GRIZZLY BEARS AND CHINOOK SALMON IN THE INLAND RAINFOREST

FRASER HEADWATERS, BRITISH COLUMBIA

WILDLIFE CONSERVATION SOCIETY

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A RECONNAISSANCE SURVEY

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A REPORT PREPARED FOR THE WILBURFORCE FOUNDATION

Introduction

The Yellowstone–to–Yukon (Y2Y) region of western North America offers one of the last, best opportunities on the continent to conserve intact ecological relationships and large carnivores (Locke 1997). The headwaters area of the Fraser River (Robson Valley) in British Columbia contains a globally-unique ecosystem of inland rainforests that is threatened by extensive logging (Zammuto 1996). Chinook salmon (*Oncorhynchus tshawytscha*) migrate 1300 km from the Pacific ocean to spawn there. Grizzly bears (*Ursus arctos*) that feed substantially on salmon have larger body size, greater population productivity, and higher density (Hilderbrand et al. 1999b). Moreover, bears may transport salmon-derived nitrogen into adjacent riparian forests (Hilderbrand et al. 1999a) which, in turn, may influence tree growth (Helfield and Naiman 2001) and biological diversity (Willson et al. 1998, Gende et al. 2002). Thus, it is important to determine if such an ecological relationship exists in this unique inland rainforest at the headwaters of the Fraser River. The objectives of this reconnaissance study were to: (1) ascertain the presence of grizzly bears at salmon streams during the salmon run, and (2) determine the contribution of salmon to the diet of grizzly bears.

Study Area

The Robson Valley contains the headwaters of the Fraser River, which drains 25% of the province of British Columbia (Bocking 1997). The valley occurs in the Interior Cedar-Hemlock biogeoclimatic zone of the Province and harbors a globally-unique antique rainforest with 1000-year old cedars and a unique assemblage of epiphytic lichens (Goward 1994). We surveyed grizzly bears along the following 7 tributaries of the upper Fraser River where chinook salmon spawn in late summer (average number of salmon 1997-1998 in parentheses): Slim (2897), Walker (257), Morkill (1474), Goat (328), West Twin (20), McKale (20), and Holmes (2783) (average total = 7779). On average, the salmon start spawning about August 9, peak about August 19, and finish by August 31 (Department of Fisheries and Ocean 2003).

Methods

Field surveys

We devised a variation of the non-invasive method pioneered by Canadian biologists and geneticists for collecting hair from bears (Woods et al. 1999). In preliminary trials with several captive grizzly bears at the Bear Research, Education, and Conservation Facility at Washington State University, all bears rubbed vigorously on 10-cm x 10-cm carpet pads impregnated with a proprietary scent lure. In the field survey, a scent station consisted of (a) a 30-cm x 30-cm carpet pad scented with animal blood and fish oil that was suspended from a tree branch out-of-reach of bears, and (b) 5 scented rub pads nailed on nearby tree trunks. We established scent stations at 29 sites along/near salmon streams during 2 concurrent 15-day sampling sessions starting August 20, 1999.

DNA analyses

The Wildlife Genetics International (WGI) lab, under the direction of Dr. David Paetkau, conducted the DNA analyses. An experienced WGI technician inspected hairs under a dissecting microscope and identified glossy black guard hairs with black tips as black bear (Mowat and Strobeck 2000). A previous study determined through mitochondrial DNA (mtDNA) analysis that this subjective sorting assigned 97% of the samples correctly (Woods et al. 1999). WGI technicians extracted DNA from the remaining samples using a QIAamp tissue kit. They identified the species by amplifying a short section of the mitochondrial control region that has a deletion of 13-15 base pairs in grizzly bears compared to black bears (Shields and Kocher 1991, Woods et al. 1999). Next, they attempted to identify individuals using a suite of 6 microstatellite loci (Paetkau 2003; loci G1A, G1D, G10B, G10C, G10L and G10X). They used GENOTYPER software (Perkin Elmer - Applied Biosystems, Foster City, CA) to score genotypes, and Dr. Paetkau independently confirmed the score visually.

