A Reconnaisance of Tuya Lake
August 7-13, 2002

Tuya Lake looking northeast from west of the Tuya River outlet.

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Abstract

A cursory reconnaissance survey was undertaken at Tuya Lake to assess the potential impacts of Tahltan Lake origin sockeye salmon introductions and as a follow up to a previous inventory study conducted in 1986 (Coombes 1986). Gillnets, conventional angling gear, electroshocking and beach seining were used to capture fish in Tuya Lake, Tuya River and in two streams tributary to Tuya Lake. One hundred and 60 fish were captured in 44.1 hours of gillnetting, of which 35% were Arctic grayling and 23.8% were kokanee. Almost 20% of kokanee captured did not possess the thermal mark given to outplanted sockeye fry, indicating that a self propagating kokanee population has established itself in Tuya Lake. Kokanee ranged in size from 169 mm to 245 mm. 60.7% of male and 37.5% of female kokanee were sexually mature. The Tuya River upstream of Tuya Lake and the unnamed creek west of Butte Creek were found to be the systems with the most spawning potential for Arctic grayling. The previous investigation determined that 64.3% of Arctic grayling sampled utilized zooplankton in their diet; in the current investigation, zooplankton were completely absent within a subset of 25% of all grayling captured. Further investigation is recommended to determine the extent of the ecological impacts of large scale sockeye fry outplants and the resulting establishment of a kokanee population on the indigenous fish species of Tuya Lake.

Study Area/Background

Tuya Lake is located 72 km northwest of Dease Lake, at L 59°05' N, Lo130°35' W, (Figure 1). It is approximately 13 km long and 3 km wide and it has an elevation of 1117 m above sea level. The surface area of the lake is 3 140 ha and it's maximum depth is 54 m; the mean depth is 20 m. Tuya Lake drains into the Tuya River, which flows 132 km in a south, southwest direction before entering the Stikine River 24 km northeast of Telegraph Creek.

There are a number of obstructions that prevent upstream anadromous fish passage in the Tuya River. The most significant is a series of vertical drops and velocity barriers situated near it's confluence with the Stikine; other velocity barriers exist, including one approximately 65 km upstream of the confluence.

The endemic fish species of Tuya Lake include Arctic grayling (*Thymalus arcticus*), bulltrout (*Salvelinus confluentus*), long nose sucker (*Catostomus catostomus*), burbot (*Lota lota*), prickly sculpin (*Cottus asper*) and slimy sculpin (*Cottus cognatus*).

Anadromous fish were not present in Tuya Lake prior to 1992, when outplants of unfed sockeye (*Oncorhynchus nerka*) fry of Tahltan Lake origin, but incubated in Port Snettisham, Alaska, began. Table 1, below, outlines the sockeye fry introductions (0.43 – 4.7 million per year between 1992 and 2000) to date in Tuya Lake. As a component

of the Pacific Salmon Treaty between Canada and the United States (Alaska), it was agreed that enhancement activities were to be undertaken to increase the return of adult sockeye salmon in each of the Stikine and Taku watersheds by 100 000 fish.

The purpose of this survey was to investigate a number of basic life history parameters primarily for, but not limited to, Arctic grayling, including age structure, size structure, diet composition, identification of spawning locations/production areas and the collection of tissue samples for future genetic analysis.

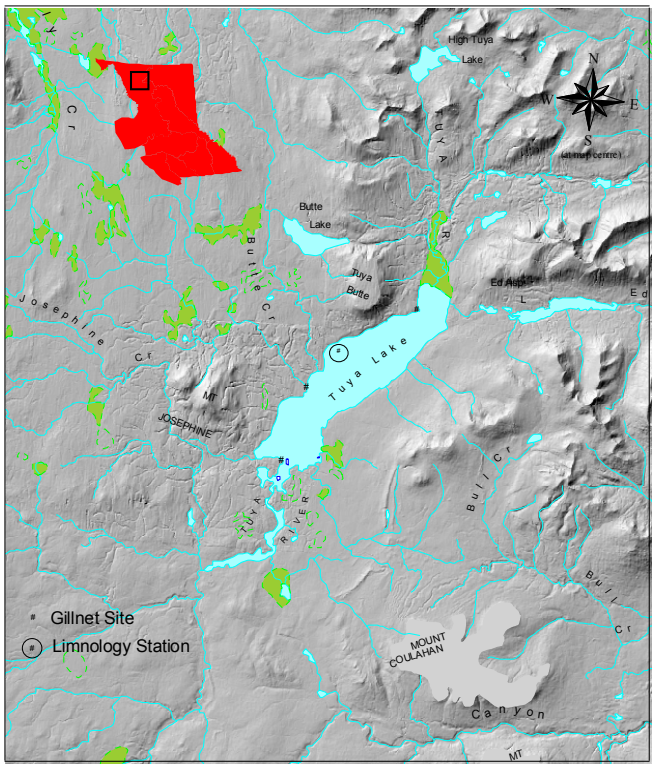

Figure 1. The Tuya Lake study area.

Table 1. Tuya Lake fry outplants.

Year	*# Fry Stocked*	*Dates Stocked*	*Mean Stocking Weight (grams)*	*Comments*
1992	1 632 000	June 17-June 21	0.13	
1993	1 990 000	June 16-July 7	0.13	
1994	4 691 000	June 24-July 13	0.13	
1995	2 267 000	June 21-July 3	0.13	
1996	2 474 000	June 21-July 3	0.11	
1997	2 611 000	June 24-July 1	0.14	
1998	433 000	Jun-26	0.12	
1999	1 603 400	June 21-July 2	0.12	
2000	866 530	June 23-June 26	unk	
2001	0	n/a	n/a	In years when the Tahltan adult sockeye return is less than 15 000 fish, Tuya Lake outplants do not occur
2002	0	n/a	n/a	

Methods

We used a DeHavilland Beaver on floats to access Tuya Lake from Dease Lake.

Two crews comprised of two individuals conducted the survey. Each crew used Zodiak Mk II inflatables (or equivalent) and 15 horsepower outboards for transportation on the lake.

Fish were sampled in Tuya Lake using a 90 m long sinking gillnet comprised of two spliced 45 m panels with four different mesh sizes (from shoreline: 76 mm, 64 mm, 25 mm x 38 mm, 64 mm, 76 mm), conventional angling gear (fly, spinner and spoon) and a Gee trap baited with fish eggs. Tributary streams were sampled using a Smith-Root backpack electroshocker (12 B-POW) and a 15 m, 6.3 mm mesh beach seine.

