State of Alaska
Department of Fish and Game
Sportfish Division

Nomination Form
Fish Distribution Database

Region: INT

USGS Quad(s): Medfra D-3, Ruby A-2, A-3, B-2, B-3, C-3, C-4, D-3 D-2

Fish Distribution Database Number of Waterway: 334-40-11000-2300-3277

Name of Waterway: Nowitna River & Sulukna River ☑ USGS Name ☐ Local Name

☑ Addition ☐ Deletion ☐ Correction ☐ Backup Information

For Office Use

Nomination #: 07-182

Revision Year: 2008

Revision to: Atlas ____ Catalog ____ Both X

Revision Code: B-1

[signature] ADF&G Fisheries Scientist — Date: 11/2/07

[signature] ADNR OHMP Operations Mgr. — Date: 11/2/07

[signature] FDD Project Biologist — Date: 05/22/07

[signature] Cartographer — Date: 12/3/07

OBSERVATION INFORMATION

Species	Date(s) Observed	Spawning	Rearing	Present	Anadromous
Sheefish	2005 - 2006	X		X	☑
					☐
					☐
					☐
					☐

IMPORTANT: Provide all supporting documentation that this water body is important for the spawning, rearing or migration of anadromous fish, including: number of fish and life stages observed; sampling methods, sampling duration and area sampled; copies of field notes; etc. Attach a copy of a map showing location of mouth and observed upper extent of each species, as well as other information such as: specific stream reaches observed as spawning or rearing habitat; locations, types, and heights of any barriers; etc.

Comments: Add sheefish presence to 334-40-11000-2300 & 334-40-11000-2300-3277 based on radio-telemetry data from USF&WS. Sample data from Fall 2003 indicated that sheefish were spawning in the Sulukna River.

Add sheefish presence to 334-40-11000-2300
Add sheefish spawning to 334-40-11000-2300-3277

Name of Observer (please print): Randy J. Brown

Signature: Randy J. Brown — Date: 5/17/07

Agency: U.S. Fish and Wildlife Service

Address: 101 12th Ave., Room 110
Fairbanks, Alaska 99701

This certifies that in my best professional judgment and belief the above information is evidence that this waterbody should be included in or deleted from the Fish Distribution Database.

Signature of Area Biologist: Reviewed by John Burr [illegible] — Date: 10/29/07

Name of Area Biologist (please print):

Revision 02/05

Date	Fish ID	Latitude	Longitude
5/25/06	21-50-may06	64.923590	-154.494380
5/25/06	22-46-may06	64.945130	-154.413570
5/25/06	20-47-may06	64.585670	-154.381590
5/25/06	21-49-may06	64.914480	-154.279490
5/25/06	20-46-may06	64.883470	-154.256210
5/25/06	20-48-may06	64.883090	-154.223620
5/25/06	22-49-may06	64.927610	-154.223150
5/25/06	24-47-may06	64.883690	-154.182940
5/25/06	20-49-may06	64.993240	-154.096160
5/25/06	21-47-may06	64.009340	-154.019760
10/4/05	22-45-f05	66.226820	-144.688050
10/4/05	24-46-f05	66.215190	-144.706790
9/20/06	21-47-f06	64.021957	-154.005310
6/29/06	21-47-s06b	64.022928	-154.006319
9/20/06	24-51-f06	64.029625	-154.007399
9/22/05	22-46-f05	64.002720	-154.010470
9/22/05	23-46-f05	63.997050	-154.011660
9/20/06	22-54-f06	63.999732	-154.018543
9/22/05	21-49-f05	64.031810	-154.019280
9/22/05	24-45-f05	63.997580	-154.020400
9/20/06	20-45-f06	64.025547	-154.024017
9/20/06	23-51-f06	64.025554	-154.026043
9/22/05	20-49-f05	63.986200	-154.031430
9/22/05	22-49-f05	64.047590	-154.032760
9/22/05	23-47-f05	64.056710	-154.033700
9/22/05	22-48-f05	63.974950	-154.048250
9/22/05	20-46-f05	63.962080	-154.066890
9/20/06	22-55-f06	63.961583	-154.068392
9/22/05	21-47-f05	63.956630	-154.073860
6/7/06	20-47-s06a	64.439520	-154.085510
6/15/2006	20-47-s06c	64.439520	-154.085510
9/22/05	21-46-f05	63.945550	-154.086060
9/22/05	21-50-f05	63.937680	-154.093870
9/20/06	21-56-f06	63.929710	-154.095560
9/22/05	23-45-f05	63.934140	-154.097590
9/20/06	23-53-f06	63.920770	-154.103250
9/22/05	23-49-f05	63.923770	-154.105120
9/22/05	21-48-f05	63.925480	-154.105820
9/20/06	21-51-f06	63.908033	-154.117635
9/20/06	24-53-f06	63.903278	-154.119539
9/20/06	24-54-f06	63.904263	-154.120929
9/20/06	22-56-f06	63.903433	-154.122709
9/20/06	20-52-f06	63.901408	-154.124544
9/20/06	20-55-f06	63.899147	-154.125177
9/20/06	24-49-f06	63.891650	-154.127130
9/22/05	23-48-f05	63.897390	-154.127720
9/20/06	20-51-f06	63.895280	-154.128030
9/20/06	21-54-f06	63.888001	-154.132654
8/2/05	20-45-t	64.872800	-154.159417
7/31/05	20-46-t	64.872800	-154.159417
7/30/05	20-47-t	64.872800	-154.159417

