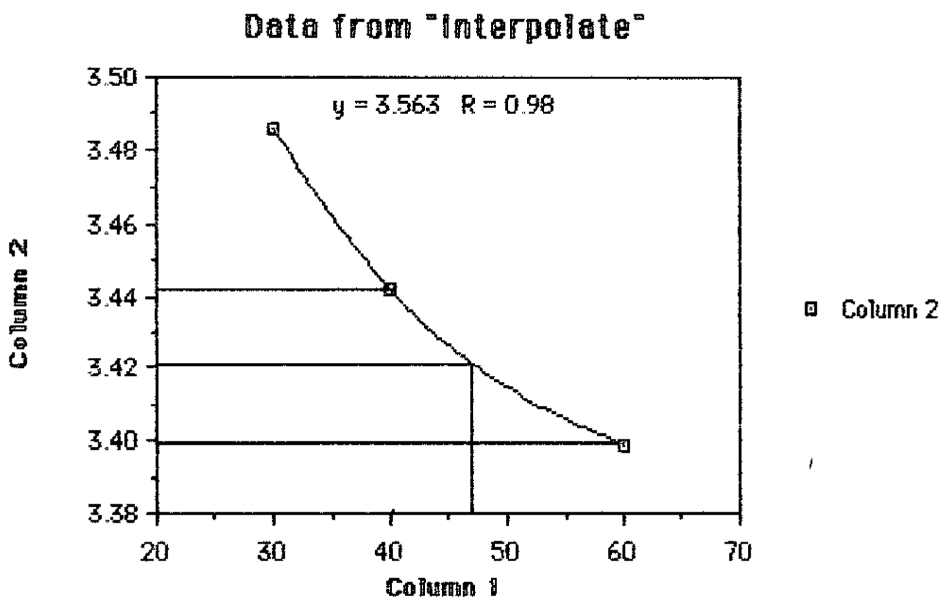
$$\bar{Y}_V - \bar{Y}_P = 89.125 - 56.625 = 32.5 < 40.715$$

$$\bar{Y}_R - \bar{Y}_P = 145.875 - 56.625 = 89.25 > 40.715$$

$$\bar{Y}_R - \bar{Y}_V = 145.875 - 89.125 = 56.625 > 40.715$$

Propin	Virilis	Rusticus
$\bar{X}_1 = 56.625$	$\bar{X}_2 = 89.125$	$\bar{X}_3 = 145.875$

Appendix 5 includes the hand calculations used to find which pairs of means were significantly different from each other. Tukey's Test was used for this calculation. It was found that O. rusticus consumes more than O. propinquua and O. virilis ($p<0.05$). The mean rates of consumption of O. propinquus and O. virilis were not significantly different.


Data from "Interpolate"
y = 3.563 R = 0.98
3.50
3.48
3.46
3.44
3.42
3.40
3.38
Column 2
20
30
40
50
60
70
Column 1
Column 2