

# DIET OF BURBOT AND IMPLICATIONS FOR SAMPLING

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## ABSTRACT

Burbot (*Lota lota*) are an apex piscivore that were illegally introduced to the Green River drainage, Wyoming, raising concerns for the conservation and management of fishes throughout the basin. However, relatively little is known about the diet of non-native burbot. The objectives of this research were to characterize diet composition of burbot and identify differences in diet composition as a function of sampling gear. Diet composition was characterized using frequency of occurrence, percent by number, and percent by weight to identify the importance of each prey type to burbot. Diet composition was compared across gears to identify the relationship between gear and diet. Fishes were present in the stomach contents of nearly all burbot sampled and composed 62–100 percent of the stomach contents of burbot greater than 300 mm. Prey diversity was greatest in diets of burbot sampled with small-mesh hoop nets. Results from the current study provide important information on the diet of non-native burbot and highlight the potential influence of gear on diet studies.

**Key Words:** Burbot, Gear bias, Diet, Green River, Wyoming

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## INTRODUCTION

Burbot (*Lota lota*) are the only freshwater species of the family Gadidae and have a circumpolar distribution throughout Europe, Asia, and North America (Stapanian et al. 2010). Burbot have been categorized as opportunistic piscivores (Rudstam et al. 1995, Amundsen et al. 2003) with fish typically dominating the diet of burbot greater than 400 mm (Rudstam et al. 1995, Schram et al. 2006). Fratt (1997) evaluated prey consumption of burbot in Green Bay, Lake Michigan, Wisconsin, and reported that 55 percent of stomach contents (by volume) of burbot less than 400 mm were fishes. Bailey (1972) reported greater than 90 percent occurrence of fishes in the diet of 119–742 mm burbot in Lake Superior, Wisconsin and Michigan. The author suggested that burbot were important competitors with other large piscivores in the system due to their non-selective diet and high consumption rates. Although burbot are apex piscivores throughout their native distribution (Cott et al. 2011),

relatively little is known about how burbot function in food webs in systems where they are non-native.

In Wyoming, burbot represent native and non-native populations and are a primary management concern for state, federal, and tribal natural resource agencies. Burbot are native to the Tongue and Wind-Bighorn river drainages, but are considered either rare (Wind-Bighorn River drainage) or extirpated (Tongue River, Krueger and Hubert 1997). In the Green River drainage, burbot were illegally introduced into Big Sandy Reservoir in the 1990s (Gardunio et al. 2011). Since their initial introduction, burbot have been found from Flaming Gorge Reservoir (FGR) to the confluence of the New Fork and Green rivers. The rapid expansion of burbot in the Green River has increased concern for the management of sport fishes and conservation of native fishes in the system. The Green River supports economically, socially, and ecologically important fishes including brown trout

(*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), Colorado River cutthroat trout (*O. clarkii pleuriticus*), roundtail chub (*Gila robusta*), bluehead sucker (*Catostomus discobolus*), and flannelmouth sucker (*C. latipinnis*). Managers have hypothesized that burbot compete with and (or) directly consume native fishes and economically important trout species. However, relatively little is known about how non-native burbot may affect the trophic dynamics of recipient systems.

Negative effects of introduced species are often not exclusive to a single mechanism. For example, both predation and resource competition may occur between native and non-native species. Mills et al. (2004) evaluated interactions between non-native western mosquitofish (*Gambusia affinis*) and native least chub (*Notichthys phlegenthontis*) in Walter Spring, California and found that adult mosquitofish greater than 30 mm fed extensively on 9–13 mm least chub. Once least chub were too large to be consumed by western mosquitofish, they were negatively influenced by resource competition. Similarly, non-native burbot likely influence native fishes through multiple mechanisms. Cott et al. (2011) investigated the trophic ecology of burbot relative to lake trout (*Salvelinus namaycush*), northern pike (*Esox lucius*), and lake whitefish (*Coregonus clupeiformis*) in four boreal Canadian lakes using stable isotope analysis. Burbot and lake trout were both described as top-level piscivores in the lakes, and burbot were thought to play a particularly important role in structuring fish assemblages via predation and competition. In the Green River drainage, burbot have been hypothesized to alter the system through resource competition (i.e., habitat, food) and predation (Gardunio et al. 2011). For instance, Gardunio et al. (2011) suggested that burbot outcompete smallmouth bass (*Micropterus dolomieu*) for available prey in FGR as evidenced by declining catch rates of smallmouth bass following establishment of burbot. Despite concerns regarding the influence of burbot on the trophic dynamics

of the Green River fish assemblage, little empirical data on diet are available for non-native burbot.