Stable isotope analyses

The U.S. Geological Survey laboratory in Denver, CO, under the direction of Dr. Robert Rye, conducted the stable isotope analyses. Lab personnel cleaned the bear hair samples using repeated rinses of a 2:1 choloroform:methanol solution. They weighed samples into tin boats and measured $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ by continuous flow methods using a Carlo Erba NC2500 elemental analyzer coupled to either a Micromass Optima mass spectrometer or a Finnigan Delta Plus XL mass spectrometer. The isotopic values are reported conventionally in δ notation as the deviation per mil (per thousand) according to

$$\delta X = [(R_{sample} / R_{standard}) - 1] \times 1000$$

where X is $\delta^{13}C$, $\delta^{15}N$ or $\delta^{34}S$ and $R_{standard}$ corresponds to the Pee Dee Bellemnite ($\delta^{13}C$), atmospheric N ($\delta^{15}N$), and CDT ($\delta^{34}S$) standards (Felicetti et al. 2003). Based upon hundreds of such measurements over the past several years, the measurement error is estimated to be $\pm$ 0.2%.

For this reconnaissance survey, we used previously reported values of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ for chinook salmon (Hilderbrand et al. 1996, Fellicetti et al. 2003) and for plants and animals potentially used by bears (Hobson et al. 2000 [no values for $\delta^{34}S$ available]). Following the approach of Ben-David et al. (1997a &b), we developed a food-mixing model using 2 isotopes ($\delta^{13}C$, $\delta^{15}N$) and 3 foods (salmon, terrestrial meat, and terrestrial plants) to estimate the contribution of these foods to the diet of bears. This model uses the carbon and nitrogen isotope values of each food corrected for its enrichment after assimilation into the bears' hair (i.e., the 'fractionation' value). We determined the Euclidean distance (= $\sqrt{x^2 + y^2}$) between the $\delta^{13}C$ value (X) and $\delta^{15}N$ value (Y) of each bear sample and the corresponding corrected value for each food on a bivariate graph. The relative contribution of each food to the bears' diet is the inverse of this Euclidean distance. Using equations reported by Felliceti et al. (2000, Fig. 1) based upon feeding trials with captive grizzly bears, we obtained the following correction values: salmon: $\delta^{13}C$ = -19.3, $\delta^{15}N$ = 15.1; terrestrial meat: $\delta^{13}C$ = -21.6, $\delta^{15}N$ = 8.2; and terrestrial plants: $\delta^{13}C$ = -22.5, $\delta^{15}N$ = 3.4.

Results

Occurrence of salmon in the Fraser Headwaters

The number of spawning salmon in the Fraser Headwaters varied between streams and between years (Table 1). The highest number of spawning salmon occurred in Slim Creek, Holmes River, and Morkill River. The number of spawning salmon in the 5 survey streams totaled 7359 in 1997 and 8118 in 1998. In 1999 -- the year of our grizzly bear survey -- the number of salmon making it to these streams dropped to 3205 (bold column in Table 1). This represented a significant decline of 60.5% from the previous year; the greatest decrease occurred in the Holmes River.

Table 1. Number of chinook salmon counted in tributary streams to Fraser River, British Columbia, 1997-2001. Data from annual surveys conducted by the Department of Ocean and Fisheries.

