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Observed Omnivory in the Herbivorous Blue tilapia (*Oreochromis aureus)*

By

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A thesis submitted in partial fulfillment
of the requirements for the

Bachelors of Science in Environmental Studies
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Abstract

Gila seminuda, a native endangered species, and *Oreochromis aureus*, a nonnative invasive species, share the same habitat in the form of the Reid Gardner Power Plant intake ponds. The purpose of this study is to characterize the feeding habits of *Oreochromis aureus* within the Reid Gardner Power Plant intake ponds and address the potential predation habits of *Oreochromis aureus*. Stomach contents of *O. aureus* were identified and analyzed using chi-square and log-likelihood ratio techniques, with respect to mass, length, girth, gender, or spatial distribution of samples. Results showed omnivorous behavior with a 7.00% predatory/prey relationship, and no difference of feeding habits in relation to any of the examined parameters.

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The First Law of Human Ecology states that we can never do one thing without doing or affecting another; that we are all interconnected. Such was the case for this study.

Table of Contents

Introduction

The Reid Gardner Power Plant is located near Moapa, Nevada, approximately 50 miles north of Las Vegas. Three intake ponds (termed throughout: East, West, and Middle) are used to cool the power plant generators, and water from the Muddy River is used to fill these ponds. Virgin River chub (*Gila seminuda*), and blue tilapia (*Oreochromis aureus*) have migrated from the Muddy River into the intake ponds. While tilapia are a known invasive species, their feeding habits were thought to be constituted mainly of plants and insects, thus predation on other fish species has not been recognized nor evaluated.

The Virgin River chub is a federally endangered species (United States Fish and Wildlife Service, 2004; United States Fish and Wildlife Service, 2002; Heinrich et al., 2003), and blue tilapia is a non-native exotic species (Trewavas, 1983). While studies of *O. aureus* feeding habits are inconsistent, most literature describes herbivorous feeding habits. Preliminary data from field workers and other investigators indicates that under certain conditions tilapia may “switch” their diets to include other fish. Because chub and tilapia share the same habitat in the form of the Muddy River, and more specifically, the Reid Gardner Power Plant intake ponds, an examination of whether tilapia are preying on other fish may suggest that they are also preying on the endangered Virgin river chub.

While studies have been done to determine the feeding habits of *O. aureus*, the findings have not been specific to predator/prey relationships to endangered species. Gophen et al. (1998) has identified blue tilapia as solely herbivorous, and Trewavas (1983) identifies the tilapia as herbivorous or planktivorous. Mallin (1985) identifies the nonnative species as being opportunistic omnivores, but does not list predation towards other fish as any part of its feeding habit. The removal of blue tilapia from the nearby Virgin River by the U. S. Fish and Wildlife

Service (2002) was the impetus for this study. Stomach contents of tilapia captured from the Virgin River contained vegetation and fish material (U.S. Fish and Wildlife Service, 2002). However, the propensity of carnivory in tilapia of different mass, length, gender, girth, and spatial distribution was not discussed.

Purpose

The purpose of this study is to examine the feeding habits of *O. aureus* and the propensity of tilapia of different mass, length, gender, girth, and spatial distribution within the Reid Gardner Power Plant to consume fish. An examination of feeding habits of *O. aureus* within the Reid Gardner Power Plant may play a significant role in blue tilapia management within the intake ponds in the future. Identifying tilapia as herbivorous may suggest Virgin River chub are endangered for other non-predatory reasons, while identification of predatory habits amongst blue tilapia may be another factor adding to the eradication of endangered endemics.

If feeding habits are found to be dependent on such factors as length, mass, girth, gender, or spatial distribution, use of a non-discriminatory eradication procedure, such as the chemical rotenone, may not be necessary to protect endemics; instead, careful removal may facilitate an ecosystem in which endemics are not eradicated by the same methods used to protect them.

The first part of the literature review will discuss the biology of blue tilapia, including temperature tolerances, reproductive strategies, and feeding habits. Additionally, there will be a discussion on the introduction of *O. aureus* to Southern Nevada and other areas within the continental United States, with emphasis on increasing tilapia populations and decreasing Virgin River chub populations since the discovery of blue tilapia in the Muddy River. The environmental assessment on the removal of tilapia on the Virgin River done by the U. S. Fish and Wildlife and the implications of using the chemical rotenone on endangered endemics will be discussed. The last part will examine the Reid Gardner Power Plant, intake ponds and the surrounding area, with respect to the Muddy River.