A subset of all fish landed were sampled for age by scale analysis and/or otolith extraction and/or fin ray segments (in the case of bulltrout). A subset of all fish landed were sampled for length, which was measured to the nearest millimeter, weight, measured to the nearest 5 grams (Accu-weigh balance) and sex/sexual maturity was assessed. Stomach contents were sampled from a subset of all kokanee and Arctic grayling landed and preserved in a buffered formalin in preparation for analysis. Bull trout stomach contents were also examined but not preserved.

Apparent histological irregularities were preserved in buffered formalin and sent to the Ministry of Water Land and Air Protection's Fish Health Lab in Nanaimo, for analysis.

An oxygen-temperature profile was obtained using a portable dissolved oxygen meter (OxyGuard Handy Mk III). Conductivity and pH was measured using a hand-held portable pH/conductivity meter (Oakton).

Sampling locations were identified using a handheld global positioning satellite unit (Garmin Etrex).

An over flight of Tuya Lake tributary streams was conducted with a Bell Jet Ranger helicopter.

Digital photographs were taken with a 2.1 megapixel camera (Olympus C-700 Ultra Zoom).

Results

Gillnet Catches

Four gillnet sets were made in Tuya Lake; two sets were made during the day (2.5 hours and 7 hours in duration) and two overnight sets were made (21.6 hours and 15 hours in duration). In total, 160 fish were captured in 44.1 hours of gillnetting (Table 2, Figure 2, Appendix 1, 4). Figure 1 identifies gillnet locations and the site of the limnology station.

Table 2. Tuya Lake Gillnet Catch Results.
Total Duration: 44.1 hours

Species	***Number***	**%**	***Catch/Hour***
bulltrout	22	13.8	0.5
long nose sucker	40	25.0	0.9
Arctic grayling	56	35.0	1.3
kokanee	38	23.8	0.9
burbot	4	2.5	0.1
TOTAL	**160**	**100.0**	**3.6**

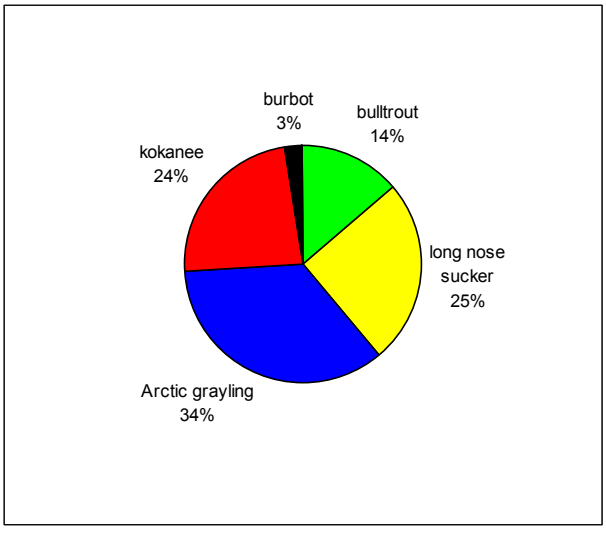

Figure 2. Gillnet catches in Tuya Lake by species, August 9-12, 2002.

Kokanee comprised almost one quarter (23.8%) of all fish captured in gillnet sets (Figure 2, 3). Kokanee ranged in size from 169 mm to 245 mm. Twenty eight (73.7%) of the kokanee were male, eight (21.1%) were female, while 2 (5.3%) were not dissected. Twenty five percent of the male kokanee (n=28) were sexually immature, 14.3% were maturing while 60.7% were sexually mature; 62.5% of the female kokanee (n=8) were sexually immature and 37.5% were sexually mature (Figures 4, 5).

Figure 3. The catch from a single sinking gillnet set. Note the kokanee in the foreground, largemouth sucker, Arctic grayling, bull trout and burbot in the background.

Figure 4. Two male kokanee showing sexual maturity.

Figure 5. Female kokanee showing sexual maturity.

Angling

Angling was conducted in the Tuya River at the outlet of Tuya Lake on August 9th, 10th and 12th using fly fishing gear. Twenty five Arctic grayling and 2 bull trout were captured. Angling was also conducted at the Tuya River at the inlet to Tuya Lake.

Thirteen Arctic grayling were captured. Finally, on August 13th, the Tuya River was angled downstream of Tuya Lake in two locations (UTMs: 9.396988.6517873; 9.395012.6511265) for two hours (1 hour fly fishing and 1 hour with spoons and spinners at each site); two bull trout (one at each site) were captured using flies spinner and spoon (Appendix 2, 4).

Other Methods

A Gee trap baited with fish eggs and fished overnight on August 10th in Tuya Lake near the outlet did not capture any fish.

On August 12th, a backpack electroshocker (12 B-POW) and a 15 m, 6.3 mm mesh beach seine were used in Butte Creek and the unnamed creek west of Butte Creek (UTMs 9.407932.6550314 and 9.407399.6549506, respectively). After 454 seconds of electroshocking Butte Creek, 28 slimy sculpin were captured. Beach seining yielded 18 Arctic grayling (Figure 6) and 3 slimy sculpin. In the unnamed creek west of Butte Creek, electroshocking yielded 2 Arctic grayling and 30 slimy sculpin. Beach seining yielded 3 bulltrout and 7 Arctic grayling. See Appendix 3.

Figure 6. A juvenile Arctic grayling beach seined from Butte Creek.

In the unnamed creek west of Butte Creek, six bulltrout redds were seen in the lower 100 meters upstream from it's confluence with Tuya Lake in run type habitat with a gravel substrate.

Otoliths

Kokanee otoliths (n=27) were examined for the presence of a thermal mark, indicating enhanced, Tahltan Lake origin fry outplants. Thermal marks were identified (Alaska Department of Fish and Game's Mark, Tag and Age Lab in Juneau, Alaska) in 81% of the otoliths examined. Almost 20% were not marked indicating that they were the progeny kokanee naturally reproducing in the tributaries of Tuya Lake (Figure 7). Kokanee ages ranged from 3 to 5 years (Appendix 4).