Information on diet is fundamental for understanding how a given species may influence the food web of a system (Garvey and Chipps 2012). Although a number of analytical techniques are available to quantify dietary information (e.g., bioenergetics modeling, stable isotope analysis), identification of gut contents is a commonly used technique. Gut contents are ideally quantified over extensive spatial and temporal scales to capture seasonal and temporal variation in diet (Hyslop 1980, Garvey and Chipps 2012). However, short-term diet studies can provide valuable data that answer narrow questions (e.g., fish- versus invertebrate-dominated diet, consumption of native fishes) and can be used to guide future management decisions and research foci.

Sampling techniques are an important consideration when describing the diet of fishes (Bowen 1996). Active gears, such as electrofishing often select for sedentary individuals (Reynolds and Kolz 2012). Sedentary individuals are not actively foraging, and studies using information predominantly from sedentary individuals may underestimate the amount or inaccurately describe the types of food consumed by fish in the population. Alternatively, fish captured with passive gears often contain greater amounts of food than those caught by active gears. For instance, Hayward et al. (1989) reported that the amount of food in yellow perch (*Perca flavescens*) stomachs was greater in fish caught with gill nets than those caught by trawling in Lake Erie, Ohio. Furthermore, passive entrapment gears can sample non-target prey species increasing the potential for post-capture consumption by piscivorous species. Breen and Ruetz (2006) examined the diets of two bowfin (*Amia calva*) and eight yellow bullhead (*Ameiurus natalis*) captured in fyke nets stocked with round goby (*Neogobius melanostomus*), banded killifish (*Fundulus diaphanous*), and bluntnose minnow (*Pimephales notatus*).

The authors reported that a single bowfin consumed 35 percent of the fish stocked in a fyke net, suggesting that piscivory is likely high in entrapment gears. Therefore, the choice of sampling technique has the potential to influence diet composition by either sampling active or sedentary fish or by confounding diet composition by post-capture piscivory.

Although the influence of sampling gear on diet analysis has been recognized for decades (Hayward et al. 1989), certain instances (e.g., target species, habitat) dictate when a particular sampling gear is used. For instance, burbot are cold-water stenotherms that prefer deep habitats (Klein et al. 2015a) and are most often sampled using passive gears such as hoop nets, cod traps, and gill nets (Bernard et al. 1991, Spence 2000). Considering the need to accurately describe the diet of non-native

burbot, we sought to evaluate the influence of passive-entrapment (hoop nets) and active (electrofishing) gears on diet composition of burbot in the Green River. In addition, we provide a short-term description of non-native burbot diet. Although we understand that short-term diet studies do not capture the spatio-temporal variability in diet, we argue that any description of diet of non-native burbot will be useful for directing management actions and future research. For instance, information on diet of non-native burbot is invaluable for understanding if targeted suppression of the species is needed in the Green River.

## METHODS

The Green River originates in the Wind River Range of western Wyoming and is a primary tributary of the Colorado River (Fig. 1). The Green River basin covers