Date	Fish ID	Latitude	Longitude
7/29/05	20-48-t	64.872800	-154.159417
7/30/05	20-50-t	64.872800	-154.159417
8/1/05	21-45-t	64.872800	-154.159417
7/30/05	21-46-t	64.872800	-154.159417
7/29/05	21-48-t	64.872800	-154.159417
7/30/05	21-50-t	64.872800	-154.159417
7/29/05	22-46-t	64.872800	-154.159417
7/29/05	22-49-t	64.872800	-154.159417
7/31/05	22-50-t	64.872800	-154.159417
7/29/05	23-45-t	64.872800	-154.159417
7/29/05	23-46-t	64.872800	-154.159417
7/30/05	23-50-t	64.872800	-154.159417
7/29/05	24-45-t	64.872800	-154.159417
7/30/05	24-47-t	64.872800	-154.159417
7/30/05	24-48-t	64.872800	-154.159417
8/1/05	24-49-t	64.872800	-154.159417
8/7/06	20-55-b106	64.863467	-154.159717
6/7/06	21-48-s06a	64.844200	-154.160750
6/15/2006	21-48-s06c	64.844200	-154.160750
6/29/06	20-46-s06b	64.851629	-154.163690
6/29/06	23-45-s06b	64.871718	-154.170933
6/29/06	21-50-s06b	64.878920	-154.172880
9/20/06	24-46-f06	64.881060	-154.172960
6/29/06	23-46-s06b	64.878681	-154.173002
6/7/06	20-45-s06a	64.877670	-154.174010
6/15/2006	20-45-s06c	64.877670	-154.174010
6/29/06	24-47-s06b	64.879980	-154.174251
8/7/06	23-51-b106	64.876683	-154.174583
9/22/05	20-47-f05	64.882050	-154.174820
7/13/06	20-55-b206	64.874780	-154.175170
6/29/06	22-46-s06b	64.878099	-154.175354
8/7/06	20-52-b106	64.873450	-154.178350
8/7/06	24-55-b106	64.874967	-154.181183
9/20/06	24-45-f06	64.884818	-154.182314
8/7/06	21-56-b106	64.882933	-154.183083
7/30/05	20-47-1	64.876580	-154.186200
9/1/05	21-46-1	64.876580	-154.186200
8/7/06	24-52-b106	64.885550	-154.187283
7/19/06	24-53-b206	64.828540	-154.192730
7/19/06	23-53-b206	64.827950	-154.193150
9/20/06	24-55-f06	64.877466	-154.205510
7/19/06	24-51-b206	64.815190	-154.218180
7/19/06	22-52-b206	64.814980	-154.221220
9/20/06	20-48-f06	64.884730	-154.225256
9/20/06	22-46-f06	64.876363	-154.227867
9/22/05	20-45-f05	64.876550	-154.228600
6/7/06	23-48-s06a	64.803470	-154.229940
6/29/06	23-48-s06b	64.809780	-154.229940
6/15/2006	23-48-s06c	64.803470	-154.229940
9/20/06	20-53-f06	64.814364	-154.230704
7/19/06	20-52-b206	64.802550	-154.231760

Date	Fish ID	Latitude	Longitude
6/7/06	20-48-s06a	64.880090	-154.233730
6/15/2006	20-48-s06c	64.880090	-154.233730
9/20/06	20-54-f06	64.869906	-154.236427
9/20/06	22-49-f06	64.922930	-154.236850
7/19/06	20-46-b206	64.801200	-154.237930
6/8/06	24-45-s06d	64.816080	-154.241800
6/7/06	24-45-s06a	64.877670	-154.242260
6/15/2006	24-45-s06c	64.877670	-154.242260
6/8/06	21-46-s06d	64.815750	-154.243600
6/8/06	22-45-s06d	64.815200	-154.243800
6/8/06	23-46-s06d	64.815650	-154.244000
6/29/06	22-45-s06b	64.889970	-154.246900
6/29/06	21-48-s06b	64.906000	-154.257380
7/31/05	21-47-t	64.810517	-154.258617
7/31/05	23-48-t	64.810517	-154.258617
6/29/06	20-49-s06b	64.891421	-154.260653
9/20/06	20-46-f06	64.797901	-154.263739
8/7/06	23-52-b106	64.905717	-154.265967
7/30/05	20-49-t	64.905017	-154.266667
8/2/05	21-49-t	64.905017	-154.266667
8/1/05	22-45-t	64.905017	-154.266667
8/1/05	22-47-t	64.905017	-154.266667
8/1/05	22-48-t	64.905017	-154.266667
7/30/05	23-47-t	64.905017	-154.266667
8/1/05	23-49-t	64.905017	-154.266667
7/30/05	24-46-t	64.905017	-154.266667
8/1/05	24-50-t	64.905017	-154.266667
8/24/05	20-47-2	64.905020	-154.266670
8/2/05	21-49-1	64.905020	-154.266670
8/23/05	21-49-2	64.905020	-154.266670
8/1/05	22-45-1	64.905020	-154.266670
8/11/05	22-45-2	64.905020	-154.266670
8/1/05	22-47-1	64.905020	-154.266670
8/21/05	22-47-2	64.905020	-154.266670
8/1/05	22-48-1	64.905020	-154.266670
8/21/05	22-48-2	64.905020	-154.266670
7/30/05	24-46-1	64.905020	-154.266670
9/9/05	24-46-2	64.905020	-154.266670
8/1/05	24-50-1	64.905020	-154.266670
9/17/05	24-50-2	64.905020	-154.266670
7/20/06	20-56-b206	64.904570	-154.267460
7/20/06	24-55-b206	64.904570	-154.267460
7/20/06	21-51-b206	64.904570	-154.267600
6/7/06	23-46-s06a	64.923240	-154.268800
6/15/2006	23-46-s06c	64.923240	-154.268800
6/29/06	22-49-s06b	64.908508	-154.272810
7/20/06	24-53-b206	64.908460	-154.274140
6/29/06	21-49-s06b	64.917272	-154.275620
9/22/05	24-50-f05	64.912100	-154.278270
7/20/06	20-55-b206	64.911850	-154.279040
9/22/05	24-47-f05	64.770880	-154.279970

