Stomach Analysis of Top Aquatic Predators in a Headwater Stream Network

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STOMACH ANALYSIS OF TOP AQUATIC PREDATORS IN A HEADWATER STREAM NETWORK

ABSTRACT

Top predators play important roles in regulating communities and ecosystem processes in freshwater ecosystems. In the headwater stream network, it is crucial to understand the interspecific interaction between multiple predators. In Oregon forested ecosystems, Coastal Giant Salamander (*Dicamptodon tenebrosus*) and cutthroat trout (*Oncorhynchus clarkii*) are the top predators in many perennial headwater streams. Both feed on aquatic invertebrates and thus, they are potential competitors. In this study, we assessed the diet variation in headwater stream predators. The research objectives are to understand the dietary composition of both predators in different locations within the headwater stream and to compare the similitudes and differences based on their diet and body size. The stream evaluated was Lookout Creek, located within the H.J. Andrews Experimental Forest, Oregon. We collected 91 Coastal Giant Salamanders, 100 Cutthroat Trout, and 10 Rainbow Trout, and applied the gastric lavage method to extract the stomach contents. A total of 4,897 identifiable prey items were found belonging to 104 prey types. Trout diets contained the highest overall proportions of terrestrial prey. Although H' indicates a similar trend of prey diversity between size classes, we detected a difference in the stomachs contents in terms of composition (or proportion) of semiaquatic and terrestrial insects. Our findings show that there is no major differences in diets between upstream and downstream for each predeator species, and sampling over relevant spatial and temporal scales is needed to understand the feeding behavior of trout and salamanders.

INTRODUCTION

Top predators play important roles in regulating communities and ecosystem processes in freshwater ecosystems. These predators always affect the composition and abundances of macroinvertebrate communities, while changing the flow of energy and nutrient dynamics. For a system in headwater streams, it is crucial to understand the interactions between multiple predators (Des Roches et al. 2018), defined through the consumption of resources and overlap in resource use. Individuals within species often differ from one another in ecologically meaningful ways. This includes prey preferences, feeding behaviors, vulnerability to predation, and competitive ability (Falke et al. 2020). Such information is vital for understanding community dynamics, predicting the resilience of ecosystem processes to species losses, and for determining how species will respond to environmental change. The presence of two predators in a single habitat may impact the relationship between prey and predator. Predators with a size-structured population can significantly change the interactions. For example, the diet of potential competitors or predators may differ between size-classes (Werner and Gilliam 1984). For such species, coexistence among predators may happen through competition with similarly sized individuals or predation by more significant individuals, and this concept is termed as intraguild predation.

Salamanders and fish are commonly known as top predators in many aquatic habitats, and they are characterized by size-structured populations and ontogenic changes in their ecological interactions (Werner and Gilliam 1984; Ebenman 1988). Fish are typically size-selective predators, and one of the more robust and general patterns of effects in streams is their relatively pronounced impact on larger prey. Salamanders are another predator in freshwater systems and are abundant throughout headwater streams. In the absence of fish, salamanders can be the dominant vertebrate predators, and their density can exceed 40 meters squared (Rundio 2002). Salamander populations rarely overlap with fish but often coexist as intraguild predators.

In Oregon forested ecosystems, Coastal Giant Salamander (*Dicamptodon tenebrosus*) and Coastal Cutthroat Trout (*Oncorhynchus clarkii*) are the top aquatic predators in headwater streams (Hawkins et al. 1983). Both species have size-structured populations with corresponding size classes. Coastal Giant Salamanders typically spend two to three years as aquatic larvae and show distinct size classes (Nussbaum and Clothier 1973). Larvae usually transform when they reach 110 to 150 mm total length, but reproductively mature, gilled adults are typical and often exceed 200 to 300 mm total length (Nussbaum and Clothier 1973). Cutthroat trout in headwater streams usually live three to four years and reach a maximum length of 150 to 200mm (Trotter 1989). The coexistence of salamanders and trout may have significant direct and indirect effects in headwater stream communities. Both feed primarily on aquatic invertebrates and thus are potential competitors. However, their foraging behavior is different in terms of diet selection, where salamanders are mostly benthic feeders, and cutthroat trout are column drift feeders. This difference in foraging mode potentially presents different varieties of invertebrate preys, and indirectly affect the structure of trophic level that influence primary production in streams.

In this study, we assessed the diet composition in headwater stream aquatic predators. We studied two predator species that co-occur in the cascades of Oregon: Coastal Giant Salamander and Coastal Cutthroat Trout. My research objectives were to understand the dietary composition of both predators in different locations within headwater stream network and to compare the similarities and differences in diets in both species, based on their diet and body size. We hypothesized that body size and a location in the network would result in different diet composition with salamanders preying on benthic sources and trout preying from terrestrial sources. This study provides insights about the baseline feeding behavior of trout and salamanders where they coexist and could be used to future studies related to the impact of climate change on the headwater stream.