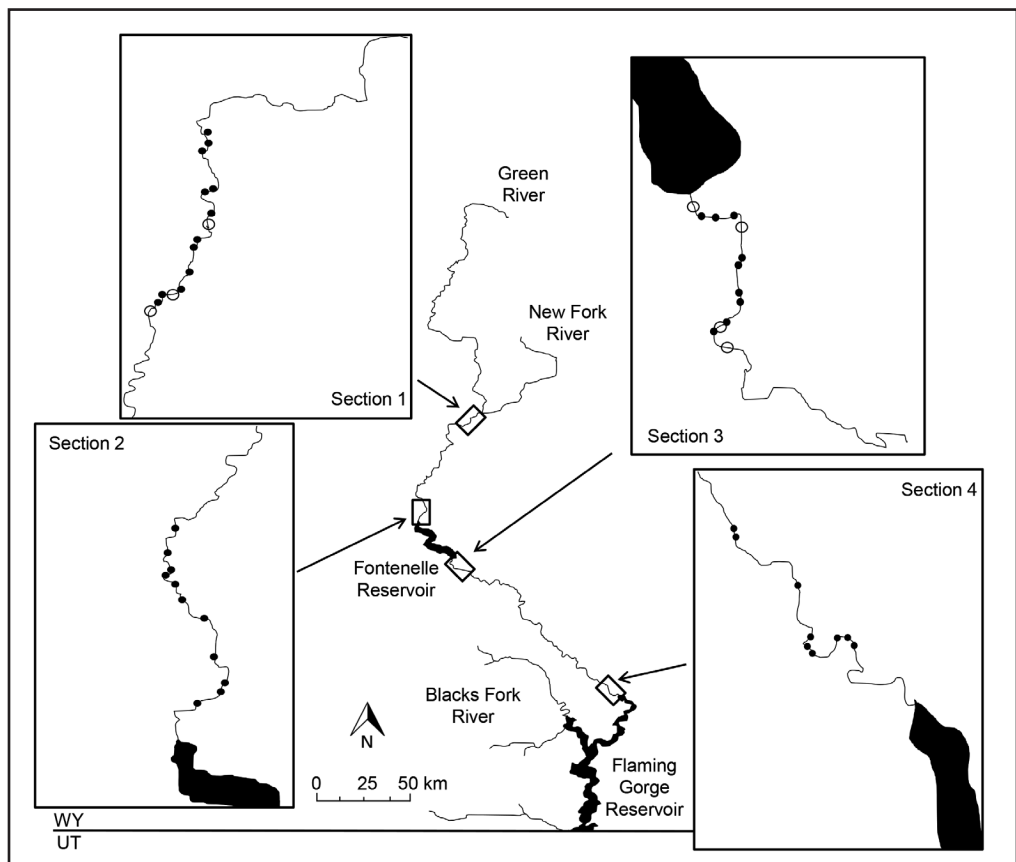


Figure 1. River sections used for Burbot sampling in the Green River, Wyoming during the summer and autumn (2013). Boxes depict each section in detail, with sites sampled in the summer (solid black circles) and autumn (open black circles).

parts of Wyoming, Colorado, and Utah. The headwaters are characterized by high-gradient runs interspersed with pool-riffle habitat (Kurtz 1980). From its headwaters, the Green River flows for approximately 235 km before entering Fontenelle Reservoir. From Fontenelle Reservoir downstream to the confluence of the Big Sandy River, the Green River is characterized by long runs averaging 450 m (Wiley 1974). From the Big Sandy River confluence to Flaming Gorge Reservoir, the Green River is relatively low gradient (Wiley 1974). Sampling was conducted in the Green River, Wyoming, from August through November 2013. The river was divided into four sections to allocate sampling effort (Klein et al. 2015b). Each river section was then divided into 150-m long reaches. Reaches were sampled using night electrofishing, small-mesh hoop nets (6.4-mm bar mesh), and large-mesh hoop nets (19-mm bar mesh). A total of 28 reaches was sampled over a 9-day period such that each reach was sampled three times with each gear. An additional 12 reaches were opportunistically sampled with either night electrofishing, small-mesh hoop nets, or large-mesh hoop nets to obtain additional diet samples.

Small-mesh hoop nets were 3.0 m long, had seven 0.6-m diameter hoops, and constructed of 6.4-mm bar mesh. Large-mesh hoop nets had an overall length of 2.9 m with four 0.91-m diameter hoops and were constructed of 19-mm bar mesh. Cod ends were anchored upstream and nets were positioned parallel to the current. A single net was baited with dead white sucker (*Catostomus commersonii*) (a non-native species common in the system) and fished for approximately 24 hours in a given reach. Bait was placed in a perforated plastic container attached in the cod end of each net. Equal effort was used at each reach and catch was recorded as the number of fish per sampling event.

A float boat equipped with a Smith-Root VVP-15B electrofisher (Smith-Root, Vancouver, Washington) powered by a 5,000 W generator was used for night electrofishing. Power output was

standardized with a frequency of 45Hz and duty cycle of 45 percent at 2,750–3,250 W (Miranda 2009). A 2.4-m long dip net with 6-mm bar knotless mesh was used by a single netter positioned on the bow of the boat. Electrofishing was initiated at the uppermost point of each 150-m reach and preceded downstream until the entire reach had been sampled.

All captured burbot were weighed (nearest 1.0 g) and measured for total length (nearest 1.0 mm). On the final sampling event for each reach, all captured burbot were euthanized with an overdose of MS-222 (tricaine methanesulfonate, Western Chemical, Inc., Ferndale, Washington). The anterior portion of burbot stomachs were removed, preserved in 10 percent formalin, and returned to the University of Idaho for diet analysis.

