PSU McNair Scholars Online Journal

Volume 2
Issue 1 *Challenging Paradigms: New Frontiers in Graduate Research*

Article 24

2006

Food Web Impacts of the Invasive New Zealand Mudsnail in an Estuarine System

Amanda L. Kelley
Portland State University

Recommended Citation
Kelley, Amanda L. (2006) "Food Web Impacts of the Invasive New Zealand Mudsnail in an Estuarine System," *PSU McNair Scholars Online Journal*: Vol. 2: Iss. 1, Article 24.
10.15760/mcnair.2006.162

Portland State University McNair Research Journal 2006-2008

Food Web Impacts of the Invasive New Zealand Mudsnail in an Estuarine System

by
Amanda L. Kelley

Faculty Mentors:
Valance Brenneis and Catherine deRivera

Citation: Kelley, Amanda L. Food Web Impacts of the Invasive New Zealand Mudsnail in an Estuarine System. Portland State University McNair Scholars Online Journal, Vol. 2, 2006-2008: pages [162-174].

Food Web Impacts Of The Invasive New Zealand Mudsnail In An Estuarine System

Amanda L. Kelley
Valance Brenneis, Faculty mentor
Catherine E. de Rivera, Faculty Mentor

Abstract

Non-indigenous species (hereafter NIS) have long been recognized as adversely affecting habitats they invade. While many of their documented ecological impacts have been to specific species, namely prey, they may impact whole food webs. Both vertebrate and invertebrate NIS have been present in the Columbia River since the mid 1800's. The New Zealand mudsnail, (*Potamopyrgus antipodarum,* hereafter NZMS) was first reported in the Columbia River Estuary in 1995. This typically freshwater NIS invaded Youngs Bay, a shallow embayment within the Columbia River estuary system, and has proliferated within this benthic community. To date, there have been no inquiries into the impact of NZMS on the food web in a brackish water estuary within the United States. To identify community-level impacts by the invasive NZMS, an ecological census of the benthic communities of Youngs and Cathlamet Bays (reference site) was conducted, including comprehensive sampling of vertebrates and benthic invertebrates from these two brackish water systems. Stable isotope analysis (SIA) from these two systems is being utilized to identify trophic level food web relationships. 50% of one common estuarine fish, the Pacific staghorn sculpin (*Leptocottus armatus)* were found to contain NZMS in their guts. Furthermore, I have found densities reaching 15,711 snails/m^2 sampled. These results indicate NZMS in Youngs Bay may affect higher trophic levels.

Introduction

The New Zealand mudsnail, (*Potamopyrgus antipodarum,* hereafter NZMS) is a freshwater snail that has invaded several parts of the globe, including the United States. Although males and female snails exist in their native New Zealand, in the Western US, this species is entirely female and parthenogenic in nature(Dybdahl and Kane 2005). Adult snails can reach 6 mm in length(Dybdahl and Kane 2005), and have the ability to tolerate a wide range of physical conditions. This is accomplished by having a hard shell with an operculum that can be sealed to protect against desiccation, digestion, and other stresses, including a wide-range of pH and salinity variation (Jacobsen and Forbes 1997; Alonso and Camargo 2004). In fact, despite the lack of genetic variation, they thrive in a diversity of habitats (Dybdahl and Kane, 2005). In general, NIS arrive in their new environment

without their natural predator, which often leaves these populations unchecked and able to experience dynamic population growth. For example, NZMS have the capability of reaching extremely high densities, up to 800,000 per m^2 in Lake Maarsseveen, in the Netherlands (Dorgelo 1987). In addition, they are able to dominate the benthic community; in one study NZMS constituted 65–92% of total invertebrate productivity (Hall, Dybdahl et al. 2006).

The NZMS was first identified in the United States in the middle section of the Snake River in central Idaho in 1985 (Langenstein and Bowler 1990). Currently, the NZMS has been identified in all of the western states. The NZMS was first reported in the Columbia River Estuary in 1995 (Sytsma et al., 2004, Wonham and Carlton, 2005). This population is believed to have been transported via human vectors from other river systems in the Western U.S. In fact, the Lower Columbia River population of NZMS is monogenic, being comprised of the same clone that is found in all the riverine populations in the Western US. The Columbia Estuary population comprised the first NZMS sighting in a brackish water system in the United States, although they are now known to exist in other estuaries such as Coos Bay, OR. High densities (up to 200,000 individuals/m^2) (Litton 2000), have been found at sites in Youngs Bay, a brackish bay in the Columbia River Estuary. At high densities, NZMS are capable of consuming large volumes of algae and detritus, potentially reducing the production of native benthic estuarine inhabitants (Hall, Dybdahl et al. 2006).