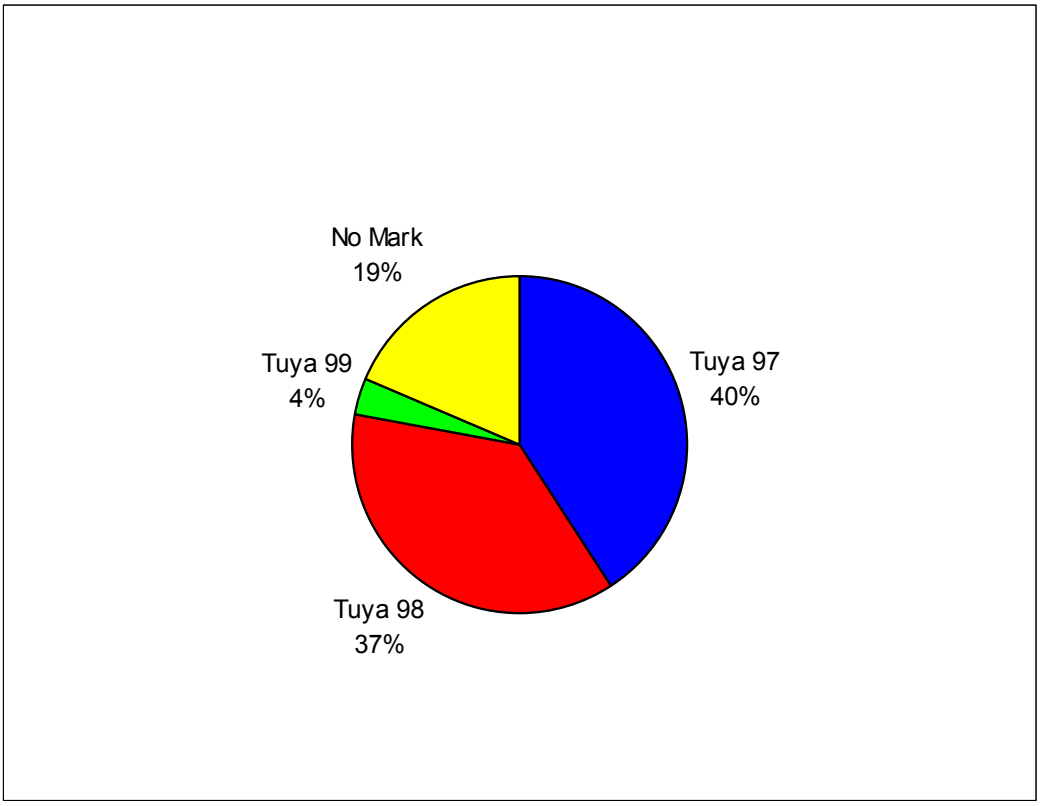

Figure 7. Tuya Lake otolith analysis results.

Tributary Streams

Tuya Lake tributaries were examined from the air to assess their potential for spawning and rearing for Arctic grayling, bulltrout and kokanee. The main inlet stream, the Tuya River (Figure 8) was found to have excellent spawning potential from approximately 2

km upstream of the lake to a potential velocity barrier, approximately 6 km upstream of Tuya Lake.

Figure 8. Tuya River upstream of Tuya Lake.

The unnamed tributary immediately to the west of Butte Creek was also found to possess favourable spawning habitat. No barriers to migration were identified in this system. In the lower reaches, well defined pool-riffle habitat was characteristic (Figure 9); in the upper reaches, larger substrate was evident within a stable, low gradient channel. Six bulltrout redds were noted in the lower 100 meters of this creek.

Figure 9. The unnamed tributary west of Butte Creek.

Arctic grayling and slimy sculpin were captured in Butte Creek. It was found to provide favorable spawning habitat. A waterfall approximately 1 km upstream of it's confluence with Tuya Lake prevents the passage of fish from the lake upstream of this point (Figure 10).

Figure 10. Waterfall in Butte Creek approximately 1 km upstream of Tuya Lake.

Tributary creeks on the south shore of Tuya Lake were found to be high gradient except in the lower 300 meters; two unnamed systems adjacent to the Tuya River outlet were found to have some spawning gravels proximate to the lake and in isolated pockets upstream. Both are small, low gradient systems with limited discharge (Figure 11).

Figure 11. The lower reach of the unnamed tributary to Tuya Lake adjacent (east) of the Tuya River outlet.

Diet

Preserved Arctic grayling stomach contents were found to contain gastropods, chironomids, oligochaetes, coleopterans and bivalves; kokanee stomach contents were found to contain chironomids, nematodes, cladocerans, rotifers, copepods and hydracarina (Table 3, Figure 12). Adult caddis flies (tricoptera) were also identified in Arctic grayling stomach contents of fish captured near the outlet of the lake.

Table 3. Stomach contents identified from a subset of all Arctic grayling and kokanee captured in Tuya Lake, August 8-12, 2002.

Arctic Grayling		Kokanee	
Species	*Number*	*Species*	*Number*
Gastropoda	203	Chironomidae	71
Chironomidae	107	Rotifera	66
Oligochaeta	4	Copepoda	36
Coleoptera	2	Hydracarina	33
Bivalvia	1	Nematoda	8

Chironomids, caddis flies, tape worms, burbot, kokanee and brown lemming (*Lemmus sibiricus*) were found among the stomach contents bulltrout; the stomach of one 430 mm bulltrout female contained two brown lemmings (Figure 13).

Figure 12. A Tuya Lake, gillnet caught kokanee showing stomach contents, comprised mostly of chironomids.

Figure 13. A 430 mm, Tuya Lake gillnet caught bulltrout dissected to show 2 brown lemmings among the stomach contents.

Water Chemistry

An oxygen-temperature profile of Tuya Lake was measured and recorded on August 12, 2002, at 2010 hours (UTM 9.408996.6551279; Figure 14).

We measured the surface temperature to be 9.0 degrees Celcius and found the lake to be mildly stratified and very oligotrophic, given the low oxygen concentrations in the hypolimnion. Oxygen concentrations ranged 10.2 mg/L on the surface to 10.4 mg/L between 10 meters and 30 meters.

In the unnamed creek west of Butte Creek, where six bulltrout redds were observed in the lower 100 meters upstream from it's confluence with Tuya Lake, the temperature was measured to be 12.5 degrees Celcius, the pH was 7.02 and conductivity was 82.1 micro Siemens.