Stomachs were opened and rinsed to ensure the removal of all contents. Seventy-five stomachs were empty and removed from further diet analysis. Prey items were enumerated and weighed to the nearest 0.01 g by taxonomic category. Non-fish categories included Insecta, (*Orconectes* spp.), Gastropoda, Amphipoda, rocks, and unknown material. Fish categories consisted of longnose dace (*Rhinichthys cataractae*), speckled dace (*R. osculus*), redbside shiner (*Richardsonius balteatus*), utah chub (*Gila atraria*), white sucker × flannelmouth sucker hybrid, mountain whitefish (*Prosopium williamsoni*), rainbow trout, burbot, mottled sculpin (*Cottus bairdii*), unknown catostomid, and unknown salmonid. Prey items identified as fish, but not assigned to taxonomic group were categorized as unidentified fish. Diagnostic structures were used when whole items were unavailable. For example, *Orconectes* spp. prey items were counted using the number of identifiable heads.

Burbot were grouped into 50-mm length bins. Proportions of diet categories by number and weight were calculated for individual burbot and averaged for each 50-mm length group. Diet composition was also categorized as frequency of occurrence, percent by number, and percent by weight

for each gear type (night electrofishing, small-mesh hoop net, and large-mesh hoop net). Frequency of occurrence was calculated as the number of individuals with prey items of a particular category divided by the total number of individuals with stomach contents. Percent by number was calculated as the number of items of each prey type divided by the total number of food items enumerated for each fish and then averaged across individuals with stomach contents. Similarly, percentage by weight was calculated as the average proportional weight of each prey category across individuals with stomach contents. Standard error was calculated for both percent by number and percent by weight for each category.

A multivariate analysis of variance (MANOVA) was used to identify differences in diet composition by gear type (Johnson 1998, Chipps and Garvey 2007). Analysis of variance (ANOVA) was then used to test for differences between gear types for a given diet category (Ott and Longnecker 2010). If differences in count data were observed between gears for a given diet category, a Tukey-pairwise comparison was used to detect differences between gears. All tests were considered significant at  $\alpha = 0.05$ .

## RESULTS

In total, 231 burbot were sampled for diet analysis (Table 1). Night electrofishing sampled 156 burbot, small-mesh hoop nets sampled 68 burbot, and seven burbot were sampled using large-mesh hoop nets. Burbot sampled using night electrofishing

averaged 418 mm ( $\pm$  SE;  $\pm$  11 mm) in length; whereas, burbot sampled with hoop nets had a mean length of 334 mm ( $\pm$  12 mm). Burbot sampled using large-mesh hoop nets averaged 340 mm ( $\pm$  40 mm) in total length.

Fish were observed in nearly all burbot stomachs ( $n = 211$ ) and varied from 25–100 percent by number across lengths (Fig. 2). Unidentified fish accounted for the greatest proportion of stomach contents among length bins, except for 200–249 mm. Non-fish contents were observed in all length bins, except for 700–749 mm ( $n = 1$ ). Diversity of prey items was greatest for 300–349 mm and 450–499 mm burbot. Proportions of prey items varied little between percent by number and weight for all burbot length categories. Fish made up 62–100 percent of the diet by number for burbot greater than 300 mm. Fish in the diet of burbot 150–300 mm represented 25–86 percent by number. Of the identified fishes, salmonids were 2–25 percent by weight of the contents for 250–699 mm burbot. Burbot less than 350 mm consumed a higher proportion of non-fish prey items relative to burbot greater than 350 mm. Of these non-fish prey items, insects were 14–67 percent by number for burbot 150–349 mm (Fig. 2). *Orconectes* spp. were observed in stomach contents of 250–699 mm burbot, but did not account for more than 15 percent by number or 11 percent by weight.

Overall diet composition varied by gear. Diversity of ingested prey items was greatest for burbot captured in small-mesh hoop nets (Table 2). White sucker  $\times$  flannelmouth

Table 1. Summary statistics for burbot (*Lota lota*) sampled from the Green River, Wyoming in August–November 2013. Burbot were sampled using night electrofishing, small-mesh hoop nets, and large-mesh hoop nets.

Sampling gear	<i>n</i>	Total length (mm)			
		$\bar{x}$	SE	Minimum	Maximum
Night electrofishing	156	418	11	31	719
Small-mesh hoop net	68	334	12	125	606
Large-mesh hoop net	7	340	40	178	497
All gears	231	391	9	31	719