Literature Review

Natural History

Oreochromis aureus is an exotic warmwater species native to northwest Africa and the Middle East (Trewavas, 1983). Temperatures for optimal habitation stated by Trewevas (1983) range from 20-35°C, while studies done by Baras et al. (2002) found 32.6ºC optimal for maximum growth rate. Temperature tolerances for blue tilapia are similar to those of the Virgin River chub and the Moapa dace (*Moapa coriacea)*, another endangered native species (Scoppettone, 1993). While cooler water temperature tolerances have restricted blue tilapia distribution in the United States (Courtenay et al., 1984), studies have shown blue tilapia to survive in temperatures as low as 5-7ºC for short periods of time (Starling et al., 1995).

Reproductive strategies of *O. aureus* can be described as hybrid (Barlow, 2000). *O. aureus* are mouth brooders who reproduce throughout the year (Barlow, 2000; Stauffer, 1984). Mouth brooding is indicative of high parental care and protection, traits representative of K reproductive strategists (Cunningham et al., 2003). More parental care and protection allow juvenile blue tilapia a higher rate of survival in comparison to native species that are nest brooders. Reproduction throughout the year, a trait representative of r reproductive strategists, allows for more offspring than that of Virgin River chub, who only reproduce twice a year (Stauffer, 1984; Cunningham et al., 2003). Using a hybrid of both strategies, Stauffer (1984) asserts, allows *O. aureus* higher reproduction rates and lower mortality rates than native species. This behavior is not only representative of its reproductive habits, but also its feeding habits, where it is aggressive in out- competing endemic species for food resources, eating whatever is available. Because a high level of phytoplankton and algae were observed in each pond, a much higher percentage of *O. aureus* samples are expected to have ingested plants, compared to ingestion of other food sources, such as zooplankton.

Scientists disagree on the feeding habits of *O. aureus*. Barlow (2000) and Gophen et al. (1998), identify tilapia as being herbivorous; Trewevas (1983) identifies tilapia as herbivorous and planktivorous. Stomach analysis of tilapia in the nearby Virgin River found piscivorous as well as herbivorous content (US Fish and Wildlife Service, 2002). Identification of blue tilapia as being herbivorous by a majority of studies suggests that stomach contents for this study will contain vegetation.

Introduction of Tilapia

Tilapia is an important economic factor for aquaculture in the Middle East and Southeast Asia; between 1995 and 2003 alone, frozen tilapia imported from Asia, had risen from 15 million to 100 million pounds (Harvey, 2004), with increased importation being forecasted as a natural alternative to higher cost crops of trout and catfish (Shelton and Smitherman, 1984). This economic justification of *O. aureus'* introduction to non-native areas is in spite of its invasive nature. The first recorded introduction of blue tilapia into the continental U.S. was the Auburn University in 1954 for the purpose of aquaculture research and sport fishing (Radonski et al., 1984). The Arizona Department of Game and Fish introduced blue tilapia in Arizona for algal control (Courtenay et al., 1984). Studies done by Leventer (1979; *in cit.* Shireman, 1984) showed *O. aureus* to have promise for use in algae control.

Introduction of blue tilapia in Southern Nevada was discovered in 1992, owing to illegal introduction to the Muddy River (U.S. Fish and Wildlife Service, 2002). In 1994, blue tilapia were found in the Virgin River basin of Lake Mead, and have since been found throughout the lake (U.S. Fish and Wildlife Service, 2002). The assessment by Courtenay et al. (1984) suggests that expansion of tilapia was due to anthropogenic use of juveniles as baitfish for sport fishing. This is in divergence with the suggestion of the U.S. Fish and Wildlife Service (2002) inference that blue tilapia had migrated from the Virgin River basin throughout the lake.