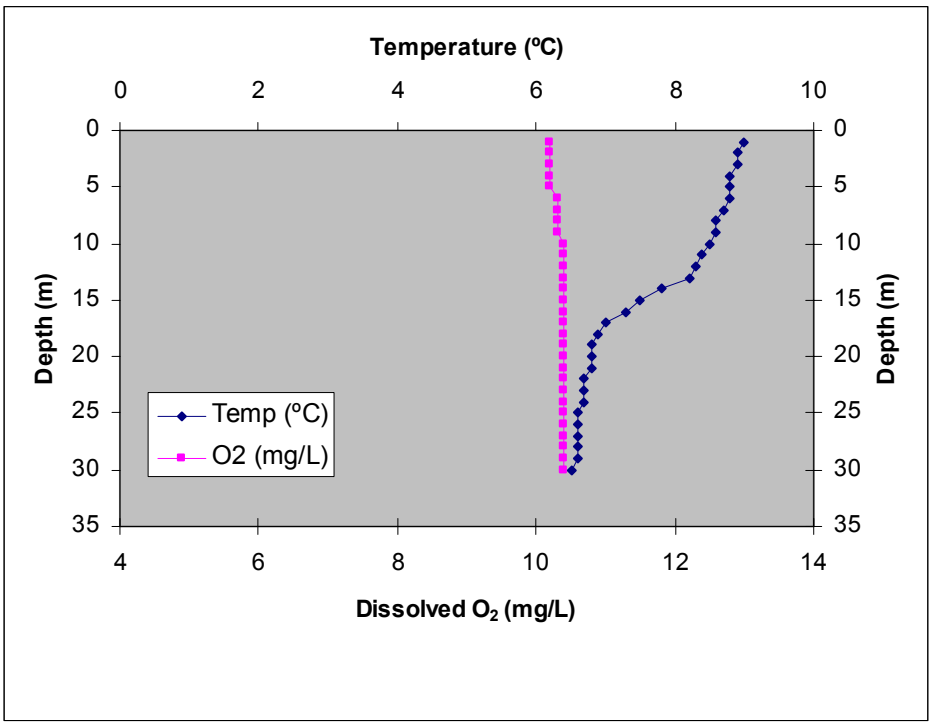

Figure 14. Oxygen-Temperature profile of Tuya Lake, August 12, 2002, 2010 hours.

Histology

Five (5.3%) of adult Arctic grayling captured were found to have fins that were red, inflamed and appeared to be hemorrhaging or decomposing (Figure 15, 16). Fin tissue samples were sent to the Provincial Fish Health Laboratory in Nanaimo. Results were not conclusive. Ovarian fluid was requested in order to test for IHNV and the request

was passed on to Department of Fisheries and Oceans staff in Whitehorse. Samples subsequently collected by DFO were reported to have been removed from a cooler by a bear.

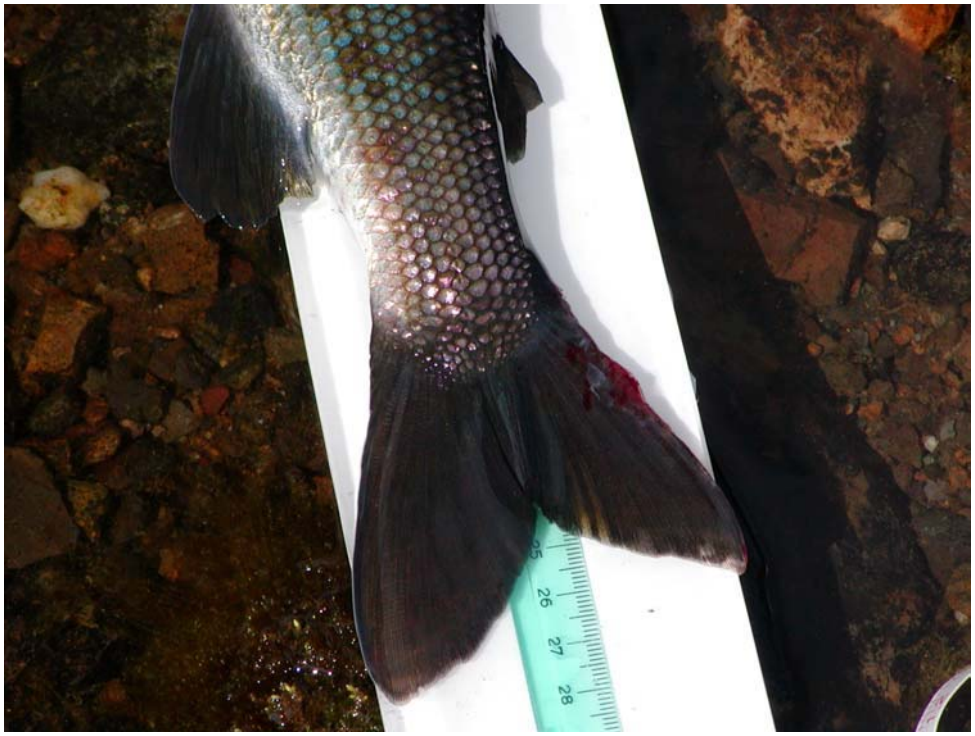

Figure 15. An angling caught Arctic grayling from the Tuya River at the outlet of Tuya Lake showing hemorrhaging on the upper caudal fin.

Figure 16. An angling caught Arctic grayling from the Tuya River at the outlet showing tissue damage at the base of the right pectoral fin.

Discussion

Tuya Lake was previously sampled in 1986, prior to sockeye fry outplants, by Coombes (1986) in August, 1986. Coombes used a 91.4 m sinking gillnet with six different mesh sizes (from shoreline: 64 mm, 38 mm, 89 mm, 51 mm, 76 mm, and 25 mm). Coombes captured 80 fish in 11.3 hours of gillnetting (Table 4). It is of interest that our gillnetting effort yielded Arctic grayling catches of 1.3 fish/hr while Coombes captured 2.8 fish/hr; with respect to bulltrout, we captured 0.5 fish/hr while Coombes captured 0.7 fish/hr. Statistical comparison was not possible due to the small sample size, different netting locations and water temperatures.

Table 4. Tuya Lake Sinking Gillnet Catches From Coombes (1986).