Date	Fish ID	Latitude	Longitude
7/20/06	23-54-b206	64.917690	-154.282620
6/7/06	22-48-s06a	64.932530	-154.283970
6/15/2006	22-48-s06c	64.932530	-154.283970
6/7/06	20-49-s06a	64.935340	-154.290600
6/15/2006	20-49-s06c	64.935340	-154.290600
6/7/06	20-46-s06a	64.924860	-154.293450
6/15/2006	20-46-s06c	64.924860	-154.293450
6/7/06	22-45-s06a	64.927680	-154.298190
6/15/2006	22-45-s06c	64.927680	-154.298190
6/7/06	21-49-s06a	64.942190	-154.300090
6/15/2006	21-49-s06c	64.942190	-154.300090
6/7/06	23-45-s06a	64.932110	-154.303870
6/15/2006	23-45-s06c	64.932110	-154.303870
8/10/05	20-49-1	64.756670	-154.388330
8/24/05	22-48-3	64.756670	-154.388330
7/25/06	24-52-f06UT	64.756670	-154.388330
8/3/06	22-51-f06UT	64.756670	-154.388330
8/29/06	21-56-f06UT	64.756670	-154.388330
9/7/06	20-53-f06UT	64.756670	-154.388330
9/28/06	24-47-f06UT	64.756670	-154.388330
10/1/06	20-51-f06UT	64.756670	-154.388330
4/4/06	23-48-w06a	64.923640	-154.400540
9/22/05	24-49-f05	64.654800	-154.561240
3/3/06	23-50-w06m	64.853100	-155.168000
6/29/06	23-50-s06b	64.850919	-155.188024
4/5/06	23-50-w06a	64.817840	-155.271700
4/5/06	21-48-w06a	64.729400	-155.875050
3/3/06	21-46-w06m	64.821400	-157.092420
4/5/06	21-46-w06a	64.816620	-157.102540
3/3/06	22-48-w06m	64.861310	-157.663080

Nowitna River: 2005 and 2006 Sheefish Radio Telemetry Project

Sample	Location	Fish ID	Latitude	Longitude	Freq.	Date	Temp.	Length	Chan.	Code	Species	Fish ID	Date
30	Big Slough	20-45-t	64.87280	154.15942	148.400	8/2/05	16	74	20	45	INCO	20-45	9/22/05
19	Big Slough	20-46-t	64.87280	154.15942	148.400	7/31/05	17	72	20	46	INCO	20-46	9/22/05
10	Big Slough	20-47-t	64.87280	154.15942	148.400	7/30/05	18	77	20	47	INCO	20-47	9/22/05
2	Big Slough	20-48-t	64.87280	154.15942	148.400	7/29/05	19	77	20	48	INCO	20-48	
13	1-mile	20-49-t	64.90502	154.2666667	148.400	7/30/05	19	75	20	49	INCO	20-49	9/22/05
11	Big Slough	20-50-t	64.87280	154.15942	148.400	7/30/05	18	86	20	50	INCO	20-50	
23	Big Slough	21-45-t	64.87280	154.15942	148.440	8/1/05	17	72	21	45	INCO	21-45	
17	Big Slough	21-46-t	64.87280	154.15942	148.440	7/30/05	19	73	21	46	INCO	21-46	9/22/05
21	Titus	21-47-t	64.81052	154.25862	148.440	7/31/05	18	78	21	47	INCO	21-47	9/22/05
6	Big Slough	21-48-t	64.87280	154.15942	148.440	7/29/05	19	65	21	48	INCO	21-48	9/22/05
29	1-mile	21-49-t	64.90502	154.2666667	148.440	8/2/05	16	74	21	49	INCO	21-49	9/22/05
8	Big Slough	21-50-t	64.87280	154.15942	148.440	7/30/05	18	83	21	50	INCO	21-50	9/22/05
26	1-mile	22-45-t	64.90502	154.2666667	148.520	8/1/05	16	69	22	45	INCO	22-45	10/4/05
5	Big Slough	22-46-t	64.87280	154.15942	148.520	7/29/05	19	79	22	46	INCO	22-46	9/22/05
27	1-mile	22-47-t	64.90502	154.2666667	148.520	8/1/05	16	82	22	47	INCO	22-47	
24	1-mile	22-48-t	64.90502	154.2666667	148.520	8/1/05	16	68	22	48	INCO	22-48	9/22/05
4	Big Slough	22-49-t	64.87280	154.15942	148.520	7/29/05	19	74	22	49	INCO	22-49	9/22/05
18	Big Slough	22-50-t	64.87280	154.15942	148.520	7/31/05	17	78	22	50	INCO	22-50	
3	Big Slough	23-45-t	64.87280	154.15942	148.540	7/29/05	19	72	23	45	INCO	23-45	9/22/05
7	Big Slough	23-46-t	64.87280	154.15942	148.540	7/29/05	19	74	23	46	INCO	23-46	9/22/05
12	1-mile	23-47-t	64.90502	154.2666667	148.540	7/30/05	19	78	23	47	INCO	23-47	9/22/05
20	Titus	23-48-t	64.81052	154.25862	148.540	7/31/05	18	69	23	48	INCO	23-48	9/22/05
28	1-mile	23-49-t	64.90502	154.2666667	148.540	8/1/05	16	70	23	49	INCO	23-49	9/22/05
16	Big Slough	23-50-t	64.87280	154.15942	148.540	7/30/05	19	70	23	50	INCO	23-50	
1	Big Slough	24-45-t	64.87280	154.15942	148.560	7/29/05	19	>75	24	45	INCO	24-45	9/22/05
14	1-mile	24-46-t	64.90502	154.2666667	148.560	7/30/05	19	80	24	46	INCO	24-46	10/4/05
15	Big Slough	24-47-t	64.87280	154.15942	148.560	7/30/05	19	80	24	47	INCO	24-47	9/22/05
9	Big Slough	24-48-t	64.87280	154.15942	148.560	7/30/05	18	78	24	48	INCO	24-48	
22	Big Slough	24-49-t	64.87280	154.15942	148.560	8/1/05	17	75	24	49	INCO	24-49	9/22/05
25	1-mile	24-50-t	64.90502	154.2666667	148.560	8/1/05	16	75	24	50	INCO	24-50	9/22/05
40	Big Slough	20-51-t	64.87280	154.15942	148.400	7/12/06	16	80	20	51	INCO	20-51	
39	Big Slough	20-52-t	64.87280	154.15942	148.400	7/12/06	16	76	20	52	INCO	20-52	
38	Titus	20-53-t	64.81052	154.25862	148.400	7/12/06	17	72	20	53	INCO	20-53	
32	1-mile	20-54-t	64.90502	154.2666667	148.400	7/13/06	17	73	20	54	INCO	20-54	
41	Big Slough	20-55-t	64.87280	154.15942	148.400	7/12/06	16	79	20	55	INCO	20-55	
33	1-mile	20-56-t	64.90502	154.2666667	148.400	7/13/06	17	74	20	56	INCO	20-56	
31	1-mile	21-51-t	64.90502	154.2666667	148.440	7/13/06	17	72	21	51	INCO	21-51	
35	Big Slough	21-52-t	64.87280	154.15942	148.440	7/13/06	17	85	21	52	INCO	21-52	
36	Big Slough	21-53-t	64.87280	154.15942	148.440	7/13/06	17	85	21	53	INCO	21-53	
34	Big Slough	21-54-t	64.87280	154.15942	148.440	7/13/06	17	78	21	54	INCO	21-54	
37	Titus	21-55-t	64.81052	154.25862	148.440	7/13/06	17	68	21	55	INCO	21-55	
46	Big Slough	21-56-t	64.87280	154.15942	148.440	7/14/06	17	84	21	56	INCO	21-56	
43	Titus	22-51-t	64.81052	154.25862	148.520	7/14/06	16	67	22	51	INCO	22-51	
42	Titus	22-52-t	64.81052	154.25862	148.520	7/14/06	16	70	22	52	INCO	22-52	
44	Big Slough	22-53-t	64.87280	154.15942	148.520	7/14/06	16	71	22	53	INCO	22-53	
45	Big Slough	22-54-t	64.87280	154.15942	148.520	7/14/06	17	88	22	54	INCO	22-54	