Blue tilapia, along with the endemic Virgin River chub were able to migrate through delivery pipelines and distribute throughout the intake ponds at the Reid Gardner Power Plant, as evidenced from fish surveys taken at the ponds at incremental times, which began in 1993 (Heinrich et al., 2003). Data from the same fish surveys shows a negative correlation between *O. aureus* and *G. seminuda* populations, giving support to the invasive character of *O. aureus* (Table 1). While this is a relatively small sample size, it can be seen that tilapia populations increased while Virgin River chub decreased, suggesting that blue tilapia are having a negative impact on the native species, further supporting previous studies done by Scoppettone (1998), in which native populations declined in conjunction with the introduction of *O. aurea*.

Table 1. Historic fish surveys at the Reid Gardner Power Plant (raw water ponds)

VRC=Virgin River chub, BT=blue tilapia, n/s=not sampled, n/c=not counted (2VRC caught by hook and line, **research collections, ***=juvenile fish						
Date	West Pond		Center Pond		East Pond	
	BT	VRC	BT	VRC	BT	VRC
12/18/2002	n/c	27***	n/c	31***	n/c	0
10/20/2002	53	0	18	1***	94	0
3/28/2002	10	0	n/s	n/s	27	0
10/13/2000	38	0	n/s	n/s	n/s	n/s
10/20/2000	n/s	n/s	n/s	n/s	12	1
10/28/2000	0	0	n/s	n/s	18	0
4/16/1999	12	2	n/s	n/s	13	3*
4/17/1999	4	3	n/s	n/s	4	12
3/21/1998	n/s	0	n/s	n/s	n/s	0
1993**						11

Source: Nevada Division of Wildlife (2002)

Management

A 2002 environmental assessment of tilapia removal from the Virgin River done by the U S Fish and Wildlife Service examined the effects of using rotenone and other less effective management techniques. Negatively affected resources through rotenone use included water quality, vegetation near riverbanks, displacement of wildlife, temporary elimination of endemics in the proposed areas of treatment, and stress of endemics owing to capture and transportation (U. S. Fish and Wildlife, 2002). Seining, or netting of species was also examined. While this had less ecological impact, it was considered much less effective in eradicating blue tilapia from given areas. The examination of possible predation in this study may suggest other methods of management in which endangered endemics may not be impacted so negatively through the use of rotenone. Another method of management, netting, is able to target tilapia for eradication with little impact to other native species, but is not wholly effective in completely eradicating the targeted species, and is more labor and cost intensive (United States Fish and Wildlife, 2002).

Fig. 1. Aerial view of Reid Gardner Power Plant, intake ponds, and Muddy River

Description of the Reid Gardner Power Plant

The Reid Gardner Power Plant (Fig. 1) is located approximately 50 miles Northeast of Las Vegas next to the Moapa Reservation, and consists of four coal-fired, thermal steam generating units which can produce 605 megawatts of electricity (Heinrich et al., 2003). Water used to cool the generators is drawn from the neighboring Muddy River, pumped into the three intake ponds, and then pumped through the generators for thermal control (Heinrich et al., 2003). Excess water after the cooling process circulates back into the intake ponds for reuse, minimizing water draw from the Muddy River (Heinrich et al., 2003). Temperatures of the intake ponds range between 20°C-30°C, relative to seasonality (Heinrich et al., 2003). The West and Middle ponds can hold 3.4 acre feet of raw water from the Muddy River and range from 5-20 feet in depth, while the East pond holds 3.9 acre feet and ranges from 5-35 feet in depth (Heinrich et al., 2003). Because of area and volume differences between ponds, temperature variances may be enough to affect gender ratios. Water temperatures were found to be a determinant of sex, where higher temperatures yielded an increased male ratio (Desprez and Melard, 1998). Temperatures that were greater than 35 ˚C can cause genotypic females to reverse to phenotypic males (Baras et al., 2002). Gender ratios with respect to temperature, though not examined during this study, may be significant if there are differences observed in feeding habits with respect to sex.

All intake ponds are lined with asphalt (Heinrich et al., 2003). Literature on the affects of asphalt lining on feeding habits of tilapia were not found, but may play a role in feeding habits owing to its possible affect on water temperatures. Blue tilapia, Virgin River chub, mosquito fish (*Gambusia affinis*), and sailfin mollies (*Poelcilia latipinna*) were identified as existing in the intake ponds.