METHODS

Study sites

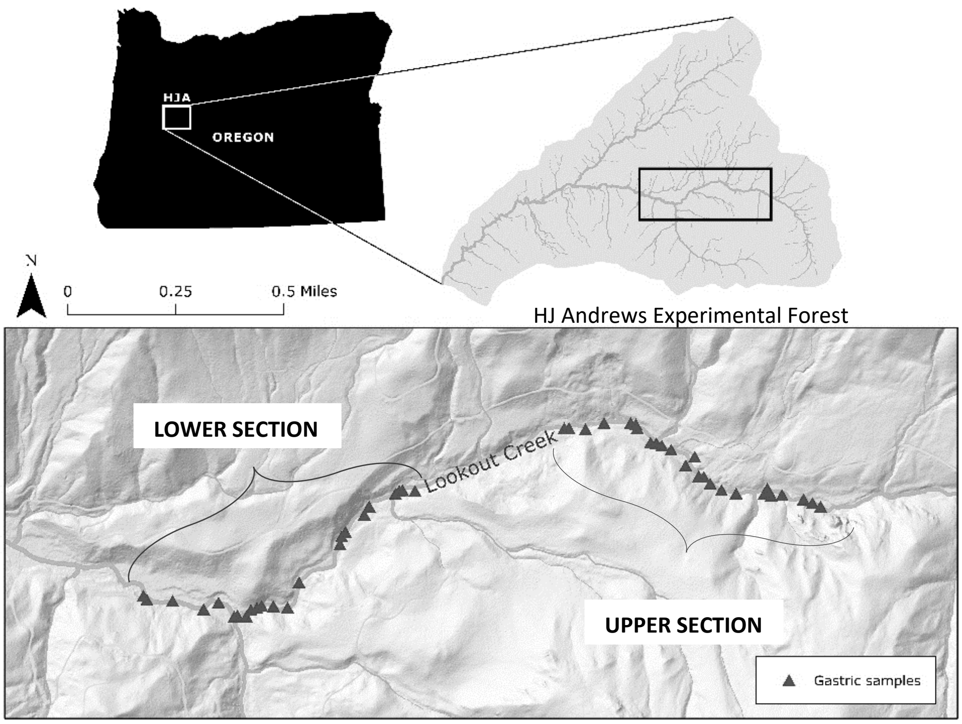

Figure 1 Map of HJ Andrews Experimental Forest and Lookout Creek, Oregon USA. The triangle dots represent every pool sampled along the Lookout Creek. The pools were categorized into lower and upper based on the position of the pools along the creek.

The stream evaluated in this study was Lookout Creek, located within the H.J. Andrews Experimental Forest, Blue River, Oregon (44.232594°, -122.202107°). Lookout Creek is one of the watersheds in the H.J. Andrews Forest that flows into Blue River Reservoir; Blue River is a tributary of the McKenzie River. Lookout Creek is surrounded by old-growth riparian forest, consisting of hemlock, cedar, and Douglas Fir trees, and supports many aquatic macroinvertebrate species. The region typically experiences wet winters and dry, warm summers. Two stream sections of Lookout Creek (upper and lower) were surveyed during the summer low-flow period from August 26 until August 29, 2019. Each reach was approximately one mile long and contained pool habitats. Several factors were considered when deciding the subset of pools to sample in each reach. For each stream section, we selected 25 pools based on slow-velocity and minimal turbulence. GPS coordinates, surface area, and depth of each pool were also measured and recorded to calculate the pool volume.

Data Collection and Animal Handling

Table 1. The total number Coastal Giant Salamander (D. tenebrosus), Cutthroat Trout (O. 8larkia), and Rainbow Trout (O.mykiss) sampled in each stream section of Lookout Creek, Oregon.

Stream Section	***D. tenebrosus***	***O. clarkii***	***O. mykiss***
Lower	46	74	9
Upper	44	26	0
Grand Total	**90**	**100**	**9**

We collected 90 Coastal Giant Salamanders (*D. tenebrosus)*, 100 Cutthroat Trout (*O. 8larkia)*, and 9 Rainbow Trout (*O.mykiss)* (Table 1), during midday by electrofishing. During each survey, block nets were set at the upper and lower ends of the pool to close the system, and only adult fish were captured with a single pass of electroshocking. Fish were anesthetized using MS-222, lavaged non-lethally, weighed, measured for the fork and total length, and released back to the stream after they regained consciousness. We followed gastric lavage methods for collecting the stomach samples of the fish, for which we inserted a non-stretchable straw attached to a 250-mL plastic wash bottle into the esophagus and flushed the stomach with stream water. The stomach contents were then filtered by a coffee filter before preserved in an ethanol solution to prevent excess water in the sample. Each sample was kept separately in 90% ethanol for transport to the lab for further analysis. We then identified every prey item to the lowest possible taxonomic level and treated different life stages as distinct prey types. Identification was based on methods provided by Merrit et al. (Merritt, Cummins, and Berg 2019). The lowest taxonomic level used was family.