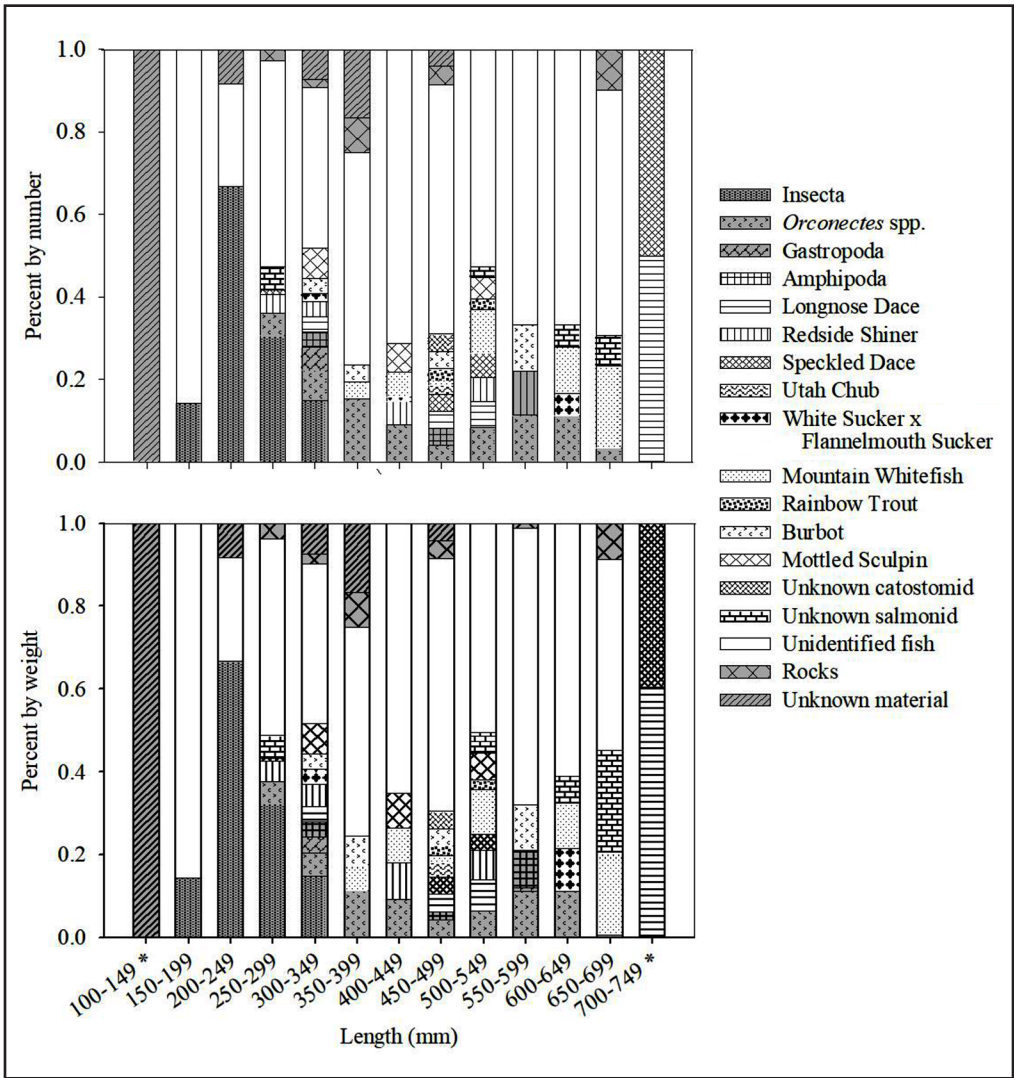


Figure 2. Diet composition of Burbot sampled from the Green River, Wyoming in August–November 2013. Diet composition presented as average percent by number (upper panel) and average percent by weight (lower panel) for Burbot by 50-mm length bin. Asterisks indicate diet samples obtained from a single fish.

sucker, unknown catostomid, burbot, and mottled sculpin were only observed in the diet of burbot captured in small-mesh hoop nets. Utah chub was only observed in stomachs from night electrofishing. Cyprinids represented nearly 10 percent of the diet of burbot caught in small-mesh hoop nets. Invertebrates composed 27 percent by number of stomach content in burbot caught by night electrofishing. The percent by weight of fish in the diet of burbot was similar among gears: 67 percent

for night electrofishing, 84 percent for small-mesh hoop nets, and 87 percent for large-mesh hoop nets (Table 2). Results of the MANOVA revealed a significant difference in diet composition among gear types ( $F_{2,153} = 1.72; P < 0.02$ ). The ANOVA identified four diet taxa that were different among gears. The diet of burbot captured with small-mesh hoop nets contained significantly higher numbers of reidside shiner ( $F_{2,153} = 3.83; P < 0.03$ ), white sucker × flannelmouth sucker hybrid ( $F_{2,153} = 3.53;$

Table 2. Diet composition of burbot (*Lota lota*) sampled from the Green River, Wyoming in August–November 2013. Diet composition is presented as frequency of occurrence (FO), mean percent by number (%N), and mean percent by weight (%W) for night electrofishing, small-mesh hoop net, large-mesh hoop net, and all gears combined. Numbers in parentheses represent one standard error.