Nowitna River: 2005 and 2006 Sheefish Radio Telemetry Project

Sample	Location	Fish ID	Latitude	Longitude	Freq.	Date	Temp.	Length	Chan.	Code	Species	Fish ID	Date
48	1-mile	22-55-t	64.90502	154.2666667	148.520	7/14/06	17	77	22	55	INCO	22-55	
47	1-mile	22-56-t	64.90502	154.2666667	148.520	7/14/06	17	81	22	56	INCO	22-56	
56	Big Slough	23-51-t	64.87280	154.15942	148.540	7/18/06	16	77	23	51	INCO	23-51	
57	Big Slough	23-52-t	64.87280	154.15942	148.540	7/18/06	16	69	23	52	INCO	23-52	
60	Big Slough	23-53-t	64.87280	154.15942	148.540	7/19/06	14	76	23	53	INCO	23-53	
59	Big Slough	23-54-t	64.87280	154.15942	148.540	7/18/06	14	69	23	54	INCO	23-54	
58	Big Slough	23-55-t	64.87280	154.15942	148.540	7/18/06	16	70	23	55	INCO	23-55	
49	Big Slough	23-56-t	64.87280	154.15942	148.540	7/15/06	16	82	23	56	INCO	23-56	
55	Titus	24-51-t	64.81052	154.25862	148.560	7/17/06	11	73	24	51	INCO	24-51	
53	Big Slough	24-52-t	64.87280	154.15942	148.560	7/17/06	14	84	24	52	INCO	24-52	
51	1-mile	24-53-t	64.90502	154.2666667	148.560	7/17/06	16	71	24	53	INCO	24-53	
54	Titus	24-54-t	64.81052	154.25862	148.560	7/17/06	14	76	24	54	INCO	24-54	
50	Big Slough	24-55-t	64.87280	154.15942	148.560	7/17/06	13	70	24	55	INCO	24-55	
52	Big Slough	24-56-t	64.87280	154.15942	148.560	7/17/06	14	71	24	56	INCO	24-56	

Nowitna River Sheefish Telemetry Update, February 28, 2007

During 2005 and 2006, 60 radio transmitters (30 per year) were surgically implanted in large sheefish in the lower Nowitna River. The tags were programmed to transmit during the spawning (September and October), overwintering (January and February), and feeding periods (May and June) for more than 5 years. Aerial surveys have been flown in all three time periods since the first tags were deployed in summer 2005.

We were trying to achieve several objectives during the course of this project. The primary objective of the study was to identify the spawning origins of sheefish feeding in the lower Nowitna River during the summer. It was hypothesized, based on Alt's (1985) original work in the drainage, that most originated in the Sulukna River spawning area, in the upper Nowitna River drainage, and that a smaller number might come from one or more of the other known spawning areas in the Yukon Drainage. We also were interested in knowing if other headwater tributaries of the Nowitna River supported spawning populations. Additionally, spawning frequency of tagged sheefish was a priority objective in the project. The prevailing thought among northern latitude ecologists is that two or more years following a spawning event, would be required to accumulate sufficient energy reserves to spawn again. Surveys conducted over the course of several years promise to reveal whether the interval between spawning events for mature sheefish is one, two, or more years. Overwintering habitats were of interest, but were not a high priority for the project except relative to the Nowitna River itself and the Yukon River in the vicinity of the Nowitna River mouth. Feeding habitats used by tagged sheefish, and the tendency to return annually to feed in the lower Nowitna River were additional objectives of the project.

Our primary hypothesis; that most sheefish feeding in the lower Nowitna River during the summer are of Sulukna River origin, appears to be true. During 2005, 18 of 30 tagged fish were determined to be spawners based on their presence in known spawning areas. Sixteen of these fish were located on the Sulukna River spawning area, and two were located in the upper Yukon Flats spawning area. During 2006, 14 of 30 newly tagged fish were determined to be spawners, and all were located in the Sulukna River spawning area. Additionally, two non-spawning fish from 2005 were also spawning in the Sulukna River during 2006, and none of the fish that spawned in 2005 were present in spawning areas during the 2006 spawning season. The entire Nowitna River drainage was surveyed during the spawning season in both 2005 and 2006 and no sheefish were located in any other tributary except the Sulukna River. At this point it seems clear that within the Nowitna River drainage there is only one spawning area, and it is located in the Sulukna River.