Data Analysis

Food items were placed into five categories based on their life cycle types: aquatic, semi-aquatic, terrestrial, vertebrates, and miscellaneous. Stomach content analysis was based on the frequency of occurrence (%F), i.e., as a percentage of fish or salamanders that contained a particular food type (Hyslop 1980). In each stream section, the number of stomachs containing one or more individuals of each prey category was expressed as a percentage of all stomach contents for every species of predator. We divided every predator species into size category based on their fork length by assigning them to small (<25th percentile), medium (25th – 75th percentile), and large (>75th percentile) groups. Shannon index of prey diversity (Magurran 1988) by stream sections was calculated to analyze the species richness of prey items and distribution of species abundance. The calculation was as below;

$$H' = - \Sigma p_i \, ln \, p_i$$

where p_i is the proportion of stomachs that contained the species I ($p_i = n_i/N$, where n_i is the number of stomachs that contained the species I and N is the total number of stomachs). The Shannon index increases as both the richness and the evenness of the community increase (Magurran 1988).

RESULTS

We used order taxa for most parts of the analysis. In total, we found a total of 4,897 identifiable prey items belonging to 104 prey types. We found food items in all Rainbow Trout stomach; however, the stomachs were empty in 17 Coastal Giant Salamanders and two Cutthroat Trout, either the food items were unidentifiable or fully digested (Table 2). Salamanders mostly eat Ephemeroptera(mayfly), which accounted for 47.9% of total stomachs sampled in salamanders (Table 3). Cutthroat Trout diets contained the highest overall proportions of Diptera, where Diptera was detected in 27% of the total stomachs (Table 3). In general, salamander primarily comprised of aquatic invertebrates, whereas trout diets contained a more even mixture of terrestrial and aquatic organisms.

Diet Composition

Coastal Giant Salamanders fed primarily on Ephemeroptera, Plecoptera, and Trichoptera in both stream sections. These prey items were found in 75.7% of the total stomachs in salamanders (Table 3). 21.1% of the stomachs were empty or fully digested. The other items contributing to salamander diets included arachnids, true fly larvae, crayfish, vertebrates, and terrestrial prey. The Shannon Index of Prey Diversity for salamander is 3.223 for the lower section and 3.201 for the upper section. Coleoptera (beetle) and Plecoptera (stonefly) were shown to have a difference between lower and upper sections (Table 3); more beetles and fewer stoneflies were consumed from the lower section. However, the Shannon Index indicates that the salamander diets have no significant differences between both sections. The other items that not listed in Table 2 are flatworms and parts of unidentifiable insects, which made up less than one percent of the diet.

Unlike salamanders, Cutthroat Trout fed more heavily on terrestrial prey than salamanders, and 59.9% of the terrestrial insects were hymenopteran such as ants. They fed primarily on Diptera, Trichoptera, and Hymenoptera, as they were present in 56.7% of total stomachs of Cutthroat Trout sampled. Two percent of the total fish stomachs were either empty or the prey items had fully digested. The remaining 41.3% contained even mixtures of prey items, with an equal proportion of aquatic and terrestrial prey in both stream sections (Table 3). The other prey items constituted in less than one percent of the stomachs are Isopoda, Scorpaeni 11 lark, Araneae, Blattodea, Neuroptera, and Polydesmida. The Shannon Index of Prey Diversity in Cutthroat Trout diet is 3.725 for the lower section and 3.405 for the upper section. There was evidence of piscivory among predators as Scorpaeniformes or sculpins were present in the diets of both Coastal Giant Salamanders and Cutthroat Trout.

Body Size

All three body size groups of Coastal Giant Salamander and Cutthroat Trout sampled in Lookout Creek were present in both stream sections and occurred sympatrically in the stream. Both terrestrial and aquatic prey taxa were present in all three size groups in Coastal Giant

Salamanders, however terrestrial taxa comprised a more substantial portion of the diet of large salamander. Ephemeroptera was the most abundant Order in all three size classes representing 47.9%, making up 54.9%, 48.5%, and 35.6% of small, medium, and large salamander diets, respectively (Table 4). Ephemeroptera was found in higher proportions in larger size classes. Small salamanders have the highest proportion of Ephemeroptera, among other body sizes comprising 54.9% of total stomachs, respectively (Table 4). They also consumed more aquatic prey compared to other body sizes (97.8%).