Taxon	Night electrofishing			Small mesh hoop net			Large mesh hoop net			All gears		
	FO	% N	% W	FO	% N	% W	FO	% N	% W	FO	% N	% W
Insecta	0.17	17.48 (3.76)	17.48 (3.76)	0.02	1.04 (1.04)	1.64 (1.64)	0.00	0.00	0.00	0.12	11.86 (2.58)	12.04 (2.60)
Orconectes spp.	0.09	6.89 (2.39)	6.30 (2.33)	0.10	7.29 (3.33)	5.60 (3.00)	0.00	0.00	0.00	0.09	6.79 (1.88)	5.88 (1.79)
Gastropoda	0.01	0.03 (0.03)	0.07 (0.07)	0.04	3.13 (2.31)	2.10 (2.08)	0.00	0.00	0.00	0.02	0.98 (0.71)	0.69 (0.64)
Amphipoda	0.03	2.82 (1.61)	2.25 (1.33)	0.00	0.00	0.00	0.00	0.00	0.00	0.02	1.86 (1.07)	1.49 (0.88)
Longnose Dace	0.04	2.62 (1.45)	3.00 (1.55)	0.02	2.08 (2.08)	2.08 (2.08)	0.00	0.00	0.00	0.03	2.37 (1.15)	2.62 (1.20)
Speckled Dace	0.01	2.30 (1.26)	1.99 (1.14)	0.13	0.94 (0.66)	0.45 (0.32)	0.00	0.00	0.00	0.04	1.81 (0.86)	1.45 (0.76)
Redside Shiner	0.04	0.32 (0.32)	0.53 (0.53)	0.04	6.59 (2.79)	8.78 (3.78)	0.00	0.00	0.00	0.04	2.24 (0.91)	3.05 (1.24)
Utah Chub	0.01	0.49 (0.49)	0.79 (0.79)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.32 (0.32)	0.52 (0.52)
White Sucker x Flannelmouth Sucker	0.00	0.00	0.00	0.06	2.31 (1.47)	4.03 (2.80)	0.00	0.00	0.00	0.02	0.71 (0.46)	1.24 (0.87)
Mountain Whitefish	0.05	3.72 (1.75)	3.93 (1.80)	0.04	2.43 (1.72)	3.05 (2.20)	0.20	10.0 (10.00)	14.93 (14.93)	0.05	3.53 (1.30)	4.01 (1.44)
Rainbow Trout	0.01	0.65 (0.65)	0.57 (0.57)	0.02	1.04 (1.04)	0.93 (0.93)	0.00	0.00	0.00	0.01	0.75 (0.53)	0.66 (0.47)
Burbot	0.00	0.00	0.00	0.08	7.29 (3.64)	7.98 (3.87)	0.00	0.00	0.00	0.03	2.24 (1.15)	2.46 (1.22)
Mottled Sculpin	0.00	0.00	0.00	0.10	7.87 (3.74)	8.20 (3.91)	0.00	0.00	0.00	0.03	2.42 (1.18)	2.52 (1.23)
Unknown salmonid	0.04	1.33 (0.72)	2.50 (1.24)	0.04	3.13 (2.31)	3.23 (2.36)	0.00	0.00	0.00	0.04	1.84 (0.85)	2.64 (1.09)
Unknown catostomid	0.00	0.00	0.00	0.02	2.08 (2.08)	2.08 (2.08)	0.00	0.00	0.00	0.01	0.64 (0.64)	0.64 (0.64)
Unidentified fish	0.60	54.51 (4.67)	53.62 (4.68)	0.56	46.53 (6.56)	43.60 (6.94)	1.00	80.00 (12.25)	71.88 (17.27)	0.60	52.87 (3.73)	51.12 (3.81)
Rocks	0.06	2.97 (1.52)	3.10 (1.54)	0.00	0.00	0.00	0.20	10.00 (10.00)	13.19 (13.19)	0.04	2.28 (1.05)	2.47 (1.10)
Unknown material	0.04	3.88 (1.91)	3.88 (1.91)	0.06	6.25 (3.53)	6.25 (3.53)	0.00	0.00	0.00	0.04	4.49 (1.66)	4.49 (1.66)

$P < 0.04$ ), burbot ( $F_{2,153} = 4.82$ ;  $P < 0.01$ ), and mottled sculpin ( $F_{2,153} = 5.48$ ;  $P < 0.006$ ) in their stomachs than other gears.