Hypotheses and Justification

1. Tilapia will be found herbivorous owing to a majority of scientific literature identifying *O. aureus* as so (Barlow, 2000; Gophen et al., 1998; Trewavas, 1983). While studies specific to Southern Nevada have indicated native fish in tilapia through stomach analysis (U.S. Fish and Wildlife, 2002), raw data was not given and no statistical analysis was done to determine if this was omnivorous behavior or behavior owing to other factors, such as mouth brooding techniques or accidental ingestion.
2. This study will show that feeding habits are independent from variables of mass, length, girth, gender, or spatial distribution. Owing to the tilapia's invasive nature, a discernable pattern of predatory/prey habits will not be demonstrated.

Methods

Field collection

On April 14, 2003, fish were captured from each intake pond at the Reid Gardner Power Plant with the use of nets. Mass (g) and length (cm) measurements were taken of the blue tilapia and grouped by intake pond. A weir was then set up to prevent further invasion of *O. aureus* into the intake ponds, thereby creating a habitat conducive to native species, in conjunction with the tilapia removal program (Heinrich et al., 2003). Fish were then taken to the University of Las Vegas Nevada toxicology laboratory for frozen storage and further analysis. On April 21, 2003, more fish were captured at the Reid Gardner Power Plant using rotenone in accordance with the United States Fish and Wildlife Service (Shawn Goodchild), Nevada Power (Vicki Tripoli), and the Nevada Division of Wildlife (Jim Heinrich) (Heinrich et al., 2003). Fish were then collected and stored in the same fashion as the tilapia previously captured with nets.

Lab sampling

A total of 220 Tilapia were analyzed in this study. Mass (g), length (cm), girth (cm), gender, and sampling location were measured, identified and recorded. Stomach and stomach contents were removed, weighed, identified, analyzed under a dissection microscope, and recorded. Any tilapia found to have piscivorous contents in their stomach were identified as being omnivorous, while those found with any other vegetative or zooplanktous content were identified as being herbivorous. “Contents of unusual distinction” were saved in vials of 10% ethanol for further analysis. Stomach sampling was done at a period from October 15, 2003, until April 7, 2004. All data was recorded on a summary information sheet (Appendix B).

Statistical Analysis

To test the first null hypothesis, a simple percentage of tilapia identified as omnivorous was calculated. To test the second null hypotheses, deviation of observed and expected frequencies was analyzed through crosstabulations using Pearson Chi- Square test, and the G statistic for log- likelihood ratio tests in accordance with Zar (1999). Significance was tested at $\alpha = 0.05$

Results and Analysis

Of the 220 tilapia sampled, 15 were found to contain piscivorous content in their stomachs, a 7% omnivorous rate within the sampled population. For the proceeding analyses, chi-square was first calculated (Table 2). In many cases, the expected values which were derived from observed values using chi-square were < 5.00, which may induce type I errors. Log-likelihood ratios (*G* statistic) use a natural occurring log that accounts for expected values < 5.00, thus having more power when compared to chi-square (Zar, 1999). For this reason, G statistic was also used.

In all cases, $p > 0.05$; hence, the null hypothesis was supported in all parameters examined (Table 3).

Table 2. Chi- square and G statistic probability p- values for parameters in relation to predation.

Variables v. predation	df[1]	chi-square	p-value for chi-square	*G*[2]	p-value for *G*[2]
length vs. predation	3	5.332	0.149	5.603	0.133
mass vs. predation	3	1.932	0.587	2.032	0.566
girth vs. predation	3	1.651	0.648	1.755	0.625
gender vs. predation	2	3.008	0.222	4.387	0.112
spatial distribution vs. predation	2	4.695	0.102	5.931	0.129

[1]Degrees of freedom. [2] Log- likelihood ratio value.

Table 3. p-values and significance of morphological parameters with respect to omnivorous behavior.

	Length	**Mass**	**Girth**	**Gender**	**Spatial Distribution**
p- value	0.133	0.566	0.625	0.122	0.129
Significance? p=0.05	No	No	No	No	No

Discussion

This study characterized the feeding habits of blue tilapia and addressed potential predator/prey relationships, particularly with other species in hopes of suggesting better management methods for this non-native species. Seven percent of the tilapia sampled were found to have ingested other fish. At what percentage tilapia have to be found to have ingested other fish to be defined as having omnivorous behavior is unknown, but owing to a majority of the literature identifying tilapia as herbivorous, even the relatively small percentage of predatory/prey behavior observed for this study supports identifying tilapia as omnivorous, and suggests more studies need to be done to understand *O. aureus* predation behavior.