A greater understanding of the impact of this invasive species in an estuarine system requires knowledge about its effects on native benthic invertebrates, their prey, and predators. It is important to understand whether the high densities of NZMS, such as those in Youngs Bay, alter the food web in this sensitive estuarine system. These shifts in food web relationships may have lateral impacts on native species that occupy roughly the same

trophic level as the NZMS, such as amphipods and isopods, due to their use of scarce resources (e.g., food or physical space). These native epibenthic invertebrates are an important food source for many predators. This bottom up effect of an invasive secondary trophic level species may also impact higher trophic level predators such as Three-Spine Stickleback (*Gasterosteus aculeatus*) and Pacific Staghorn Sculpin (*Leptocottus armatus*). These species may inadvertently feed on the NZMS, which are nutritionally inferior to the native benthic invertebrates that are present (McCarter 1986; Sagar and Glova 1995; Bruce and Moffitt 2005; Vinson, Dinger et al. 2006). New Zealand mudsnails have been documented in the digestive system of juvenile Chinook sampled from the Lower Columbia Estuary (Bersine et al., in prep), demonstrating that they may have become incorporated into the diet of this endangered species.

NZMS primarily feed on algae, which predominantly occurs in the photic zone. Therefore, we expected that higher NZMS densities would be found in the shallowest sampling depth, five feet. Also we expected to find a relationship between lower salinity values and an increase in mudsnail density, bearing in mind that this NIS primarily lives in freshwater river systems.

Materials and Methods

Site description

Columbia River

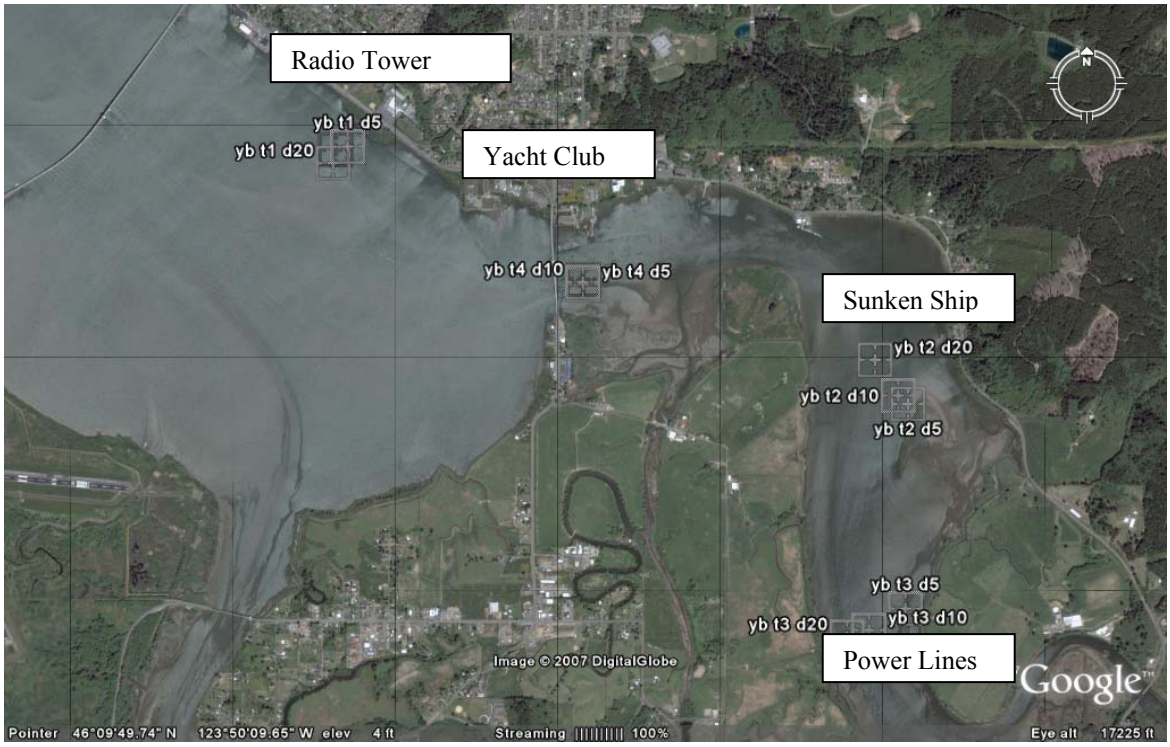
The Columbia River Basin is the largest freshwater river system in the Pacific Northwest, and is the second largest river system in the U.S. with reference to volume discharged. Its drainage basin covers 671,000 km^2 in seven states and one Canadian province. From the mouth to Skamokawa, WA (~river km 56) the lower Columbia River is a coastal plain estuary (Simenstadt et al., 1990). Both vertebrate and invertebrate invasive species have