## DISCUSSION

Our results suggest non-native burbot from the Green River have similar diets to burbot found in their native distribution. In the current study, 25-100 percent of the stomach content (by weight) for non-native burbot contained fish. Schram et al. (2006) reported that fishes constituted greater than 90 percent by weight of the diet of burbot greater than 400 mm in the Apostle Islands of Lake Superior, Wisconsin. Similarly, Fratt et al. (1997) described the diet of burbot in Green Bay and western Lake Michigan and reported that 94 percent by volume was fishes. Additionally, the consumption of fish by burbot is often reported as being positively related to fish length. Amundsen et al. (2003) observed that percent by number of fish prey items increased from 30 percent in 100–200 mm burbot to nearly 100 percent for burbot greater than 400 mm in the subarctic Pasvik watercourse of northern Norway and Russia. Similarly, Tolonen et al. (1999) concluded that the probability of burbot consuming fish was positively correlated with length in Kilipisjärvi, a lake in northern Finland. In the current study, an average of 56 percent (by weight) of the diets of burbot less than 300 mm contained fish; whereas, diets of fish greater than 300 mm contained an average of 82 percent fish. The observed differences between the diets of small and large non-native burbot is likely related to ontogenetic diet shifts associated with behavior and gape limitation. Small burbot (<300 mm) are likely gape limited as evidenced by Damsgard's (1995) commonly used (Stockwell et al. 2010, Harrison et al. 2013) prey vulnerability model (maximum prey length (cm) =  $[0.535 \times \text{predator length (cm)}] - 0.487$ ). Based on Damsgard's model, a 300 mm burbot could only ingest a 155 mm prey item. Although small burbot could theoretically consume fish roughly half their body size, prey items may not be available for some burbot due to a lack of

spatial overlap between predator and prey. Burbot occupy deep habitats with rocky substrate (Dixon and Vokoun 2009, Klein et al. 2015a); whereas, many juvenile stream-dwelling fishes occupy shallow habitats to avoid predation (Schlosser 1987, Delbert-Lobb and Orth 1990). Harrison et al. (2013) suggested that burbot move into the littoral zone during the crepuscular period to forage. However, the authors noted a size-structured pattern in depth distribution; whereby, small burbot did not exhibit pronounced diel movements compared to large burbot. The authors suggested that small burbot avoid foraging in littoral zones to reduce interspecific and intraspecific predation. As such, small burbot in the Green River may be constrained to a diet composed primarily of invertebrates until they are no longer gape limited or the threat of size-dependent predation is negligible. Regardless of the exact mechanism resulting in the diet of non-native burbot, our results suggest burbot may negatively influence the trophic dynamics of the Green River.

Non-native species can negatively influence recipient ecosystems through various mechanisms including predation, competition, and hybridization (Vitule et al. 2009). For example, Ruzyccki et al. (2003) suggested non-native lake trout negatively influenced the persistence of Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) in Yellowstone Lake, Wyoming, by consuming approximately 14 percent of the vulnerable cutthroat trout population in a single year. Similarly, Saunders et al. (2014) described the diet of burbot in FGR and concluded that *Orconectes* spp. occurred in 78-85 percent of the stomachs. The authors suggested non-native burbot could negatively influence smallmouth bass populations in FGR through competition for *Orconectes* spp. Although our results indicate that non-native burbot do not consume high proportions of *Orconectes* spp., the abundance of fish in burbot diet suggest the species could alter the trophic dynamics of the Green River through direct predation and competition. Klobucar et al. (2016) concluded that burbot in FGR



consume an estimated 45,400 kg of fish annually assuming a population size of 80,000 burbot. Although a population estimate of burbot is not available for the Green River, the results of Klobucar et al. (2016) suggest burbot in the Green River could negatively influence fish populations through direct predation. Furthermore, Klobucar et al. (2016) estimated that burbot diets in FGR contained an average of 32 percent (by weight) fish; whereas, our results indicate that fish constituted an average of 75 percent (by weight) of burbot diet in the Green River. As such, burbot may have a higher per capita rate of predation in the Green River compared to predation rates in FGR. In addition to direct predation, non-native burbot may negatively influence fish populations and species assemblages through indirect effects. Knudsen et al. (2010) reported that burbot negatively influenced Arctic charr (*Salvelinus alpinus*) populations through direct predation and predation-induced shifts in resource use (i.e., habitat, diet). Although additional research is likely needed to understand the influence of non-native burbot on the food web of the Green River, the presence of an apex piscivore in the system is a concern for the conservation and management of native and sport fishes.