Tagged sheefish from the Nowitna River were located during the winter at the mouth of the Nowitna River and in the Yukon River. Aerial surveys of the Yukon River were limited to a 200 km reach between the mouths of the Koyukuk and Nowitna rivers, where five fish were located during February 2006, and 27 were located during February 2007. It is not clear why there was such a difference in the number of located fish during the two years. During 2007, there was a concentration of overwintering sheefish in the vicinity of the mouth of the Nowitna River, and others were scattered throughout the entire 200 km stretch of River. It is thought that if the survey extended farther downstream, more overwintering sheefish would have been located. These data indicate that in the late fall or early winter, sheefish exit the Nowitna River and overwinter in the Yukon River itself, over a wide geographic area. An otolith chemistry study of Sulukna River sheefish, conducted in 2003, indicated that some individuals from the stock migrate to marine water. Therefore, we might expect that overwintering habitat would extend downstream to the mouth of the Yukon River.

During summer 2006, 20 of the original 30 sheefish tagged in 2005 were located in the lower Nowitna River again. These preliminary data suggest that many sheefish exhibit feeding habitat fidelity. However, additional seasons of data collection will be required before this issue can adequately be addressed.

This project is a cooperative venture involving field, logistical, financial, and flight support from the U.S. Fish and Wildlife Service, the Alaska Department of Fish and Game, and the Bureau of Land Management.

Please contact Randy Brown, Fishery Biologist, U.S. Fish and Wildlife Service, with any additional questions about this project. Phone: (907) 456-0295

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[Article]

Otolith Trace Element Chemistry as an Indicator of Anadromy in Yukon River Drainage Coregonine Fishes

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Abstract.—Eight coregonine species have been documented in the Yukon River drainage. They include inconnu *Stenodus leucichthys*, broad whitefish *Coregonus nasus*, humpback whitefish *C. pidschian*, Alaska whitefish *C. nelsonii*, least cisco *C. sardinella*, Bering cisco *C. laurettae*, round whitefish *Prosopium cylindracium*, and pygmy whitefish *P. coulterii*. Personal use, sport, and commercial fisheries within the drainage target several of these species. Some species are capable of anadromous life histories, as evidenced by their presence in estuaries, yet few studies have investigated the upstream migrations of anadromous components of these populations. Only inconnu migrations have been previously examined in the Yukon River drainage. We investigated the distribution of anadromous coregonine fish in the Yukon River drainage in Alaska using sampling and otolith chemistry procedures. Six species were identified in sample collections from eight regions of the drainage between 1,200 and 2,000 km upstream from the Bering Sea. Gonadosomatic indices indicated that most sampled fish of all species were mature and preparing to spawn. Anadromous inconnu, broad whitefish, and humpback whitefish were distributed in the Yukon River and its tributaries to a maximum distance of 1,700 km from the sea. Anadromous least cisco were distributed in the Yukon River and its tributaries up to 1,600 km from the sea, whereas anadromous Bering cisco were present in the Yukon River main stem as far upstream as 2,000 km. No anadromous round whitefish were detected. Few coregonine spawning areas have been identified, so the actual migration distances of anadromous species may be greater than presented here.

Worldwide, coregonine fishes exhibit a range of variation in life histories that include both freshwater residence and anadromous migrations related to spawning. With respect to North American coregonines, the three species of *Prosopium* are known to live almost exclusively in freshwater and to make seasonal migrations within stream systems; one species, the round whitefish *P. cylindraceum*, sometimes moves to brackish water (Scott and Crossman 1973). Only half of the 14 species of *Coregonus* in North America appear to be restricted entirely to freshwater, while the remaining species are known to be anadromous based on their presence in saltwater environments (Behnke 1972; Scott and Crossman 1973). Inconnu *Stenodus leucichthys* has some strictly freshwater populations and some that are anadromous, but these apparently move only to brackish water in estuaries (Alt 1969; Reist and Bond 1988; Howland et al. 2001).

In the Yukon River drainage in Alaska and Canada (Figure 1), six distinct and two less defined coregonine species are recognized: inconnu, broad whitefish *Coregonus nasus*, humpback whitefish *C. pidschian*, Alaska whitefish *C. nelsonii*, least cisco *C. sardinella*, Bering cisco *C. laurettae*, round whitefish, and pygmy whitefish *P. coulterii*. Humpback whitefish and Alaska whitefish are members of a group that McPhail and Lindsey (1970) called the "*Coregonus clupeaformis* complex" of species, which also includes lake whitefish *C. clupeaformis*. This complex consists of ecologically related morphological variants that are grossly differentiated through population level modal gill raker counts on the first gill arch. Identification of individual fish is nearly impossible due to overlap in these characteristics. As a result, Alt (1979) recommended that all members of the complex in Alaska be referred to as humpback whitefish. We adhere to this recommendation, though Morrow (1980) indicates that

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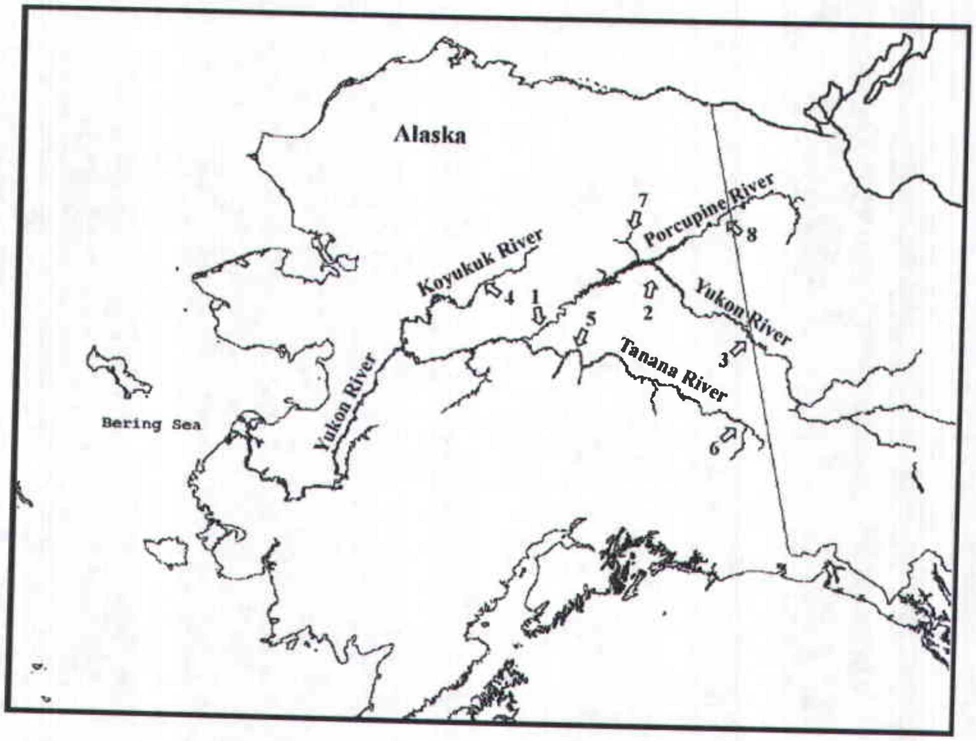