been present in the Columbia River since the mid 1800's. Domestic and international shipping are thought to be the primary vectors for the introduction of NIS on the Columbia River. The two study sites, Youngs and Cathlamet Bays, are shallow embayments within the Columbia River Estuary (Holton, 1984).

Youngs Bay

Youngs Bay is a shallow embayment on the south shore of the Columbia River. Youngs River flows into Youngs Bay, which stretches approximately three and a half miles from the confluence of the Walooski River to the mouth of Youngs bay on the Columbia River Estuary. Youngs Bay is roughly a mile and a half across at the widest point. Its bathometry can be described as a wide, gentle demersal slope, which generally is no deeper than 15 feet on average. The middle of the bay has been dredged repeatedly to allow larger ship traffic, but is only 35 feet deep at its deepest point. Seasonal water temperature varies from nine to 20 °C, and salinity measurements generally were below 10 parts per thousand (here after ppt), but occasionally exceeded 25 ppt (Higley 1974).

Fig. 1. Youngs Bay Sample Sites



Cathlamet Bay

Cathlamet Bay is also a shallow embayment on the south shore of the Columbia River, upstream of Youngs Bay. At the mouth of the John Day River, the bay reaches its deepest point, roughly 30 feet. Temperature ranges between 2.4 and 23.9 °C, and salinity values ranging from 0 to 23.7 ppt (Database 2001-2007). However, primary production in Cathlamet bay is considerable lower than Youngs Bay at 22.63 g C m^3/yrcompared to 71.19 g C m^3/yr^{-2} yr^1 respectively (McIntire 1984).

Field Sampling

Fish and benthic invertebrates were sampled to characterize the estuarine food webs in Youngs and Cathlamet Bays and to determine the potential impacts of mudsnails on these food webs. Biological and physical samples were collected at three depths (5, 10 and 20 ft) along four transect perpendicular to the shore, for a total of twelve samples per bay.

Youngs Bay was sampled from the 5th of July 2007 through 22nd of July 2007, and Cathlamet Bay was sampled from the 30th of July 2007, through the 2nd of August, 2007.

Fish were collected with baited (canned cat food) Wildco collapsible mesh minnow traps deployed at the five foot depth of each transect for 24 hours. Fish were identified to species, counted, and then randomly chosen for gut content analysis. To analyze the gut contents, we opened the digestive tract and noted the presence or absence of NZMS (only Youngs Bay fish samples) as well as presence of other invertebrates. Fish muscle tissue samples were collected from these fish and placed in a 1.5ml tube and frozen for later analysis.

A petite ponar grab was employed to sample benthic invertebrates. Two grabs (totaling 0.045 m^2) were taken per sample site with the resulting sediment being sieved through a 1mm mesh. The remaining invertebrates were then stored in a 500 ml Nalgene sample bottle and suspended in 70% ethanol solution. Invertebrate tissue samples were taken randomly for later analysis. Plankton net with an 80 μm cod end was towed through the water to full length of the retrieving rope, 15 ft. The sample (phytoplankton and water) was then taken up by a 50 ml syringe, retained on filter paper, stored in a 1.5 ml tube, and frozen for future analysis.

Abiotic characteristics were measured at each site to describe the physical parameters. An Eagle Cuda Fish finder was used to determine water depth. The petite ponar grab was used to retrieve water samples directly adjacent to the benthic sediment at each sample depth (5, 10, 20 ft). The resulting water was then subject to a series of measurements: temperature, salinity, conductivity, pH, and TDS using an Extech II Extik pH/conductivity EC 500. Sampling was done between 9 am and 6 pm, and no special consideration was

taken in regards to the tidal influence. A Magellan Explorist 100 was used to record geographic coordinates at each sample site.

Animal tissue (1 mg) and phytoplankton (on precombusted Whatman GF/C filters) samples were dried for 48 hours at 60°C and weighed into tin capsules (Costech) for stable isotope analysis. Stable isotope analysis will be performed by the Stable Isotope Facility at the University of California, Davis using a Europa Hydra 20/20 continuous flow isotope ratio mass spectrometer. This data will be coupled with previous stable isotope data to construct a food web for the system.