Set #1 - Guide Outfitter's Point
10-Aug-86
2230-0950
Duration: 11.3 hours

Species	*Number*	*%*	*Catch/Hour*
bulltrout	8	10.0	0.7
long nose sucker	40	50.0	3.5
Arctic grayling	32	40.0	2.8
TOTAL	**80**	**100**	**7.1**

Previous to this survey, it was believed that lake trout (*Salvelinus namaycush*) and Dolly Varden char (*Salvelinus malma*) existed in Tuya Lake. Lake trout were found not to be present and what had been previously identified as Dolly Varden were confirmed to be bulltrout by morphometric analysis. The slimy sculpin was also identified in Tuya lake.

Coombes' survey did not identify Tuya River upstream of Tuya Lake as having spawning potential, however, they did not have helicopter access; we were able to identify excellent spawning habitat in the Tuya River, the main inlet tributary to Tuya Lake. Coombes identified Butte Creek as the tributary with the most spawning potential; although Butte Creek looks favorable for spawning and rearing in the lower reaches, our aerial survey identified an impassible barrier approximately 1 km upstream of Tuya Lake.

Oxygen-temperature profiles were taken on the same date in 1986 and 2002. Coombes (1986) measured the surface water temperature to be 13.7 degrees Celcius while we measured the surface temperature to be 9.0 degrees Celcius; we found the lake to be mildly stratified. Oxygen concentrations ranged from 9.6 mg/L at 4 meters to 10.2 mg/L in 1986 while we determined oxygen concentrations ranged from 10.2 mg/L on the

surface to 10.4 mg/L between 10 meters and 30 meters. The 4.7 degree difference in surface water temperatures may account for some of the reduction in catch rates in gillnet sets as fish may have been less active in the cooler water temperatures experienced in 2002.

Coombes (1986) conducted a diet analysis of the fish he captured and determined that 18 (64.3%) of 28 grayling sampled fed upon zooplankton. In the current investigation, we analyzed a subset of 25% of all gillnet caught grayling and found that none had fed upon zooplankton. Our sample indicates that a shift in diet has taken place since the previous investigation by Coombes in 1986. Arctic grayling are no longer utilizing zooplankton.

Recommendations

Further investigation into the apparent diet shift in Arctic grayling away from zooplankton is warranted based on our results; it would be useful to determine the ecological effect on grayling populations.

Further investigation into histological irregularities is also warranted; IHNV has been detected at the Port Snettisham Central Incubation Facility where Tahltan River origin sockeye are incubated before being introduced into Tuya Lake, a site where anadromous salmonids previously did not occur.

Otolith analysis demonstrated that almost 20% of kokanee sampled were not thermally marked and were therefore assumed to be spawning naturally in Tuya Lake tributaries. The ecological effect of this newly established, naturally reproducing kokanee population on indigenous species such as Arctic grayling and bulltrout needs to be investigated.

Acknowledgements

DFO, Whitehorse co-funded this study; Pete Etherton administered payments for flights and supplies. Funding was also provided by B.C. Parks' Protected Areas Conservation Fund. Pat Milligan, DFO, Whitehorse, drove to Dease Lake and flew in to Tuya Lake with Matt Jessop to assist Paul Giroux and myself with the lake survey. Bruce McNaughton, B.C. Yukon Air Service, Dease Lake, flew us to Tuya Lake. Jim Reed, Pacific Western Helicopters, transported us for the survey of Tuya Lake tributary streams and returned half of the survey crew to Dease Lake. Greg Fornier, the guide outfitter at Tuya Lake, provided free access to his camp near the outlet of Tuya Lake. Matt Jessop entered fish data into a database and shipped samples for analysis. North/South Consultants (Winnipeg, Manitoba) aged scale, otolith and fin ray samples in addition to processing stomach samples. Ron Josephson at the Alaska Department of Fish and Game's Mark, Tag and Age lab in Juneau reviewed performed the thermal mark analysis of kokanee otoliths.

References

Coombes, D.M. 1986. A reconnaissance survey of Tuya Lake. Recreational Fisheries Branch. Ministry of Environment and Parks. 33 pp + appendices.

Mathias, K.L. 2000. Growth and survival of juvenile sockeye salmon (*Oncorhynchus nerka*) in three northwestern British Columbia lakes – an evaluation of an International stock enhancement program. MSc thesis. York University, North York, Ontario. 246 pp + appendices.

Appendices

Appendix 1. Tuya Lake sinking gillnet catches.

Set #1 – Near Tuya River Outlet
09-Aug-02
1435-1705
Duration: 2.5 hours

Species	*Number*	*%*	*Catch/Hour*
Bulltrout	1	9.1	0.4
long nose sucker	1	9.1	0.4
Arctic grayling	4	36.4	1.6
Kokanee	5	45.5	2.0
TOTAL	**11**	**100**	**4.4**

Set #2 - Guide Outfitter's Point
10-Aug-02
1015-1515
Duration: 5 hours

Species	*Number*	*%*	*Catch/Hour*
Bulltrout	4	23.5	0.8
long nose sucker	6	35.3	1.2
Arctic grayling	2	11.8	0.4
Kokanee	5	29.4	1.0
TOTAL	**17**	**100**	**3.4**

Set #3 – Near Butte Creek
10-Aug-02
1715-1450
Duration: 21.6 hours

Species	*Number*	*%*	*Catch/Hour*
Bulltrout	15	23.1	0.7
long nose sucker	14	21.5	0.6
Arctic grayling	20	30.8	0.9
Kokanee	13	20.0	0.6
Burbot	3	4.6	0.1
TOTAL	**65**	**100.0**	**3.0**

Set #4 - Adjacent Outlet Island
11-Aug-02
2000-1100
Duration: 15 hours

Species	*Number*	*%*	*Catch/Hour*
Bulltrout	2	3.0	0.1
long nose sucker	19	28.4	1.3
Arctic grayling	30	44.8	2.0
Kokanee	15	22.4	1.0
Burbot	1	1.5	0.1
TOTAL	**67**	**100.0**	**4.5**

Tuya Lake Gillnet Results
Total Duration: 44.1 hours

Species	*Number*	*%*	*Catch/Hour*
bulltrout	22	13.8	0.5
long nose sucker	40	25.0	0.9
Arctic grayling	56	35.0	1.3
kokanee	38	23.8	0.9
burbot	4	2.5	0.1
GRAND TOTAL	**160**	**100.0**	**3.6**

Appendix 2. Tuya Lake angling catches.