FIGURE 1.—The eight coregonine fish sampling regions in the Yukon River drainage: (1) lower Yukon River (river kilometer [rkm] 1,200), (2) middle Yukon River (rkm 1,700), (3) upper Yukon River (rkm 2,000), (4) Koyukuk River (rkm 1,600), (5) lower Tanana River (rkm 1,300), (6) upper Tanana River (rkm 2,000), (7) Chandalar River (rkm 1,800), and (8) Porcupine River (rkm 2,000).

members of this complex in the lower Yukon River are humpback whitefish and those upstream from approximately river kilometer 600 are Alaska whitefish.

Coregonine species are extensively harvested for human and dog food throughout the Yukon River drainage, yet there have been few attempts to monitor or manage these fisheries. There is a growing movement in Alaska to include user groups in fisheries management discussions (Buklis 2002), and the recent initiation of a commercial coregonine fishery in the lower Yukon River has generated calls for improved understanding of these resources. At present, however, no migration or stock assessment data are available for any species except inconnu that would lead to the identification of user groups or the development of management strategies. This study was initiated to improve our understanding of these fishery resources by identifying the upstream ranges of anadromous components of these populations within the drainage.

Otolith chemistry techniques have provided fisheries scientists with powerful new approaches to monitoring fish migrations and habitat use (Campana 1999). Otolith strontium (Sr) distribution in particular has been widely used to describe fish migrations between marine and freshwater environments (Babaluk et al. 1997; Tzeng et al. 1997; Brown 2000; Howland et al. 2001). Strontium is a bivalent ion in solution and precipitates in otoliths, replacing calcium (Ca) in the mineral matrix in proportion to the atomic ratio of Sr to Ca (mmol/mol) in ambient water (Kraus and Secor 2004). In most estuary systems Sr:Ca is positively correlated with salinity, which has resulted in the routine use of salinity as the habitat variable. Zimmerman (2005) experimented with salmonid species specifically and documented a significant rise in otolith Sr concentration when treatment conditions changed from freshwater to salt water of salinity 6.3‰.

Inferring habitat use from otolith Sr analysis is based on our understanding of the chemical variation between freshwater and saltwater environments. The salinity of surface waters in the eastern Bering Sea is between 30‰ and 32‰ (Takenouti and Ohtani 1974; Luchin et al. 1999), and the Sr:Ca ratio is approximately 8.54 mmol/mol (de Villiers 1999). The Sr:Ca ratios in five regions of the Yukon River averaged 1.87 mmol/mol (range, 1.16–2.59) and were relatively stable across the drainage at high and low flows (USGS 2005; Figure 2). We modeled the variation in the Sr:Ca ratio across the brackish water interface at the Yukon River mouth by mixing freshwater and saltwater chemical fractions for

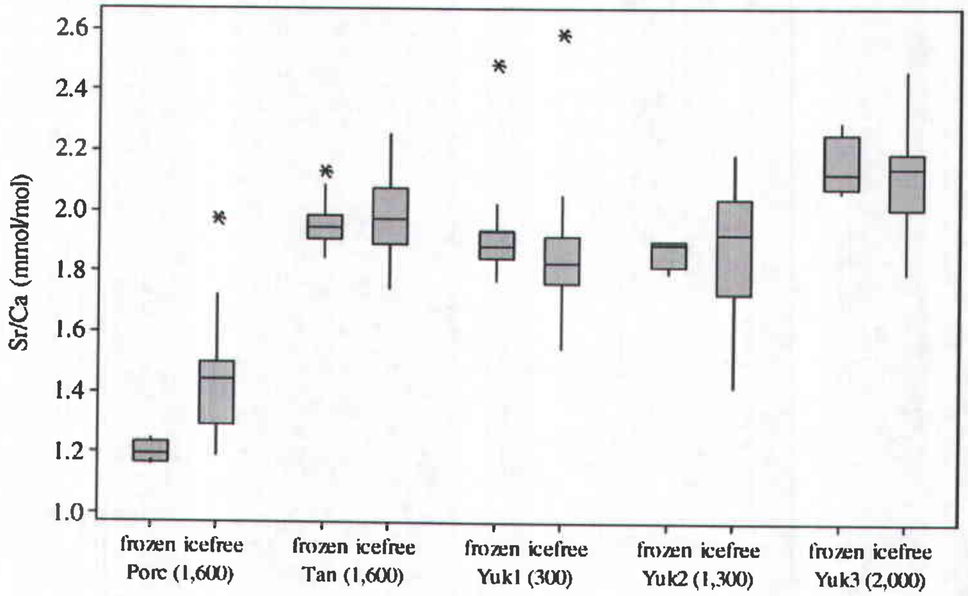

FIGURE 2.—Box plots of water Sr:Ca ratios (mmol/mol) from the Porcupine River (Porc) at rkm 1,600, the Tanana River (Tan) at rkm 1,600, and three Yukon River sites (Yuk 1, 2, and 3) at rkm 300, 1,300, and 2,000, respectively. Water chemistry data ($n =$ 226) were collected for more than 20 years during frozen (November through April) and ice-free (May through October) seasons (USGS 2005).

low (frozen conditions) and high (ice-free conditions) flow periods (Figure 3). The full range of variation in the Sr:Ca ratio within the Yukon River was small compared with the variation across the brackish water interface. The basis for inferring migration between freshwater and saltwater environments from otolith Sr analysis appeared to be well founded for coregonine fish in the Yukon River system.