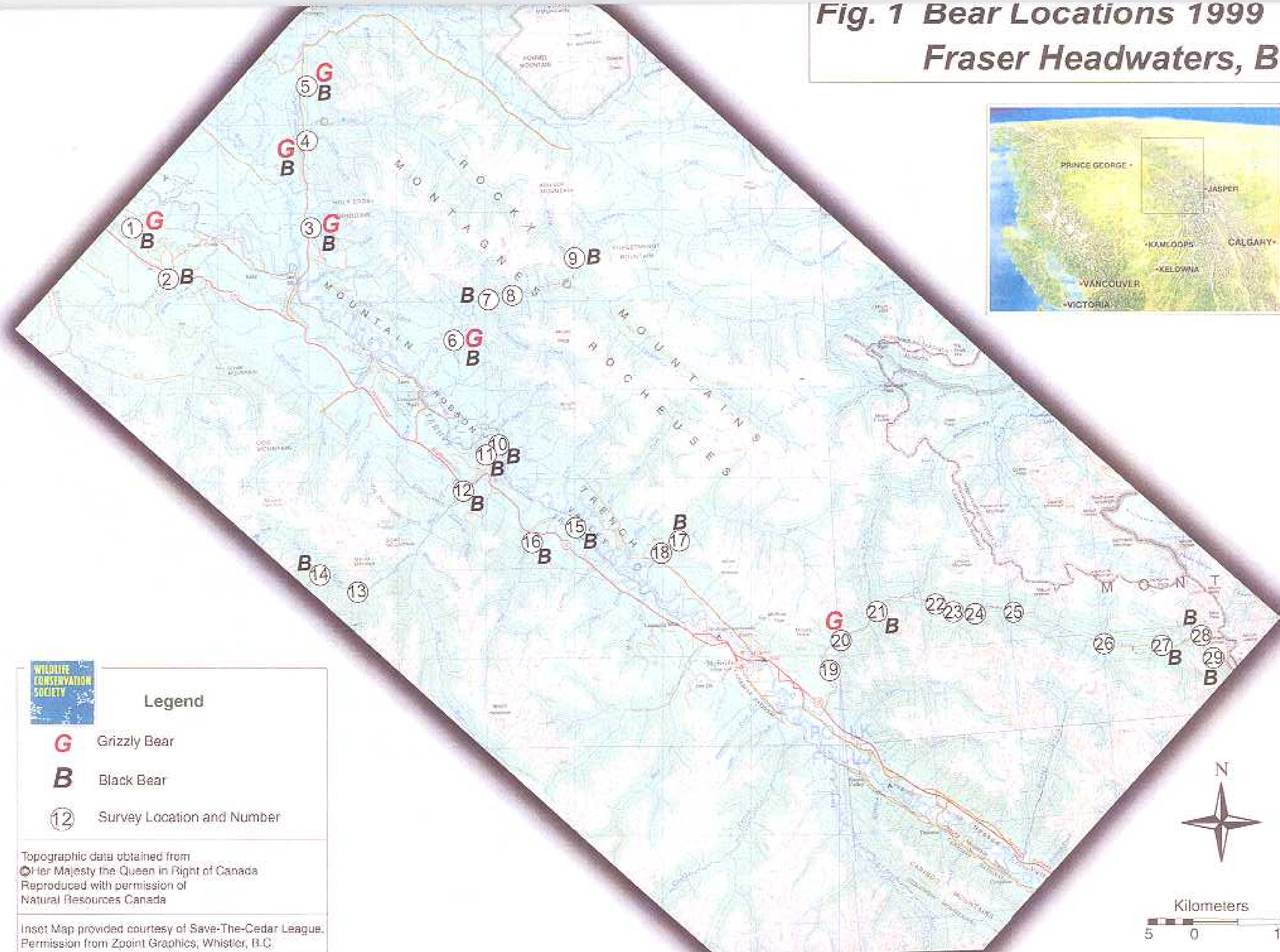
Stream	1997	1998	**1999**	2000	2001	Mean (± SE)
Slim	3130	2664	**1235**	2112	2876	2403 (337)
Walker	122	392	**206**	252	177	230 (46)
Morkill	550	2398	**1152**	926	+	1257 (400)
Goat	354	302	**89**	212	411	274 (57)
Holmes	3203	2362	**523**	1795	1018	1780 (476)
TOTAL	7359	8118	**3205**	5297	n.a.	
Mean (± SE)	1472 (695)	1624 (524)	**641 (237)**	1059 (390)	1121 (611)	1186 (220)

+ no inventory but salmon were present

Occurrence of grizzly bears at salmon streams

Grizzly bears visited 6 (21%) of the 29 survey sites and left hair on 12 pads (Fig. 1, Table 2). Most of the grizzly activity occurred in the lower reaches of the Slim Creek, Walker Creek, and Morkill River tributaries to the Fraser River (Fig. 1). Grizzly bears did make visits during both sessions at stations in Slim Creek (#1), Morkill River (#6), and Holmes River (#20). Only 1 grizzly bear hair sample (Slim Creek #1), however, amplified a complete genotype to determine individual identity. Black bears visited 20 (69%) sites along all surveyed tributaries and left hair on 74 pads.

Fig. 1 Bear Locations 1999
Fraser Headwaters, BC



Legend

G Grizzly Bear

B Black Bear

(12) Survey Location and Number

Topographic data obtained from
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Inset Map provided courtesy of Save-The-Cedar League.
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Table 2. Number of rub pads with bear hair along salmon streams, headwaters of the Fraser River, British Columbia, Aug 20-Sep 25 1999.