Tuya River Outlet
9-Aug-02

Species	***Number***	**%**
Bulltrout	1	4.0
Arctic grayling	24	96.0
TOTAL	**25**	**100**

Tuya River Inlet
10-Aug-02

Species	***Number***	**%**
Bulltrout	0	0.0
Arctic grayling	13	100.0
TOTAL	**13**	**100**

Tuya River Outlet
10-Aug-02

Species	***Number***	**%**
Bulltrout	0	0.0
Arctic grayling	1	100.0
TOTAL	**1**	**100**

Tuya River Outlet
12-Aug-02

Species	***Number***	**%**
Bulltrout	1	100.0
Arctic grayling	0	0.0
TOTAL	**1**	**100**

Tuya River
13-Aug-02

Species	***Number***	**%**
Bulltrout	2	100.0
Arctic grayling	0	0.0
TOTAL	**2**	**100**

Species	***Number***	**%**
bulltrout	4	9.5
Arctic grayling	38	90.5
GRAND TOTAL	**42**	**100**

Appendix 3. Other methods: electrofishing and beach seine catches.

Duration: 454 seconds

Butte Creek

Species	***Number***	***%***
Bulltrout	0	0.0
Arctic grayling	0	0.0
slimy sculpin	28	100.0
TOTAL	**28**	**100.0**

Creek West of Butte Creek

Species	***Number***	***%***
Bulltrout	1	3.0
Arctic grayling	2	6.1
slimy sculpin	30	90.9
TOTAL	**33**	**100.0**

Beach Seine

Butte Creek

Species	***Number***	***%***
Bulltrout	0	0.0
Arctic grayling	18	85.7
slimy sculpin	3	14.3
TOTAL	**21**	**100.0**

Creek West of Butte Creek

Species	***Number***	***%***
Bulltrout	3	30.0
Arctic grayling	7	70.0
slimy sculpin	0	0.0
TOTAL	**10**	**100.0**

Appendix 4. Fish sex, length, weight, maturity and age data.

Site	Date	Method	Species	Length	Weight (grams)	Sex	Maturity	Age Str. 1	Age Str. 2	Samp. No.	Fin Age	Oto. Age	Scale Age	DNA #	Comments
Outlet	9/8/2002	Fly	BT	480		M	U	FR		8	7			8	Very fit looking fish
Outlet	9/8/2002	Fly	GR	370		M	U	SC		1			5	1	Photos 10, 11
Outlet	9/8/2002	Fly	GR	405		F	U	SC		2			6	2	Photos 15-17
Outlet	9/8/2002	Fly	GR	410		M	U	SC		3			5	3	
Outlet	9/8/2002	Fly	GR	435		M	U	SC		4			5	4	
Outlet	9/8/2002	Fly	GR			M	U	SC		5			7	5	No length
Outlet	9/8/2002	Fly	GR	390		F	U	SC		6		9	7	6	Photos 20-24, caudal fin damage on dorsal side, chironamid pupae in gut
Outlet	9/8/2002	Fly	GR	445		U	U	SC		7		8	8	7	Adult caddis and chiron pupae in gut
Outlet	9/8/2002	Fly	GR	390		M	U	SC		20			6	20	
Outlet	9/8/2002	Fly	GR	390		M	U	SC		21			5	21	
Outlet	9/8/2002	Fly	GR	380		F	U	SC		22			8	22	
Outlet	9/8/2002	Fly	GR			M	U	SC		23			5	23	No length
Outlet	9/8/2002	Fly	GR	422		F	U	SC		24			7	24	
Outlet	9/8/2002	Fly	GR	400		M	U	SC		25			6	25	
Outlet	9/8/2002	Fly	GR	400		M	U	SC		26			5	26	
Outlet	9/8/2002	Fly	GR	370		M	U	SC		27			7	27	
Outlet	9/8/2002	Fly	GR	420		F	U	SC		28			7	28	
Outlet	9/8/2002	Fly	GR	410		M	U	SC		29			6	29	
Outlet	9/8/2002	Fly	GR	415		F	U	SC		30			6	30	
Outlet	9/8/2002	Fly	GR	360		F	U	SC		31			6	31	
Outlet	9/8/2002	Fly	GR	410		F	U	SC		32			7	32	
Outlet	9/8/2002	Fly	GR	380		M	U	SC		33			5	33	
Outlet	9/8/2002	Fly	GR	360		F	U	SC		34			7	34	
Outlet	9/8/2002	Fly	GR	430		F	U	SC		35			6	35	
Outlet	9/8/2002	Fly	GR	420		F	U	SC		36			7	36	
1	9/8/2002	SGN	BT	490	1100	M	IM	OT	FR	10	6	7		10	Tape worms in gut
1	9/8/2002	SGN	BT	355	460	M	IM	OT	FR	37	4	un.age		37	Tape worms in gut
1	9/8/2002	SGN	BT	360	460	M	IM	OT	FR	38	4	4		38	Tape worms in gut, photo
1	9/8/2002	SGN	GR	400		F		SC		11			7	11	Tail haemorrhaging
1	9/8/2002	SGN	GR	305		F		SC		12			4	12	Tail haemorrhaging
1	9/8/2002	SGN	GR	335		F		SC		13			3	13	
1	9/8/2002	SGN	GR	180		F		SC		14			2	14	Photo
1	9/8/2002	SGN	SK	220		U		SC		15			3		
1	9/8/2002	SGN	SK	240		U		SC		16			4		
1	9/8/2002	SGN	SK	218	110	M	M	OT	SC	17		4	4		Tape worms in gut
1	9/8/2002	SGN	SK	231	135	M	M	OT	SC	18		3	3		Tape worms in gut
1	9/8/2002	SGN	SK	245	155	M	M	OT	SC	19		5	4		Tape worms in gut
Outlet	10/8/2002	Fly	BT	520		M	U	FR		1002	6			1002	
Inlet	10/8/2002	Fly	GR	380		F	U	SC		39			6	39	
Inlet	10/8/2002	Fly	GR	415		M	U	SC		40			7	40	