In this paper we describe the distribution of anadromous coregonine fish in the Yukon River drainage in Alaska based on field sampling and otolith chemistry. We hypothesized that anadromous individuals of all species would be identified far upstream in the drainage, similar to distribution of inconnu, because they share the same downstream larval distribution mechanism (Naesje et al. 1986; Shestakov 1991; Bogdanov et al. 1992).

Methods

Sampling.—We collected samples of coregonine fishes between 1997 and 2003 from eight sampling regions within the Yukon River drainage, including the Yukon River itself as well as the Koyukuk, Tanana, Chandalar, and Porcupine rivers (Figure 1). The sampling regions ranged from 1,200 to 2,000 km from the sea. Collections were made during all open-water seasons in main-stem habitats and tributary systems with sampling gear that included gill nets, beach seines, and fish wheels, in an effort to sample all species and sizes present. Government agencies, local fishers, and other organizations contributed to the effort. All fish captured were identified, measured (fork length), and weighed whole, and egg skeins were removed from females and weighed separately. Otoliths were extracted from each fish, rinsed in water, and stored dry in paper envelopes.

Spawning maturity and readiness were determined based on gonadosomatic index (GSI) values of female fish in the late summer and fall. Values for GSI were calculated as the percentage of egg weight in the whole body weight following the methods of Snyder (1983), that is,

$$\mathrm{GSI} = (\text{egg weight}/\text{whole body weight}) \times 100.$$

The eggs of nonspawning coregonines remain small throughout the summer and fall (Lambert and Dodson 1990), while those of fish preparing to spawn increase rapidly from GSI values less than 3 in June to values as great as 20 or more by the fall spawning period (Petrova 1976; Bond and Erickson 1985). Female fish with GSI values greater than 3 in the late summer and fall were considered to be mature and preparing to spawn.

Otolith preparation and analysis.—One otolith from each fish was sectioned in the transverse plane and mounted on a glass slide with thermoplastic glue (Secor et al. 1992). Each section was approximately 200 μm thick, and growth increments were visible with

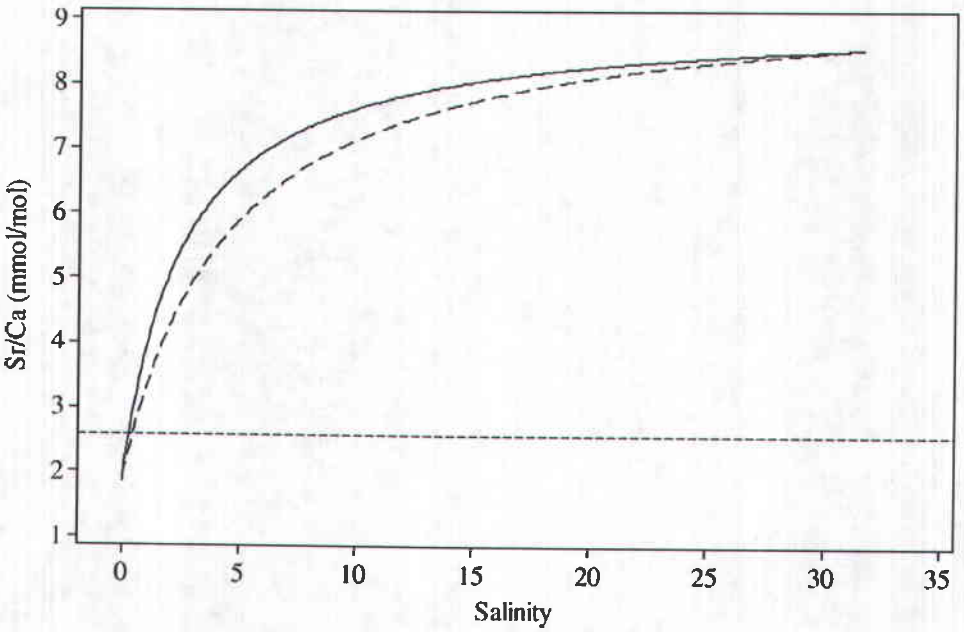

FIGURE 3.—Predicted Sr:Ca ratios across the salinity gradient at the Yukon River–Bering Sea interface during frozen (dashed curve) and ice-free (solid curve) conditions. The horizontal dashed line represents the highest freshwater Sr:Ca ratio from U.S. Geological Survey data within the Yukon River drainage (USGS 2005).

transmitted light. Random subsamples from the collections were selected for chemical analysis. Samples of 10 otoliths from each species collected in each region were adequate to detect anadromy at an occurrence of 30% with greater than 95% confidence based on a binomial distribution. Otoliths selected for chemical analyses were polished on a lapidary wheel with 1-μm diamond abrasive and coated with a thin layer of conductive carbon in preparation for microprobe analysis.

A wavelength-dispersive electron microprobe was used for chemical analyses of otoliths. The technology functions by directing a focused beam of electrons to points on a sample surface. Atoms within the material are ionized by the electron beam and emit X-rays unique to each element. Spectrometers are tuned to count the X-rays from elements of interest, in this case, Sr. The X-ray counts at each sample point are proportional to the elemental concentration in the material (Potts 1987; Reed 1997; Goldstein et al. 2003).