Statistical Analyses

Analysis of variance (ANOVA) was used to determine whether there were any correlations between NZMS density and the varying sampling depths in Youngs Bay. The assumptions of ANOVA were met (normality of residuals, homogeneity of variance).

Results

Fish Gut Content Analysis:

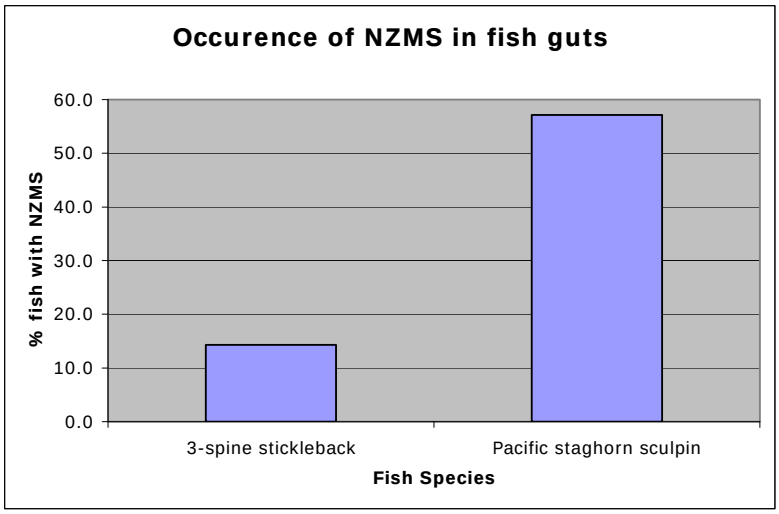
The most striking result of the gut content analysis was that 57% of Pacific Staghorn Sculpin with full stomachs contained NZMS. However, statistical analysis of fish species versus NZMS predation did not yield any statistically significant data because of the small sample size of fish collected. Power was low (0.4) but it is likely that a larger samples size would show significant effects. Also, the assumptions of ANOVA were not met because the data gathered was not normally distributed (Table 1, Figure 2).

Table 1. Percentage of fish with NZMS in full stomach

Fish Species	Total n	Non-empty	% empty	**# w/NZMS**	**% w/NZMS**
3-spine stickleback	14	7	50	1	14.3
Pacific staghorn sculpin	8	7	12.5	4	57.1
Prickly sculpin	2	1	50	0	0.0

Shiner surfperch	4	0	100	0

Fig. 2. Percentage of fish with NZMS found in gut



Density and Depth Correlation in Youngs Bay:

There was no significant correlation between NZMS density and the different sampling sites (Table 2, 3 and Figure 3).

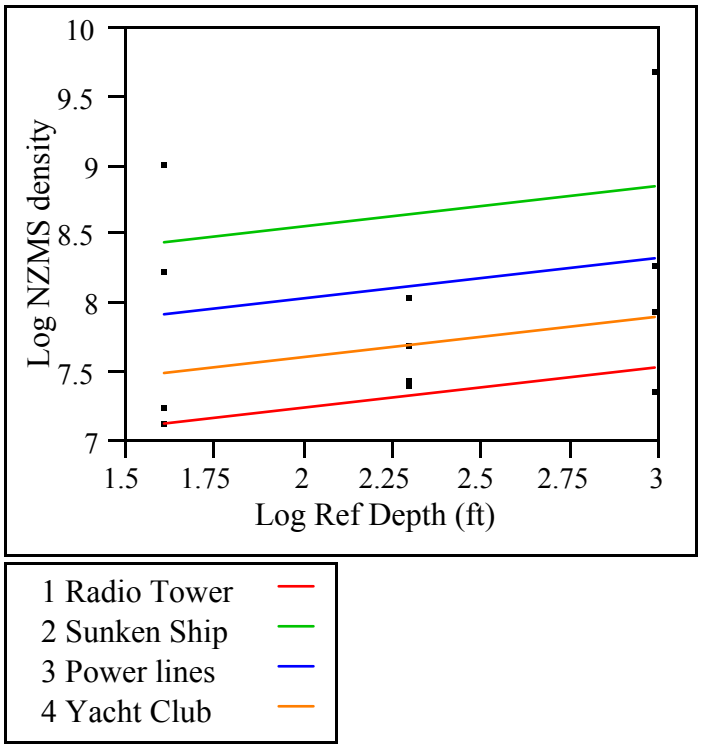
Table 2. Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	3.22	0.80	1.73
Error	7	3.26	0.47	**Prob > F**
C. Total	11	6.47		0.2473

Table 3. Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Transect name	3	3	2.8826182	2.0652	0.1934
Log Ref Depth (ft)	1	1	0.3349124	0.7198	0.4243

Fig. 3. NZMS density by depth and transect
Regression Plot



Multivariate correlation between NZMS density and abiotic parameters:

The multivariate analysis of NZMS density and various abiotic parameters yielded no significant correlation between snail density and the spectrum of abiotic characteristics that were measured in Youngs Bay. Not surprisingly, several abiotic parameters were highly correlated with one another (Table 4).