		Session I		Session II	
Stream	**Station**	**Black Bear**	**Grizzly Bear**	**Black Bear**	**Grizzly Bear**
Slim	1	3	1	4	1
	2	1	0	3	0
Walker	3	0	3	1	0
	4	0	0	2	1
	5	-	-	4*	1*
Morkill	6	2	1	1	1
	7	1	0	0	0
	8	2	0	0	0
	9	4	0	3	0
Goat	10	1	0	3	0
	11	1	0	2	0
	12	5	0	5	0
	13	0	0	-	-
	14	1	0	-	-
West Twin	15	1	0	-	-
	16	3	0	1	0
McKale	17	4	0	-	-
	18	0	0	-	-
Holmes	19	0	0	-	-
(Beaver)	20	0	2	0	1
	21	1	0	0	0
	22	-	-	0	0
	23	0	0	0	0
	24	0	0	-	-
	25	0	0	-	-
	26	-	-	0	0
	27	4	0	1	0
	28	4	0	3	0
	29	-	-	3	0
TOTALS	29	38	7	36	5

* 1 sample had mixed hair from both species

Stable isotope profiles of bears detected at salmon streams

Grizzly bears detected at salmon streams exhibited values (mean ± SD) of -23.73 (± 0.69) for $\delta^{13}C$, 4.39 (± 1. 41) for $\delta^{15}N$, and 12.35 (± 2.52) for $\delta^{34}S$ (Table 3, Fig. 2). Black bears had similar values for these isotopes.

Table 3. Stable isotope values for hair of grizzly bears (n=10) and black bears (n=16) collected at salmon streams, headwaters of the Fraser River, British Columbia, Aug 20-Sep 25 1999. Parenthetical numbers refer to site locations shown in Fig. 1 and letters refer to the first (a) or second (b) survey session.

Stream	Grizzly Bear $\delta^{13}C$	Grizzly Bear $\delta^{15}N$	Grizzly Bear $\delta^{34}S$	Stream	Black Bear $\delta^{13}C$	Black Bear $\delta^{15}N$	Black Bear $\delta^{34}S$
Slim (1a)	-24.0	4.5	8.4	Slim (1a)	-25.7	4.2	5.5
Slim (1b)	-23.8	4.5	9.8	Slim (1b)	-25.0	4.0	9.3
Walker (3a)	-23.8	4.7	11.3	Slim (2b)	-25.0	4.2	9.9
Walker (3a)	-23.7	4.6	11.1	Walker (5b)	-25.6	5.5	16.2
Walker (3a)	-22.0	7.6	15.6	Morkill (6a)	-24.3	3.2	12.1
Walker (4b)	-23.9	5.0	11.9	Morkill (6b)	-24.3	5.1	12.1
Morkill (6a)	-23.5	3.9	12.2	Morkill (9a)	-23.2	4.8	13.7
Morkill (6b)	-24.7	3.9	12.1	Goat (10b)	-26.3	3.6	10.3
Holmes (20a)	-23.8	2.8	16.3	Goat (11b)	-24.7	4.1	9.1
Holmes (20b)	-24.1	2.4	14.8	Goat (12a)	-23.9	5.3	11.7
				Goat (12b)	-24.5	4.7	10.3
				Holmes (21a)	-25.1	3.1	15.4
				Holmes (27a)	-23.0	5.0	13.8
				Holmes (27b)	-22.6	5.1	13.9
				Holmes (28a)	-23.6	3.9	13.4
				Holmes (28b)	-23.6	3.8	12.2
Mean	-23.73	4.39	12.35		-24.40	4.35	11.81
±SD	0.69	1.41	2.52		1.04	0.74	2.69