Results of data in relation to differences of feeding habits owing to length, mass, girth, gender, or spatial distribution supported a null hypothesis of no difference. The data and analyses suggests that tilapia of shorter lengths were just as likely to be omnivorous at a similar rate as tilapia of longer lengths. No alternative management methods for blue tilapia in relation to length, mass, girth, gender, or spatial distribution can be suggested, given the results of the data. The current practice of netting, transporting endemics, and then using rotenone to eradicate unwanted species is supported by this study as the best possible method.

Results also support a null hypothesis of no difference in feeding habits between genders. Support of this null hypothesis suggests that accidental ingestion of juvenile fry due to mouth brooding by females, a notion stated earlier in this paper, may not be happening. Data would have shown a higher percentage of predatory behavior amongst females in comparison to males. With respect to spatial distribution, while the p-value comes closest in value to being < 0.05 (Table 2), it is still greater and fails to reject the null hypothesis of no difference in feeding habits with respect to spatial distribution. The two smaller intake ponds, West and Middle, showed no difference in feeding habits when compared to the larger East pond. Further examination of feeding habits in relation to spatial distribution is suggested, such as comparing small rivers as the Muddy River to larger open bodies, such as Lake Mead, two areas where blue tilapia are known to have invaded (Heinrich et al., 2003; U S Fish and Wildlife Service, 2002).

This study found that only 7% of blue tilapia sampled could be characterized as omnivorous, which may explain why previous studies that were not specific to predator/prey relationships did not identify tilapia as ingesting fish. Though samples of the ingested fish were saved, taxonomic identification has not taken place; it is unknown whether or not blue tilapia are ingesting Virgin River chub, other blue tilapia, or another species such as the shortfin molly (*Poecilia mexicana*), another non-native species found in the Upper Muddy River and intake ponds (Scoppettone et al., 1993). Suggestion for further studies would include a yearlong examination of blue tilapia predation habits. While samples for this study were euthanized, a live sample study might even suggest omnivory to a higher percentage.

Although the results characterize the predator/prey relationship of tilapia as having no specific pattern, there are some factors which can be studied more closely. Feeding habits may be related to temperature differences. Courtenay et al., (1984) suggest a lack of tolerance for water temperatures around 10°C, which may also affect feeding habits, a factor not examined in this paper due to temperature ranges in the Reid Gardner Power plant intake ponds fluctuating between 20°C – 30°C (Heinrich et al., 2003)- conditions which may differ when compared to the Muddy river, a natural habitat for endemics.

Conclusion

Oreochromis aureus, while playing an increasing economic role as an easily grown food commodity, is invasive through out-competing other species for valuable resources. An understanding of predatory/prey habits in relation to other species, particularly endemics, may find a better economic and ecological balance. This study has supported the notion that despite the majority of scientific literature cited, *O. aureus* are omnivorous. Historical data has indicated that tilapia populations are increasing and immigrating to other areas in Southern Nevada, thus facilitating the need to hasten the process of examining specific characteristics, such as predatory/prey behavior. Not addressing the issue of this invasive species may lead to a loss of aesthetic value and a major change in the ecology of Southern Nevada.

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Appendix A. Crosstabulations of Morphological Values and Feeding Habits

Mass	1	2	3	4	Total	G- statistic	p-value (df=3)
Herbivorous	50 (51.25)	52 (51.25)	50 (51.25)	53 (51.25)	205		
Omnivorous	5 (3.75)	3 (3.75)	5 (3.75)	2 (3.75)	15		
Total	55	55	55	55	220	2.032	**0.566**

Length	1	2	3	4	Total	G- statistic	p-value (df=3)
Herbivorous	52 (51.25)	51 (51.25)	48 (51.25)	54 (51.25)	205		
Omnivorous	4 (3.75)	3 (3.75	7 (3.75)	1 (3.75)	15		
Total	56	54	55	55	220	5.603	**0.133**

Girth	1	2	3	4	Total	G- statistic	p-value (df=3)
Herbivorous	50 (51.25)	52 (51.25)	53 (51.25)	49 (51.25)	204		
Omnivorous	5 (3.75)	2 (3.75)	5 (3.75)	3 (3.75)	15		
Total	56	54	55	55	220	1.755	**0.625**