Table 4: Pairwise Correlations

Variable	by Variable	Correlation	Count	p-value
Temp F	NZMS #/m2	0.4493	12	0.1428
Salinity ppt	NZMS #/m2	-0.3530	12	0.2604
Salinity ppt	Temp F	-0.9380	12	0.0000
Conductivity ms	NZMS #/m2	-0.3496	12	0.2652
Conductivity ms	Temp F	-0.9309	12	0.0000
Conductivity ms	Salinity ppt	0.9990	12	0.0000
pH	NZMS #/m2	-0.3022	11	0.3664
pH	Temp F	-0.7922	11	0.0036

Variable	by Variable	Correlation	Count	p-value
pH	Salinity ppt	0.8797	11	0.0004
pH	Conductivity ms	0.8739	11	0.0004
TDS ppt	NZMS #/m2	-0.3494	12	0.2655
TDS ppt	Temp F	-0.9277	12	0.0000
TDS ppt	Salinity ppt	0.9992	12	0.0000
TDS ppt	Conductivity ms	0.9997	12	0.0000
TDS ppt	pH	0.8736	11	0.0004
Actual depth (ft)	NZMS #/m2	0.3228	12	0.3062
Actual depth (ft)	Temp F	0.0046	12	0.9886
Actual depth (ft)	Salinity ppt	0.1220	12	0.7056
Actual depth (ft)	Conductivity ms	0.1202	12	0.7098
Actual depth (ft)	pH	0.0920	11	0.7878
Actual depth (ft)	TDS ppt	0.1293	12	0.6889

Discussion

Although the fish gut content analysis did not produce any statistically significant data due to the small sample size, we can still glean useful information from it. The mudsnail was found in the digestive track of two fish species, Pacific staghorn sculpin (*Leptocottus armatus*), and three-spine stickleback (*Gasterosteus aculeatus*). Of fish with non-empty stomachs, the Pacific staghorn sculpin had a high frequency of ingested NZMS, 57% of this species (4 out of 7) sampled had NZMS in their gut. The three-spine stickleback had a lower frequency of NZMS ingestion, with 14.3% of fish (1 out of 7) sampled having mudsnail in their stomachs. We can compare this data with a NOAA report that was executed in 2002 through 2005 where the diet of juvenile Chinook was examined for the presence of NZMS. They found no snails present in 2002 or 2003, but in 2004 two out of 370 salmon had NZMS in their gut, which is only about a 0.5% frequency. In 2005, 64

Chinook were sampled, and only one was found to have NZMS in its stomach. This rate of occurrence is only 1.5% for 2005 (Bersine, Brenneis et al. in prep.). The rate of NZMS ingestion occurrence we found in Youngs Bay was drastically higher than what the NOAA report concluded. This is likely due to feeding differences, with a higher NZMS occurrence expected in benthic feeders such as sculpin.

Contrary to our predictions, depth did not appear to limit NZMS distribution in Youngs Bay. There was no correlation between NZMS density and depth (from 0 to 20 ft) or transect site. In fact, the highest NZMS density, 15,711 snails/m^2 was collected at the 20 foot depth. The lack of correlation with depth indicates that NZMS populations are consuming benthic detritus in addition to algae. The observation that NZMS are not limited to the shallow inter-tidal increases the potential impact of this invasive species on the benthic food web.

Individually, pH, salinity, temperature, conductivity, and TDS had virtually no influence on NZMS densities. We can also view this information from the perspective that the NZMS is so well suited for a wide range of physical environments that they can proliferate unhindered across a wide range of environments. That is to say that the density of NZMS in Youngs Bay does not appear to be limited by the range of the abiotic parameters we measured.