Inlet	10/8/2002	Fly	GR	385		F	U	SC		42			6	42	Snagged
Inlet	10/8/2002	Fly	GR	335		F	U	SC		43			5	43	
Inlet	10/8/2002	Fly	GR	410		M	U	SC		44			7	44	Fin haemorrhaging
Inlet	10/8/2002	Fly	GR	435		F	U	SC		45			5	45	Tail haemorrhaging
Inlet	10/8/2002	Fly	GR	370		F	U	SC		46			6	46	
Inlet	10/8/2002	Fly	GR	380		M	U	SC		47			6	47	
Inlet	10/8/2002	Fly	GR	390		F	U	SC		48			7	48	
Inlet	10/8/2002	Fly	GR	360		F	U	SC		49			5	49	
Inlet	10/8/2002	Fly	GR	385		F	U	SC		50			6	50	
Inlet	10/8/2002	Fly	GR	425		M	U	SC		380			6	380	
3	10/8/2002	SGN	BB	391	320	M	MTG	OT		60		14			
3	10/8/2002	SGN	BB	373	270	M	MTG	OT		61		14			
3	10/8/2002	SGN	BB	384	315	M	MG	OT		94		16			snails, chiron in gut
2	10/8/2002	SGN	BT	445	840	F	MTG	OT	FR	53	8	8		53	
2	10/8/2002	SGN	BT	305	270	F	IM	OT	FR	54	3			54	
3	10/8/2002	SGN	BT	347	420	F	IM	OT		95		4			gut empty
3	10/8/2002	SGN	BT	385	440	F	MG	OT		96		7			juvenile BB in gut
3	10/8/2002	SGN	BT	465	920	F	MG	OT		97		7			gut empty, chiron.
3	10/8/2002	SGN	BT	400	660	M	IM	OT		98		4			2 SK in gut
3	10/8/2002	SGN	BT	430	770	F	MG	OT		99		un.age			2 voles in gut
3	10/8/2002	SGN	BT	261	170	F	IM	OT		100		4			2 BB in gut
3	10/8/2002	SGN	BT	284	250	M	IM	OT		101		5			1 BB in gut, tape worms
3	10/8/2002	SGN	BT	330	340	M	IM	OT		102		4			1 BB in gut
3	10/8/2002	SGN	BT	340	400	F	IM	OT		103		5			1 BB in gut
3	10/8/2002	SGN	BT	350	440	M	IM	OT		104		4			inverts and tape worms in gut
3	10/8/2002	SGN	BT	288	240	M	IM	OT		105		5			1 BB in gut, inverts
2	10/8/2002	SGN	GR	296	305	F	IM	SC		51			4	51	Stomach contents sampled
2	10/8/2002	SGN	GR	205	70	U	IM	SC		52			2		
3	10/8/2002	SGN	GR	280		M		SC		62			3		
3	10/8/2002	SGN	GR	188		F	IM	SC		63			2		
3	10/8/2002	SGN	GR	292	255	F	MG	OT	SC	64		5	4		Dorsal fin abrasion/ haemorrhaging, fin sent to Sherry Guest
3	10/8/2002	SGN	GR	178		F	IM	SC		65			1		
3	10/8/2002	SGN	GR	460	1100	M	MT	OT	SC	79		8	9		
3	10/8/2002	SGN	GR	176	50	F	IM	OT	SC	80			2		
3	10/8/2002	SGN	GR	222	115	F	IM	OT	SC	81			2		otoliths shattered
3	10/8/2002	SGN	GR	230	125	M	IM	OT	SC	82			2		otoliths shattered
3	10/8/2002	SGN	GR	193	75	M	IM	OT	SC	83		2	2		1 otolith in envelope
3	10/8/2002	SGN	GR	215	105	F	IM	OT	SC	84		2	2		1 otolith in envelope
3	10/8/2002	SGN	GR	221	105	F	IM	OT	SC	85			2		1 otolith in envelope
3	10/8/2002	SGN	GR	314	335	F	IM	OT	SC	86		5	4		
3	10/8/2002	SGN	GR	377	560	M	MT	OT	SC	87		6	5		
3	10/8/2002	SGN	GR	296	275	M	MT	OT	SC	88		5	4		

3	10/8/2002	SGN	GR	321	320	F	MG	OT	SC	89		7	5		1 otolith in envelope
3	10/8/2002	SGN	GR	363	420	M	MT	OT	SC	90		7	7		otoliths shattered
3	10/8/2002	SGN	GR	370	550	M	MT	OT	SC	91		10	8		1 otolith in envelope
3	10/8/2002	SGN	GR	385	565	M	MT	OT	SC	92		6	6		
3	10/8/2002	SGN	GR	380	580	M	MT	OT	SC	93		6	un.age		1 otolith in envelope
2	10/8/2002	SGN	SK	218	115	M	MTG	OT	SC	55		3	3		Stomach contents sampled
2	10/8/2002	SGN	SK	195	80	M	MTG	OT	SC	56		3	2		Stomach contents sampled
2	10/8/2002	SGN	SK	206	90	M	MTG	OT	SC	57		2	2		Stomach contents sampled
2	10/8/2002	SGN	SK	185	55	M	IM	OT	SC	58		2	2		Stomach contents sampled
2	10/8/2002	SGN	SK	174	60	F	IM	OT	SC	59		2	2		Stomach contents sampled
3	10/8/2002	SGN	SK	244	155	F	M			66		4			Photo of eggs and stomach
3	10/8/2002	SGN	SK	227	110	M	MG	OT	SC	67		4	4		
3	10/8/2002	SGN	SK	223	115	M	MT	OT	SC	68		4	3		1 otolith in envelope
3	10/8/2002	SGN	SK	220	105	M	MT	OT	SC	69		4	3		
3	10/8/2002	SGN	SK	211	105	M	MT	OT	SC	70		3	2		
3	10/8/2002	SGN	SK	221	100	F	MT	OT	SC	71		un. age	4		
3	10/8/2002	SGN	SK	212	105	M	MT	OT	SC	72		2	3		
3	10/8/2002	SGN	SK	210	90	F	MT	OT	SC	73		3	3		
3	10/8/2002	SGN	SK	207	90	M	MT	OT	SC	74		3	2		
3	10/8/2002	SGN	SK	197	75	M	MT	OT	SC	75		3	3		
3	10/8/2002	SGN	SK	190	75	F	IM	OT	SC	76					
3	10/8/2002	SGN	SK	181	55	F	IM	OT	SC	77		2	2		
3	10/8/2002	SGN	SK	169	43	M	IM	OT	SC	78			3		
Outlet	12/8/2002	AN	BT	460	1010	F	IM	FR		322	7			322	Small mammal in gut
12	12/8/2002	EF	BT	184		U	J	FR	SC	321	2		2	321	
4	12/8/2002	SGN	BT	289		U	U	FR		106	3				
4	12/8/2002	SGN	BT	510		U	U	FR		107	6				
4	12/8/2002	SGN	GR	201	80	F	U	SC		109			2		
4	12/8/2002	SGN	GR	365	520	M	U	OT		124		8			
4	12/8/2002	SGN	GR	370	560	M	U	OT		125		10			
4	12/8/2002	SGN	GR	305	420	F	U	OT		126		7			
4	12/8/2002	SGN	GR	335	395	F	U	OT		127		7			
4	12/8/2002	SGN	GR	410	640	M	U	OT		128		un. age			
4	12/8/2002	SGN	GR	380	560	F	U	OT		129		11			
4	12/8/2002	SGN	GR	390	700	F	U	OT		130		7			
4	12/8/2002	SGN	GR	395	620	M	U	OT		131		7			
4	12/8/2002	SGN	GR	425	750	F	U	OT		132		11			
4	12/8/2002	SGN	GR	365	470	F	U	OT		133		8			
4	12/8/2002	SGN	GR	380	430	F	U	OT		134		10			
4	12/8/2002	SGN	GR	370	570	M	U	OT		135		7			
4	12/8/2002	SGN	GR	390	630	F	U	OT		136		8			
4	12/8/2002	SGN	GR	325	365	M	U	OT		137		5			
4	12/8/2002	SGN	GR	365	475	F	U	OT		138		6			