Table 2. Body size, sample size(N), fork length, number of empty stomachs, and Shannon Index of Prey Diversity(H') for Coastal Giant Salamander and Cutthroat Trout sample in Lookout Creek. High H' indicates that the predator is a generalist.

Species	Body size	N	Fork length (cm)	Empty stomach	H'
D. tenebrosus	Small	22	7.9 (5 – 9.1)	1	2.602
	Medium	46	11.5 (9.5 – 12.8)	9	2.782
	Large	22	14.0 (13 – 16.4)	7	2.971
O. clarkii	Small	23	12.6 (9.4 – 13.6)	2	2.817
	Medium	52	14.8 (13.7 – 16.6)	0	2.926
	Large	24	19.0 (16.8 – 26.3)	0	2.888

Trichoptera (caddisfly) was the second most abundant Order consumed for small salamanders, medium, and large salamanders, with 12.1%, 19.6%, and 13.6%, respectively (Table 4). However, only large salamanders consumed the terrestrial Trichoptera. Dipterans were the most consumed by Cutthroat Trout, with the highest proportion was eaten by large trout. Large trout diets had an equal proportion for aquatic and terrestrial dipterans. However, small and medium trout consumed more aquatic compared to terrestrial dipterans. Small trout consummed primarily on Trichoptera (16.7%), including aquatic and emergent trichopteran adults. The Shannon Index of Prey Diversity (H') for all three sizes of Cutthroat Trout shows that there was no significant difference between their diets (Table 2).

Table 3. Percent of the stomach of Coastal Giant Salamander (D. tenebrosus) and Cutthroat Trout (O. 13larkia) caught in lower and upper stream sections that contained the prey items using order taxa. The numbers (%F) reflect the proportion of stomachs contained prey item for each stream section.

	D. tenebrosus			*O. clarkii*		
Prey Items (order taxa)	**Lower (%F)** N = 34	**Upper (%F)** N = 34	**Total (%F)** N = 68	**Lower (%F)** N = 69	**Upper (%F)** N = 26	**Total (%F)** N = 95
AQUATIC	**91.7**	**94.7**	**93.3**	**53.9**	**54.5**	**54.1**
Coleoptera	6.3	3.0	4.5	5.7	7.4	6.1
Decapoda	2.8	3.0	2.9			0.0
Diptera	8.3	9.5	8.9	17.0	15.3	16.5
Ephemeroptera	45.8	49.7	47.9	10.2	10.2	10.2
Isopoda			0.0	0.2		0.2
Megaloptera	0.7		0.3			0.0
Plecoptera	9.0	13.6	11.5	7.8	10.8	8.6
Scorpaeniformes	2.1	0.6	1.3	0.4		0.3
Trichoptera	16.7	15.4	16.0	12.6	10.8	12.1
TERRESTRIAL	**8.3**	**5.3**	**6.7**	**45.0**	**45.5**	**45.1**
Araneae			0.0	0.4	0.6	0.5
Blattodea			0.0	0.2		0.2
Coleoptera	3.5	1.2	2.2	5.2	7.4	5.8
Diptera	1.4		0.6	9.8	12.5	10.5
Ephemeroptera			0.0	2.0	2.3	2.0
Hemiptera			0.0	4.3	2.3	3.8
Hymenoptera	2.1	2.4	2.2	17.0	15.9	16.7
Lepidoptera			0.0	1.5	2.8	1.9
Neuroptera			0.0		0.6	0.2
Orthoptera	0.7	0.6	0.6			0.0
Plecoptera			0.0	0.7	0.6	0.6
Polydesmida		0.6	0.3	0.2		0.2
Psocoptera		0.6	0.3	2.6		1.9
Trichoptera	0.7		0.3	1.1	0.6	0.9
Grand Total	**100.0**	**100.0**	**100.0**	**98.9**	**100.0**	**99.2**

Table 4. Frequency of occurrence of stomachs that contained preys based on three body sizes of D. tenebrosus and O. 14larkia from Lookout Creek, Oregon, based on the percentage (%F).