Although we describe diet composition of non-native burbot, inferences should be made with caution. Burbot were sampled from August to November and the diet data presented here likely do not reflect seasonal variations in diet. Rudstam et al. (1995) concluded that the diet of burbot in Green Bay, Lake Michigan, was dominated by alewives (*Alosa pseudoharengus*) in winter and spring, and shifted to rainbow smelt (*Osmerus mordax*) in summer and autumn. Similarly, Chisholm et al. (1989) reported that largescale sucker (*Catostomus macrocheilus*) were most important to burbot in Libby Reservoir, Montana, in autumn and winter; whereas, yellow perch dominated burbot diets in spring. Burbot in FGR primarily consumed northern crayfish in the autumn and increase piscivory in the winter (Klobucar et al. 2016). The authors

suggested that reduced activity due to colder water temperatures in the winter subjected resident fishes to increased levels of predation by burbot. If burbot in the Green River exhibit similar seasonal diet shifts, piscivory may increase in the winter further threatening native and sport fish species.

Our results suggest diet composition is likely influenced by gear type. Specifically, selectivity for small-bodied fishes in entrapment gears could bias diet analysis due to post-capture piscivory by target species. Merriner (1975) used multiple sampling techniques (i.e., gill nets, haul seines, trawls, and pound nets) to characterize the diet of weakfish (*Cynoscion regalis*) in Pamlico Sound and waters near Morehead City, North Carolina. The author reported contrasting occurrences of diet items in relation to gear type and only observed thread herring (*Opisthonema oglinum*) in stomachs of weakfish captured with pound nets. Interestingly, diet of burbot captured by small-mesh hoop nets in the current study contained a majority of small-bodied fishes such as redbreasted shiners and mottled sculpin. Alternatively, larger-bodied fish such as mountain whitefish were observed in the diet of burbot captured by large-mesh hoop nets. The fact that burbot consumed higher proportions of small-bodied fishes in small-mesh hoop nets may be the result of the size selectivity of small- and large-mesh hoop nets. For example, 1,258 redbreasted shiners were captured in small-mesh hoop nets over the course of the study; whereas, no redbreasted shiners were caught in large-mesh hoop nets. Bowen (1996) cautioned that large fish captured in entrapment gears may feed on prey types disproportionate to natural occurrences or consume prey not normally in the diet. Duffy et al. (2011) quantified the number of juvenile salmonids (*Oncorhynchus* spp.) that had been consumed by piscivores in downstream migrant traps in Prairie Creek, California. Adult Coastal cutthroat trout (*O. clarkii clarkii*) captured in live boxes consumed five to six times as many juvenile salmonids as those sampled using other techniques. Thus, greater occurrence of

redside shiner, white sucker × flannelmouth sucker, burbot, and mottled sculpin in diets of burbot captured in small-mesh hoop nets may have been an artifact of opportunistic feeding behavior associated with sampling gear. Based on our data, a single sampling technique would have yielded a different diet composition for burbot in the Green River. White sucker × flannelmouth sucker, unknown catostomid, burbot, and mottled sculpin were only observed in the diet of burbot captured in small-mesh hoop nets, and utah chub was only observed in stomach contents of burbot captured by night electrofishing. Burbot are often sampled using passive entrapment gears (e.g., hoop nets, cod traps) due to the habitat use (e.g., deep water) of the species. As such, diet collected from burbot sampled using entrapment gears may not adequately reflect what burbot would consume under normal conditions.

Our results suggest the diet of non-native burbot was similar to the diet of burbot within their native distribution. Non-native burbot are a functional apex piscivore and have the potential to influence trophic dynamics in the Green River. As such, managers of the Green River may want to focus efforts on understanding how an apex piscivore may influence species interactions in the system. As additional research will likely require further diet analysis, managers should be cognizant of the potential biases associated with using entrapment gears. Although entrapment gears are commonly used to sample burbot, alternative sampling techniques should be used for diet studies focused on the species. Gill nets or similar passive sampling techniques (e.g., trammel nets) are effective for sampling benthic species (e.g., burbot) in lentic systems (Beauchamp et al. 2009). However, gill nets are not effective in high-current velocities typical of many small, non-wadeable rivers; therefore, active techniques such as electrofishing may be the best alternative (Klein et al. 2015a). Collectively, our results highlight the importance of gear selection for diet studies while providing

baseline data on diet of non-native burbot in the Green River.

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