4	12/8/2002	SGN	GR	334	380	M	U	OT		139		6			
4	12/8/2002	SGN	GR	300	265	F	U	OT		140		5			
4	12/8/2002	SGN	GR	380	610	F	U	OT		141		11			
4	12/8/2002	SGN	GR	398	670	F	U	OT		142		12			
4	12/8/2002	SGN	GR	357	430	F	U	OT		143		7			
4	12/8/2002	SGN	GR	334	380	F	U	OT		144		7			
4	12/8/2002	SGN	SK	228	120	M	M	OT	SC	108		4	3		Orange zooplankton in stomach
4	12/8/2002	SGN	SK	198	85	M	M	OT	SC	110		3	3		
4	12/8/2002	SGN	SK	196	75	M	IM	OT	SC	111		2	2		
4	12/8/2002	SGN	SK	231	125	M	M	OT	SC	112		3	3		
4	12/8/2002	SGN	SK	180	65	M	IM	OT	SC	113		2	2		
4	12/8/2002	SGN	SK	211	95	M	M	OT	SC	114		3	2		
4	12/8/2002	SGN	SK	200	85	F	IM	OT	SC	115		3	2		
4	12/8/2002	SGN	SK	203	85	M	M	OT	SC	116		un-age	3		
4	12/8/2002	SGN	SK	198	75	M	IM	OT	SC	117		3	2		
4	12/8/2002	SGN	SK	195	75	F	IM	OT	SC	118		3	3		
4	12/8/2002	SGN	SK	219	113	M	M	OT	SC	119		3	3		
4	12/8/2002	SGN	SK	214	105	M	M	OT	SC	120		3	3		
4	12/8/2002	SGN	SK	212	105	M	M	OT	SC	121		4	3		
4	12/8/2002	SGN	SK	218	110	M	IM	OT	SC	122		3	3		
4	12/8/2002	SGN	SK	191	69	M	IM	OT	SC	123		3	3		
11	12/8/2002	SN	BT	373	560	M	IM	OT	FR	318	4	4		318	Empty gut, 27 branch. Rays
11	12/8/2002	SN	BT	388		M	IM	FR		319	4			319	
11	12/8/2002	SN	BT	375		F	IM	FR		320	4			320	
10	12/8/2002	SN	GR	44	0.7	U	J	SC		301			0		Beach seine
10	12/8/2002	SN	GR	45	0.9	U	J	SC		302			0		
10	12/8/2002	SN	GR	44	0.7	U	J	SC		303			N/A		
10	12/8/2002	SN	GR	48	1	U	J	SC		304			0		
10	12/8/2002	SN	GR	47	0.9	U	J	SC		305			0		
10	12/8/2002	SN	GR	42	0.6	U	J	SC		306			N/A		
10	12/8/2002	SN	GR	43	0.7	U	J	SC		307			un.age		
10	12/8/2002	SN	GR	53	1.2	U	J	SC		308			0		
10	12/8/2002	SN	GR	47	0.7	U	J	SC		309			0		
10	12/8/2002	SN	GR	41	0.4	U	J	SC		310			N/A		
10	12/8/2002	SN	GR	49	0.9	U	J	SC		311			0		
10	12/8/2002	SN	GR	47	0.8	U	J	SC		312			0		
10	12/8/2002	SN	GR	48	0.6	U	J	SC		313			un.age		
10	12/8/2002	SN	GR	47	0.6	U	J	SC		314			0		
10	12/8/2002	SN	GR	56	1.2	U	J	SC		315			0		
10	12/8/2002	SN	GR	50	0.8	U	J	SC		316			0		
10	12/8/2002	SN	GR	99	8	U	J	SC		317			1		
21	13/8/2002	AN	BT	356		M	IM	FR		323	4			323	Caught on spinning gear
22	13/8/2002	AN	BT	331	375	M	MTG	OT	FR	324	4	3		324	Caught on spinning gear, photo of gonads

Appendix 5. Tuya Lake oxygen-temperature profile.

Depth (m)	O2	Temp (ºC)
1	10.2	9
2	10.2	8.9
3	10.2	8.9
4	10.2	8.8
5	10.2	8.8
6	10.3	8.8
7	10.3	8.7
8	10.3	8.6
9	10.3	8.6
10	10.4	8.5
11	10.4	8.4
12	10.4	8.3
13	10.4	8.2
14	10.4	7.8
15	10.4	7.5
16	10.4	7.3
17	10.4	7
18	10.4	6.9
19	10.4	6.8
20	10.4	6.8
21	10.4	6.8
22	10.4	6.7
23	10.4	6.7
24	10.4	6.7
25	10.4	6.6
26	10.4	6.6
27	10.4	6.6
28	10.4	6.6
29	10.4	6.6
30	10.4	6.5

Depth at sample site = 36.4m
UTM at sample site = 9.408996.6551279
Elevation = 1124m