	D. tenebrosus				*O. clarkii*			
Prey Items (order taxa)	**Small (%F)**	**Medium (%F)**	**Large (%F)**	**Total (%F)**	**Small (%F)**	**Medium (%F)**	**Large (%F)**	**Total (%F)**
	N = 18	N = 35	N = 15	N = 68	N = 21	N = 51	N = 22	N = 94
AQUATIC	97.8	95.2	81.5	93.3	62.8	54.1	47.2	54.0
Coleoptera	6.6	3.1	5.1	4.5	5.6	6.3	6.2	6.1
Diptera	12.1	7.4	8.5	8.9	18.3	17.3	13.7	16.5
Ephemeroptera	54.9	48.5	35.6	47.9	12.7	11.5	5.6	10.2
Plecoptera	11.0	12.9	8.5	11.5	11.1	6.9	9.9	8.6
Trichoptera	12.1	19.6	11.9	16.0	15.1	11.8	10.6	12.1
Decapoda	1.1	2.5	6.8	2.9				0.0
Scorpaeniformes		0.6	5.1	1.3			1.2	0.3
Isopoda				0.0		0.3		0.2
Megaloptera		0.6		0.3				0.0
TERRESTRIAL	**2.2**	4.8	18.5	6.7	36.4	44.7	52.8	45.2
Coleoptera	1.1	1.2	6.8	2.2	1.6	6.9	6.8	5.8
Diptera		0.6	1.7	0.6	12.7	8.4	13.7	10.5
Ephemeroptera				0.0		2.6	2.5	2.0
Plecoptera				0.0		1.2		0.6
Trichoptera			1.7	0.3	1.6	0.9	0.6	0.9
Araneae				0.0		0.3	1.2	0.5
Blattodea				0.0			0.6	0.2
Hemiptera				0.0	2.4	4.9	2.5	3.8
Hymenoptera		1.8	6.8	2.2	15.9	16.1	18.0	16.7
Lepidoptera				0.0	1.6	2.3	1.2	1.9
Neuroptera				0.0		0.3		0.2
Orthoptera		0.6	1.7	0.6				0.0
Polydesmida	1.1		0.3	0.0		0.3		0.2
Psocoptera		0.6	0.3	0.0	0.8	0.6	5.6	1.9
Grand Total	**100.0**	**100.0**	**100.0**	**100.0**	**99.2**	**98.8**	**100.0**	**99.2**

Prey types

All prey items were subdivided into different prey types based on their life cycles. The groups are aquatic(i.e., larvae, nymphs, and adult insects that live in freshwater), semi-aquatic (larvae and nymphs with at least one nonaquatic life-cycle stage), terrestrial (includes terrestrial organisms and aquatic insects that had emerged from the stream), vertebrates, and miscellaneous.

Within each predator species, proportional diet composition varied based on the stream section. For Coastal Giant Salamander, aquatic and terrestrial prey were found in higher proportions in the diets within the lower section (13%), whereas for Cutthroat Trout, higher proportions of aquatic and terrestrial preys were found in the lower section (8.4%) (Table 5). However, salamanders consumed more semiaquatic preys by 7.9% in the upper section, while trout consumed about equal proportions of semiaquatic items for both stream sections. No vertebrates were eaten by Cutthroat Trout in the upper section. In general, Coastal Giant Salamander eats more semiaquatic prey in both stream sections, while Cutthroat Trout consumes an even mixture of semiaquatic and terrestrial prey (Figure 2).

Table 5. Proportional composition of prey types based on frequency(F) in the diets of Coastal Giant Salamander (D. tenebrosus) and Cutthroat trout (O. 15larkia) in the lower and upper section of Lookout Creek. Semiaquatic preys are grouped separately from terrestrial insects without aquatic life stages.

	D. tenebrosus		*O. clarkii*	
Prey types	**Lower (%F)**	**Upper (%F)**	**Lower (%F)**	**Upper (%F)**
Aquatic	13.0	8.9	8.4	10.4
Semiaquatic	75.3	83.2	45.6	45.4
Terrestrial	7.8	5.0	43.6	44.3
Vertebrate	2.6	1.7	0.6	0.0
Miscellaneous	1.3	1.1	1.8	0.0
Grand Total	**100.0**	**100.0**	**100.0**	**100.0**