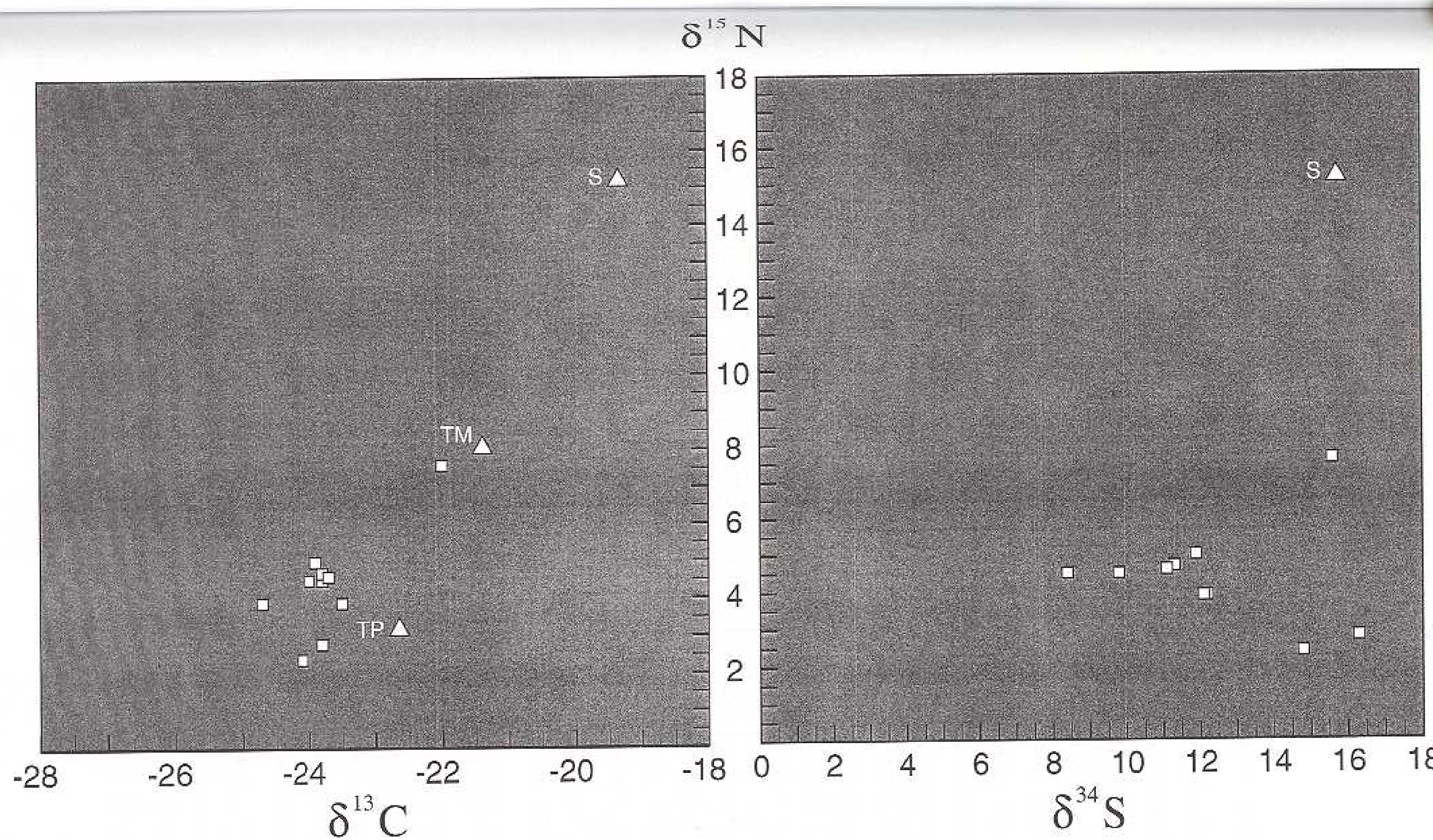

Fig. 2 Stable isotope values of hair collected from grizzly bears along salmon streams, Fraser Headwaters, British Columbia, Aug-Sep 1999. S = chinook salmon, TM = terrestrial meat, and TP = terrestrial plant.

Contribution of salmon to the bears' diet

Using the dual-isotope ($\delta^{13}C$, $\delta^{15}N$) mixing model, we calculated that chinook salmon contributed an average of 8.9% to the diet of grizzly bears and 10.9% to the diet of black bears in the Fraser Headwaters in 1999 (Table 4). The highest contribution of salmon to the diet of both grizzly (20.7%) and black bears (15.4%) occurred in the Walker Creek drainage. Terrestrial meat (possibly ants: Hobson et al. 2000) comprised an average of 23.8% and 27.2% to the diet of grizzlies and black bears, respectively, with plants contributing 67.3% and 61.9%.