Gender	1	2	Total	G- statistic	p-value (df=1)
Herbivorous	99 (97.05)	84 (85.95)	204		
Omnivorous	6 (7.95)	9 (7.95)	15		
Total			220	1.755	**0.625**

Spatial Distribution	1	2	3	Total	G-Statistic	p-value (df=2)
Herbivorous	55 (55.90)	82 (84.80)	68 (64.30)	205		
Omnivorous	5 (4.10)	9 (6.20)	1 (4.70)	15		
Total	60	91	67		5.931	**0.096**

Appendix B. Summary Information Sheet Date:

Time:
Initials:

Tilapia Virgin River Chub Project (2003)
Reid Gardner Power Plant

Summary
Information:

Secimen#/Pond	Gender	Length (cm)	Mass (g)	Girth (cm)
	Male Female			

Stomach Contents:

	Order/Family	Genus/Species	Dimensions/Descriptions	Wet Mass (g)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Notes/Comment: Fish captured on 4/14/03 by nets: fish captured on 4/21/03 with rotenone in accordance with US Fish and Wildlife Service (Shawn Goodchild), Nevada Power (Vicki Tripoli) and Nevada Division of Wildlife (Jim Heinrich).

Appendix C. Animal Users/Handlers Certification

P.2

University and Community College System of Nevada

ANIMAL USERS/HANDLERS SHORT COURSE

CERTIFICATE OF COMPLETION

Awarded to: Stephen Oliveira

For successful completion of the Animal Users/Handlers Short Course presented by the University and Community College System of Nevada.

7 March 2005
Date

Richard C. Simmonds, D.V.M., M.S.
Course Director and Instructor

Apr 07 05 11:58a

Stephen M. Oliveira Jr.

1267 N. Christy Ln * Las Vegas, NV 89011 * 702-595-1235* stephenoliveira@hotmail.com

Objective: To utilize past experiences and education while developing further skills in the environmental science field.

EDUCATION:

2001- Present — University of Nevada Las Vegas

- Pursuing a Bachelor of Science degree in Environmental Studies
- Cumulative 3.65 GPA

Experience:

May 2005- Present

Honeywell Corporation
Conservation Aide
Las Vegas, NV
Responsibilities: Contracted under Southern Nevada Water Authority. Hired on owing internship (see below)

Experience:

Sept. 2003- Present

Southern Nevada Water Authority, Conservation Dept., Residential Team
Intern III
Las Vegas, NV
Responsibilities: Meet with Clark County residents around the Las Vegas Valley to explain Water Smart Desert Xeroscape Program. Process and approve applications of Clark County residents.

May 2003- Present

University of Nevada Las Vegas Department of Environmental Studies
Assistant Field Researcher
Las Vegas, NV
Responsibilities: Collaborate with UNLV professors and graduate students on Small Mammals Project. Work with small mammals includes but is not limited to trapping, identifying, tagging, and collecting and recording population density data.

September 1999- Present
Las Vegas, NV

ARK of Las Vegas
Banquet Server and Bartender
Responsibilities: Work at banquet set-up, service, and breakdown for sit-down, buffet, Fine dining, industry and corporate parties, and receptions.

April 1999- August 1999
Salt Lake City, UT

Resource Management, Inc.
Residential Treatment Program Team
Responsibilities: Responsible for treatment program participants' safety, security, and transportation. Also dispensed medication and served as task manager, helping participants follow through with their treatment.

November 1998- March 1999 & December 1997- April 1998

Redcliff Ascent Inc.
Wilderness Therapy Head Instructor
Meryl Junction, UT
Responsibilities: Led eight-day wilderness therapy trips for at-risk youth. In charge of supervising co-workers, client intake, designing hiking routes, food drops, teaching life skills, teaching wilderness skills (i.e. building fires, first aid, and trapping food), building shelter, distributing medication, fostering motivation, and behavior management.

June 1997- August 1997

Alaska Department of Fishing and Gaming
Fish Sampler II
Anchorage, AK

Responsibilities: Worked in the field identifying chum salmon species. Took muscle, liver, and heart samples, collected various data, and recorded data in Microsoft Excel.

* Personal and professional references available upon request.