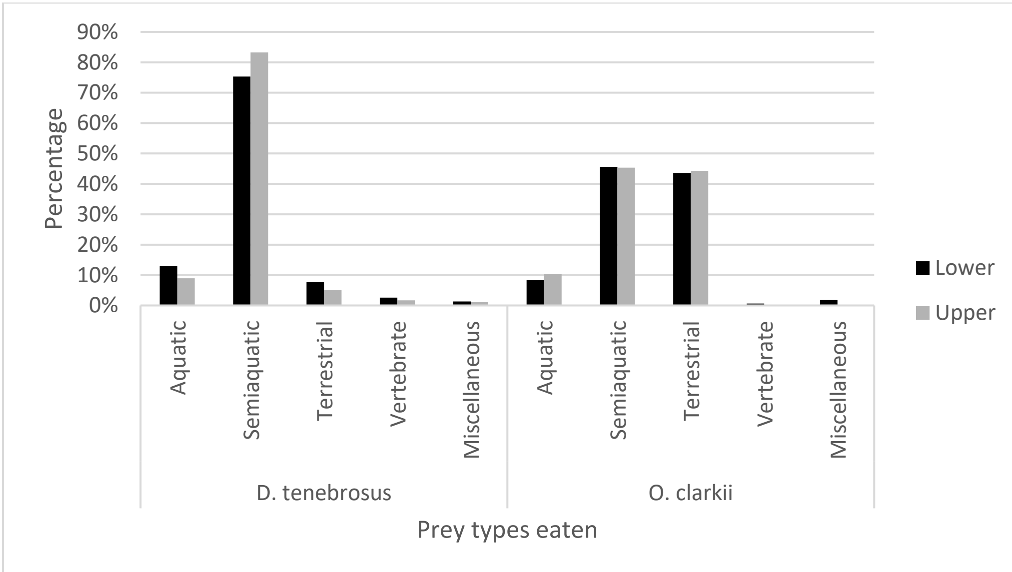

Figure 1 Comparison between lower and upper stream sections based on the percentage of stomachs contained preys by Coastal Giant Salamander (D. tenebrosus) and Cutthroat Trout (O. 16larkia).

Diet Composition of Rainbow Trout

Rainbow Trout diets exhibited a variety of aquatic and terrestrial prey types, including Urodela (salamander), Hemiptera (true bugs), and Orthoptera (crickets). Diptera was also found to be the highest proportion in the Rainbow Trout diet, representing 25% of total stomachs, respectively. Predation on salamanders and sculpin was observed in 8.4% of the stomach samples. The second largest consumption by rainbow trout is trichopteran (16.7%). In general, rainbow trouts consumed more aquatic prey by 44.6%. However, due to the small sample size, we could not make a comparison of rainbow trout diets between the lower and upper sections and between body sizes.

Table 6. Percent of total stomachs of Rainbow Trout (O. mykiss) caught in the lower stream section that contained the prey items using prey types and order taxa. The numbers (%F) reflect the percentage of occurrence of each prey item. N_{total} = 9.

O. mykiss		
Prey items (order taxa)	**Lower (%F) N = 9**	**Total (%F)**
AQUATIC		**72.3**
Coleoptera	8.3	8.3
Trichoptera	16.7	16.7
Ephemeroptera	5.6	5.6
Plecoptera	11.1	11.1
Diptera	22.2	22.2
Scorpaeniformes	5.6	5.6
Urodela	2.8	2.8
TERRESTRIAL		**27.7**
Hymenoptera	8.3	8.3
Hemiptera	2.8	2.8
Orthoptera	2.8	2.8
Lepidoptera	2.8	2.8
Ephemeroptera	5.6	5.6
Diptera	2.8	2.8
Coleoptera	2.8	2.8
Total	**100.0**	**100.0**

DISCUSSION

Lookout Creek supports a diverse community of aquatic organisms, and it is an essential habitat for Coastal Giant Salamander and Cutthroat Trout. The focus of the study was to understand the dietary composition of both predators in different locations within the Lookout Creek and to compare similarities and differences in both species, based on their diet and body size. We hypothesized that body size and a location would influence the diet compositions of salamanders and trout. This study provides insights about their baseline feeding behavior where they coexist and could be used to future studies related to the impact of climate change on the headwater stream. The results of this study support the idea that diet changed substantially with variation in predator body size. These relationships are strongly influenced by prey availability and feeding strategy of the predators.

Diet Composition – Coastal Giant Salamander has a broad diet that, in our study, was composed of 50 prey types. Ephemeroptera represents a critical component of the diet across all salamander body sizes, and stream sections with a higher proportion is found in small salamanders (50 – 91mm). In contrast to this study, Falke et al.'s (2020) reported that the consumption of Ephemeroptera was higher in larger size classes (96 – 242 mm). These potential differences may be related to spatial variation and diversity of habitats. Although the Shannon Index of Prey Diversity shows no difference in prey diversity between body sizes overall, we detected a difference in the stomachs with terrestrial prey. Large salamanders tended to eat more terrestrial prey, such as Hymenopteran (Family taxa = Formicidae). As the body size of salamander increased, the lesser the occurrence of aquatic prey in salamander diets, and the more terrestrial prey eaten by salamanders. The food habits of the Coastal Giant Salamander were first described by Bury (1972). They examined the stomach contents of 12 adult salamanders collected from Del Norte, Humboldt, and Marin counties in northern California. They found 13 prey types, excluding rocks and vegetable matter, seven of prey types were similar to those observed in our study. In contrast, prey in the Order Acarina, Isopoda, Gastropoda, Reptilia, Mammalia, and Diplopoda were not represented in our diet analysis, however Bury (1972) sampled the aquatic and terrestrial adults and this would hugely impact the diet result.