We can conclude from this investigation that the mudsnail has indeed been incorporated into the food web of the benthic community in Youngs Bay. Clearly, sample depth or transect site had no influence on NZMS density. Also, we found that all the abiotic parameters measured had absolutely no effect on mudsnail density. Further study will include constructing a food web of this community using stable isotope analysis and comparing the results with that of our reference site, Cathlamet Bay. SIA laboratory

analysis includes the carbon and nitrogen isotope values of these samples will be used in conjunction with gut content data and previously collected invertebrate and primary producer data to compile an integrated description of food web structure (Peterson and Fry 1987; Ilken, Brey et al. 2001). Armed with this information, we will be able to better describe the effect of the invasive New Zealand mudsnail on this estuarine food web.

Acknowledgments

I would like to thank Dr. Cathrine deRivera, Valance Brenneis, Dr. Brad Buckley, Dr. Debbie Duffield for all of your advice and support. Also, thanks to Lee Cain at Astoria High School for the use of the laboratory, as well as all of the information he employed us with.

Grants

This project was funded by the Ronald McNair Scholarship program at Portland State University. This scholarship allows first generation college graduates and underrepresented minority students the opportunity to conduct original research, as well as preparing students for the rigors of graduate school, and succeed in completing a doctoral program.

References

Alonso, A. and J. A. Camargo (2004). "Sub-lethal responses of the aquatic snail *Potamopyrgus antipodarum* (Hydrobiidae, Mollusca) to unionized ammonia: A tolerant invading species." Fresenius Environmental Bulletin **13**(7): 607-615.

Bersine, K., V. Brenneis, et al. (in prep.). Distribution of the invasive New Zealand mudsnail (Potamopyrgus antipodarum) in the Columbia River Estuary and its first recorded occurrence in the diet of juvenile Chinook salmon (Oncorhynchus tshawytscha). Pt. Adams, OR, NOAA, PSU.

Bruce, R. L. and C. M. Moffitt (2005). Survival of New Zealand Mudsnails (Potamopyrgus antipodarum) in the gastrointestinal tract of Rainbow Trout (Oncorhynchus mykiss). 4th New Zealand Mudsnail Conference, Montana State University, Bozeman, MT.

Database, C. (2001-2007). "Center for Coastal and Land-Margin Research."

Dorgelo, J. (1987). "Density fluctuations in populations (1982-1986) and biological observations of *Potamopyrgus jenkinsi* in two trophically differing lakes." Hydrobiological Bulletin **21**(1): 95-110.

Dybdahl, M. F. and S. Kane (2005). "Adaptation vs. phenotypic plasticity in the success of a clonal invader." Ecology **86**(6): 1592-1601.

Hall, R. O., M. F. Dybdahl, et al. (2006). "Extremely high secondary production of introduced snails in rivers." Ecological Applications **16**(3): 1121-1131.

Higley, d. H., Robert (1974). "Biological Baseline Data Youngs Bay, Oregon."

Ilken, K., T. Brey, et al. (2001). "Food web structure of the benthic community at the Pocupine Abyssal Plain (NE Atlantic): a stable isotope analysis." Progress in Oceanography **50**: 383-405.

Jacobsen, R. and V. E. Forbes (1997). "Clonal variation in life-history traits and feeding rates in the gastropod, *Potamopyrgus antipodarum*: Performance across a salinity gradient." Functional Ecology **11**(2): 260-267.

Langenstein, S. and P. A. Bowler (1990). "On-going macroinvertebrate analysis using the biotic condition index and the appearance of *Potamopyrgus antipodarum* (Gray) in Box Canyon Creek, Southern Idaho." Proceedings of the Desert Fishes Council **21**: 183-194.

McCarter, N. H. (1986). "Food and energy in the diet of brown and rainbow trout from Lake Benmore, New Zealand." N Z J Mar Fresh Res **20**: 551-559.

McIntire, C. D. (1984). "Benthic Primary Production In The
Columbia River Estuary." 111-112.

Peterson, B. and B. Fry (1987). "Stable isotopes in ecosystem studies." Annual Review of Ecology and Systematics **18**: 293-320.

Sagar, P. M. and G. J. Glova (1995). "Prey availability and diet of juvenile brown trout (*Salmo trutta)* in relation to riparian willows (*Salix* spp.) in three New Zealand streams." New Zealand Journal of Marine and Freshwater Research **29**: 527-537.

Vinson, M., E. Dinger, et al. (2006). Flaming Gorge Tailwater Aquatic Biomonitoring Program, 1994-2005. Logan, UT, National Aquati Monitoring Center, Bureau of Reclamation, Utah Division of Wildlife Resources**:** 54 pps.