Table 4. Contribution (%) of different foods to diet of grizzly and black bears, headwaters of the Fraser River, British Columbia, 1999.

Stream	Salmon		Terrestrial Meat		Terrestrial Plants	
	Grizzly	Black	Grizzly	Black	Grizzly	Black
Slim	9.8	12.9	25.7	29.5	64.5	57.6
Walker	20.7	15.4	32.6	36.7	46.7	47.9
Morkill	9.2	9.5	22.6	24.9	68.2	65.6
Goat	-	12.3	-	29.6	-	58.1
Holmes	9.1	8.0	19.8	21.1	71.1	70.9
Mean	8.9	10.9	23.8	27.2	67.3	61.9

Discussion

Occurrence of grizzly bears along salmon streams

We detected grizzly bears during the salmon spawning period in the lower reaches of Slim Creek and Morkill River and especially along Walker Creek (Fig. 1). The number of occurrences, however, was rather low. Perhaps few grizzly bears visited streams in 1999 because there were fewer salmon. Fishery biologists believe that El Niño caused an unusually warm body of water to form at the mouth of the Fraser River in the summer of 1999, which prompted returning salmon to go further up the BC coast (D. Schindler, pers. commun.). Perhaps fewer grizzly bears than black bears visited the sites because gravel roads closely paralleled many of these streams for considerable stretches. Finally, scented stations may not be as effective in late summer when food is abundant.

Contribution of salmon to the bears' diet

The contribution of salmon to bears' diet has been inferred from enriched values of carbon and nitrogen (Hilderbrand et al. 1999a & b, Jacoby et al. 1999). More recently, sulfur has been used as a marker of marine foods (R. Rye, unpublished data). In this study, carbon values indicated that salmon comprised a minor proportion (9-11%) of the bears' diet (Table 4), whereas the sulfur values suggested a more substantial contribution of salmon. One possible explanation (suggested by K. Hobson, Canadian Wildlife Service, pers. commun.) is that grizzly bears may have consumed relatively few salmon in 1999 (thus, the values of $\delta^{13}C$ and $\delta^{15}N$ that were only slightly enriched), but those salmon may constitute the primary source of sulfur in the bears' dietary environment (thus, the higher values of $\delta^{34}S$). A study of redhead ducks wintering along the Gulf coast of Texas also reported a paradox between carbon and sulfur values (Trust 1993).

We have noted that the number of salmon returning to spawn in the headwaters of the Fraser River was quite low in 1999. Hence, typical use of salmon by bears in the Fraser Headwaters cannot be assessed on the basis of a single, anomalous year of data collection. Nonetheless, we conclude that grizzly bears feed on salmon in the Fraser Headwaters on the cumulative basis of: (1) occurrence of grizzly bears at salmon streams during the salmon run, (2) observations reported to us of grizzly bears fishing for salmon, and (3) levels of $\delta^{34}S$ and (to a lesser extent) $\delta^{13}C$ indicative of salmon in the diet.

Conservation of a Unique Grizzly Bear-Salmon Relationship

Prior to the 1930s, salmon comprised 33-90% of the assimilated diet of grizzly bears in the Columbia River watershed draining the west slope of the Rocky Mountains (Hilderbrand et al. 1996). Grizzly bears have been extirpated from that area in the U.S., (U.S. Fish & Wildlife Service 1996), and salmon runs have decreased by more than 90% (Gresh et al. 2000).

The Robson Valley at the headwaters of the Fraser River appears to be the only place in the Rocky Mountains where grizzly bears still feed on anadramous chinook salmon. Thus, it comprises a unique ecological relationship that warrants careful stewardship.

Based (in part) upon preliminary findings of this reconnaissance survey as reported by Save-The-Cedar-League (Zammuto 2002), the provincial government of British Columbia has protected several key areas recently. Most importantly, much of the 'rainforest conservation corridor' spanning 75 km across Robson Valley as proposed by STCL in 2002 has been protected through designation of 'old-growth management areas' and various ecological reserves. These protect several key stretches along the lower reaches of Slim Creek, Walker Creek, and Morkill River. They also provide an important linkage between known grizzly bear areas in SugarBowl/Grizzly Den and Kakwa Provincial Parks (see maps at www.savethecedarleague.org).

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