Coastal cutthroat trout ingest a diverse variety of prey that included 85 taxa groups in the lower section and 59 taxa groups in the upper section. Trout are known as drift feeders and are therefore expected to eat more terrestrial organisms. Semiaquatic prey is the most common prey ingested, collectively accounting for about 45% of total identifiable invertebrate count ingested in the lower and upper section, respectively. Large trout consume higher proportions of terrestrial prey than small trout. This difference in diet variation is consistent with previous studies that show that predator body size can influence diet composition (Falke et al. 2020; Cudmore and Bury 2014).

Prey Diversity – The food web structures in headwater streams can be predictable along geophysical gradients due to different stream slope and habitat size. Thus, the diet variation in top predators would be different in upstream and downstream. However, this study found that patterns in the diets of salamanders and trout collected were similar in both stream sections of Lookout Creek. This is further supported by the study done by Zatkos (2019) observed that food web structure does not associate with geographical proximity. Both predators feed on a wide variety of prey and appear to consume whatever is most abundant in their habitats.

Overall, prey selections vary depending on body sizes of Coastal Giant Salamander and Cutthroat Trout and the composition of other species in these headwater communities. However, there is no major differences of the predators' diets between both stream sections. Though this result did not support our hypothesis, this information is essential to predict the relationship between spatial component and prey selection by the predators along headwater streams, and this allows researchers to analyze the temporal component of the study better to understand the impact of climate change on the diets. Comparison involving different age-classes of both predators should also be studied so that we can predict the potential interactions between salamander and Cutthroat Trout and possible community-wide effects of these top predators in headwater streams.

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Appendix A. List of all taxa present in diets

Taxonomic Identification						Predator		
Phylum	**Class**	**Subclass**	**Superorder**	**Order**	**Family**	***D. tenebrosus***	***O. clarkii***	***O. mykiss***
Annelida		Hirudinea						x
Chordata	Actinopterygii			Scorpaeniformes	Cottidae	x	x	x
Chordata	Amphibia			Urodela	Ambystomatidae			x
Arthropoda	Arachnida			Araneae	Salticidae		x	
Arthropoda	Arachnida		Acariformes			x	x	x
Arthropoda	Arachnida						x	
Arthropoda	Chilopoda						x	
Annelida	Clitellata	Oligochaeta					x	
Arthropoda	Insecta			Lepidoptera	Acanthopteroctetidae		x	
Arthropoda	Insecta			Hemiptera	Achilidae		x	
Arthropoda	Insecta			Ephemeroptera	Ameletidae	x	x	
Arthropoda	Insecta			Trichoptera	Apataniidae	x	x	
Arthropoda	Insecta			Hemiptera	Aphididae		x	
Arthropoda	Insecta			Blattodea	Archotermopsidae		x	
Arthropoda	Insecta			Ephemeroptera	Baetidae	x	x	x
Arthropoda	Insecta			Trichoptera	Brachycentridae		x	
Arthropoda	Insecta			Psocoptera	Caeciliusidae		x	
Arthropoda	Insecta			Trichoptera	Calamoceratidae	x		
Arthropoda	Insecta			Diptera	Cecidomyiidae		x	
Arthropoda	Insecta			Coleoptera	Cerambycidae	x	x	
Arthropoda	Insecta			Hymenoptera	Chalcidoidea		x	
Arthropoda	Insecta			Diptera	Chironomidae	x	x	x

Phylum	**Class**	**Subclass**	**Superorder**	**Order**	**Family**	***D. tenebrosus***	***O. clarkii***	***O. mykiss***
Arthropoda	Insecta			Plecoptera	Chloroperlidae		x	
Arthropoda	Insecta			Coleoptera	Chrysomelidae	x	x	
Arthropoda	Insecta			Neuroptera	Chrysopidae		x	
Arthropoda	Insecta			Coleoptera	Chyrsomelidae		x	
Arthropoda	Insecta			Hemiptera	Cicadellidae		x	x
Arthropoda	Insecta			Coleoptera	Coccinellidae		x	
Arthropoda	Insecta			Megaloptera	Corydalidae	x		
Arthropoda	Insecta			Coleoptera	Cryptophagidae	x		
Arthropoda	Insecta			Diptera	Culicidae		x	
Arthropoda	Insecta			Coleoptera	Curculionidae	x	x	
Arthropoda	Insecta			Psocoptera	Dasydemellidae		x	
Arthropoda	Insecta			Diptera	Dixidae		x	
Arthropoda	Insecta			Diptera	Dolichopodidae		x	
Arthropoda	Insecta			Coleoptera	Dytiscidae	x	x	
Arthropoda	Insecta			Coleoptera	Elmidae	x	x	x
Arthropoda	Insecta			Diptera	Empididae	x	x	x
Arthropoda	Insecta			Ephemeroptera	Ephemerellidae	x	x	
Arthropoda	Insecta			Psocoptera	Epipsocidae		x	
Arthropoda	Insecta			Hymenoptera	Figitidae		x	
Arthropoda	Insecta			Hymenoptera	Formicidae	x	x	x
Arthropoda	Insecta			Lepidoptera	Geometridae		x	
Arthropoda	Insecta			Trichoptera	Glossosomatidae	x	x	
Arthropoda	Insecta			Hymenoptera	Halictidae		x	
Arthropoda	Insecta			Ephemeroptera	Heptageniidae	x	x	
Arthropoda	Insecta			Coleoptera	Hydrophilidae		x	x

Phylum	Class	Subclass	Superorder	Order	Family	*D. tenebrosus*	*O. clarkii*	*O. mykiss*
Arthropoda	Insecta			Trichoptera	Hydropsychidae	x	x	
Arthropoda	Insecta			Trichoptera	Hydroptilidae	x	x	x
Arthropoda	Insecta			Coleoptera	Latridiidae		x	
Arthropoda	Insecta			Trichoptera	Lepidostomatidae	x	x	x
Arthropoda	Insecta			Trichoptera	Leptoceridae		x	
Arthropoda	Insecta			Ephemeroptera	Leptophlebiidae	x	x	
Arthropoda	Insecta			Plecoptera	Leuctridae	x		
Arthropoda	Insecta			Trichoptera	Limnephilidae		x	
Arthropoda	Insecta			Psocoptera	Mesopsocidae		x	
Arthropoda	Insecta			Diptera	Mycetophilidae		x	
Arthropoda	Insecta			Plecoptera	Nemouridae	x	x	
Arthropoda	Insecta			Diptera	Oestridae		x	
Arthropoda	Insecta			Plecoptera	Peltoperlidae		x	
Arthropoda	Insecta			Hemiptera	Pentatomidae		x	
Arthropoda	Insecta			Hymenoptera	Perilampidae		x	
Arthropoda	Insecta			Plecoptera	Perlidae	x	x	
Arthropoda	Insecta			Plecoptera	Perlodidae	x	x	x
Arthropoda	Insecta			Trichoptera	Philopotamidae	x	x	x
Arthropoda	Insecta			Psocoptera	Philotarsidae		x	
Arthropoda	Insecta			Trichoptera	Polycentropodidae	x	x	
Arthropoda	Insecta			Hymenoptera	Proctotrupidae		x	
Arthropoda	Insecta			Diptera	Psychodidae		x	
Arthropoda	Insecta			Hemiptera	Psyllidae		x	
Arthropoda	Insecta			Plecoptera	Pteronarcyidae	x	x	
Arthropoda	Insecta			Orthoptera	Rhaphidophoridae	x		

Phylum	**Class**	**Subclass**	**Superorder**	**Order**	**Family**	***D. tenebrosus***	***O. clarkii***	***O. mykiss***
Arthropoda	Insecta			Trichoptera	Rhyacophilidae	x	x	
Arthropoda	Insecta			Hemiptera	Rhyparochromidae		x	
Arthropoda	Insecta			Lepidoptera	Saturniidae		x	
Arthropoda	Insecta			Coleoptera	Scraptiidae		x	
Arthropoda	Insecta			Lepidoptera	Sesiidae		x	
Arthropoda	Insecta			Diptera	Simuliidae	x	x	x
Arthropoda	Insecta			Hymenoptera	Sphecidae		x	
Arthropoda	Insecta			Coleoptera	Staphylinidae		x	
Arthropoda	Insecta			Diptera	Tabanidae		x	
Arthropoda	Insecta			Diptera	Tachinidae		x	
Arthropoda	Insecta			Diptera	Therevidae		x	
Arthropoda	Insecta			Hemiptera	Tingidae		x	
Arthropoda	Insecta			Diptera	Tipulidae	x	x	
Arthropoda	Insecta			Trichoptera	Uenoidae			x
Arthropoda	Insecta			Hymenoptera	Vespidae		x	
Arthropoda	Insecta			Polydesmida	Xystodesmidae	x		
Arthropoda	Insecta			Lepidoptera				x
Arthropoda	Insecta			Orthoptera				x
Arthropoda	Insecta			Polydesmida			x	
Arthropoda	Insecta			Psocoptera		x		
Arthropoda	Malacostraca			Decapoda		x		
Arthropoda	Malacostraca			Isopoda			x	
Arthropoda	Ostracoda					x		
Platyhelminthes	Turbellaria					x	x	
Arthropoda	Insecta			Coleoptera	Cerpopidae	x		

Arthropoda	Insecta	Coleoptera	Cerylonidae	x