Strontium X-ray counts were collected from a series of points along a core-to-margin transect (core precipitated early in life, margin precipitated just before death) for each otolith. The electron beam was 5 μm in diameter and was operated at an accelerating voltage of 15 kilo–electron volts (keV) and a nominal current of 20 nA. Strontium X-rays were counted for 25 s at each point and normalized to X-rays $\cdot$ s^{-1} $\cdot$ nA^{-1}, hereafter referred to as Sr counts. The counts were converted to estimates of Sr concentration based on a regression equation relating the two measures, similar to the process described by Howland et al. (2001). To do this, we conducted 885 quantitative analyses following standard methodologies detailed in Goldstein et al. (2003) from high and low Sr regions of otoliths from 17 freshwater, diadromous, and marine species. Strontium count and concentration data were available for all sample points. A least-squares linear regression of these values (Figure 4) revealed a strong positive relationship ($r^2 = 99.8\%$) that was defined by the equation

$$\mathrm{Sr(mg/kg)} = -2,637 + 1,709\,\mathrm{Sr(counts)}.$$

Howland et al. (2001) took a multivariate analytical approach to the classification of anadromous and nonanadromous inconnu in the Mackenzie River in northern Canada. They used the range and maximum Sr concentration values from a series of sample points to determine if fish had been to salt water during specific time intervals, in their case within annuli. This numerical approach considered the overall point-to-point variation in the distribution of Sr values and spikes in Sr concentration that occur in marine precipitate. We modified the procedures of Howland et al. (2001) because Sr concentration for a small number of data points approached or fell below our detection limit, which was approximately 320 mg/kg.

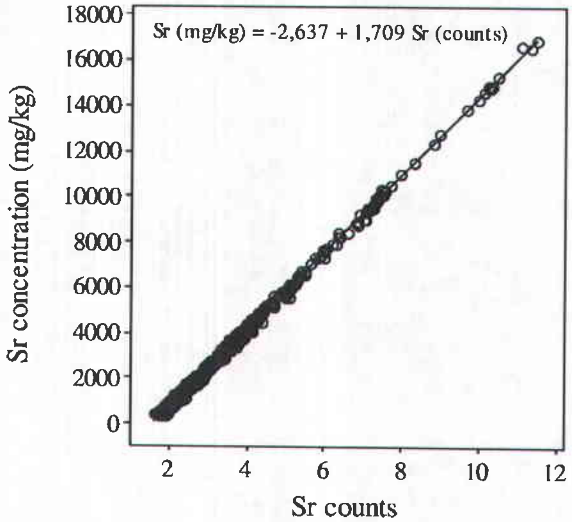

FIGURE 4.—Regression equation from 885 sample points describing the relationship between Sr X-ray counts and the Sr concentration in fish otoliths.

As a substitute for Sr concentration range we used an index of the coefficient of variation (CV = SD/mean) of the Sr counts as a measure of the overall Sr variation along core-to-margin transects. Strontium counts from homogeneous material are Poisson distributed with the mean equal to the variance (Goldstein et al. 2003). Therefore, we were able to calculate the CV expected from a series of sample points across homogeneous material using the mean Sr count. The CV index (CVI), a relative measure of otolith heterogeneity, was calculated for each otolith as

$$\text{CVI} = (\text{actual CV})/(\text{expected CV}).$$

A chemically homogeneous otolith would have a CVI of 1, and a chemically heterogeneous otolith would have a CVI greater than 1. The other value we used was the maximum Sr concentration estimate from the core-to-margin transect. Used together, the CVI and the maximum Sr concentration values provided similar numerical criteria for life history classification as the range and maximum Sr concentration values used by Howland et al. (2001).

We empirically established critical point criteria for life history classification using CVI and maximum Sr concentration data from a selection of known anadromous and nonanadromous salmonid fishes. Anadromous fish included coho salmon *Oncorhynchus kisutch*, sockeye salmon *O. nerka*, steelhead *O. mykiss* (anadromous rainbow trout), Dolly Varden *Salvelinus malma*, inconnu, broad whitefish, humpback whitefish, least cisco, Bering cisco, and Arctic cisco *C. autumnalis*. Nonanadromous fish included Dolly Varden, Arctic grayling *Thymallus arcticus*, lake trout *S. namaycush*, rainbow trout, inconnu, broad whitefish, lake whitefish, humpback whitefish, least cisco, and round whitefish. We evaluated one otolith from each species within each category. A scatter plot of the CVI and maximum Sr concentration values from the two life history categories was used to establish classification criteria (Figure 5). Anadromous fishes were distributed between CVI values of 3.7 and 12.7 and maximum Sr concentration values between 1,790 and 6,000 mg/kg. Nonanadromous fishes were confined to a region in which the CVI was less than 2 and the maximum Sr concentration was less than 1,700 mg/kg. Based on these findings, a fish with unknown life history was considered to be anadromous if the CVI was greater than 2 and the maximum Sr concentration was greater than 1,700 mg/kg, otherwise it was considered to be nonanadromous.

Despite the qualitative nature of visual analysis of otolith Sr line graphs, it has been common practice to present them when evaluating anadromy because the patterns in anadromous and nonanadromous fish are so distinctive (Secor et al. 1995; Babaluk et al. 1997; Tzeng et al. 1997; Stephenson et al. 2005). In consideration of this practice we present graphs displaying the Sr distribution along core-to-margin transects from one anadromous fish of each species

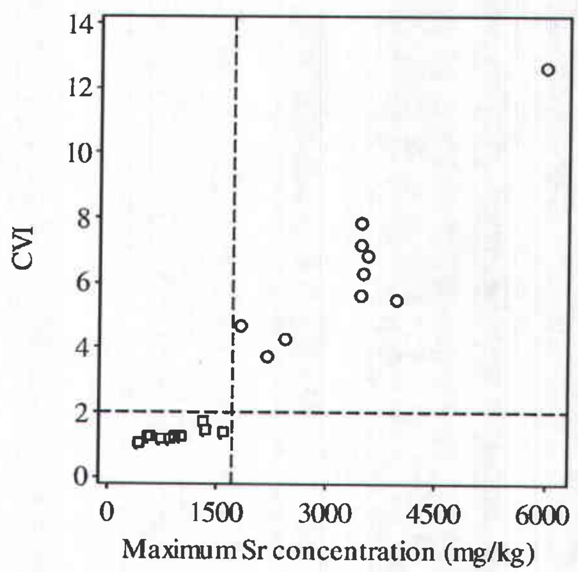

FIGURE 5.—Plot of the coefficient of variation index (CVI, i.e., the ratio of the actual to the expected coefficient of variation) versus the maximum Sr concentration for 10 anadromous (circles) and 10 nonanadromous (squares) salmonid fishes. The vertical dashed line denotes a Sr concentration of 1,700 mg/kg and the horizontal dashed line a CVI of 2.0.

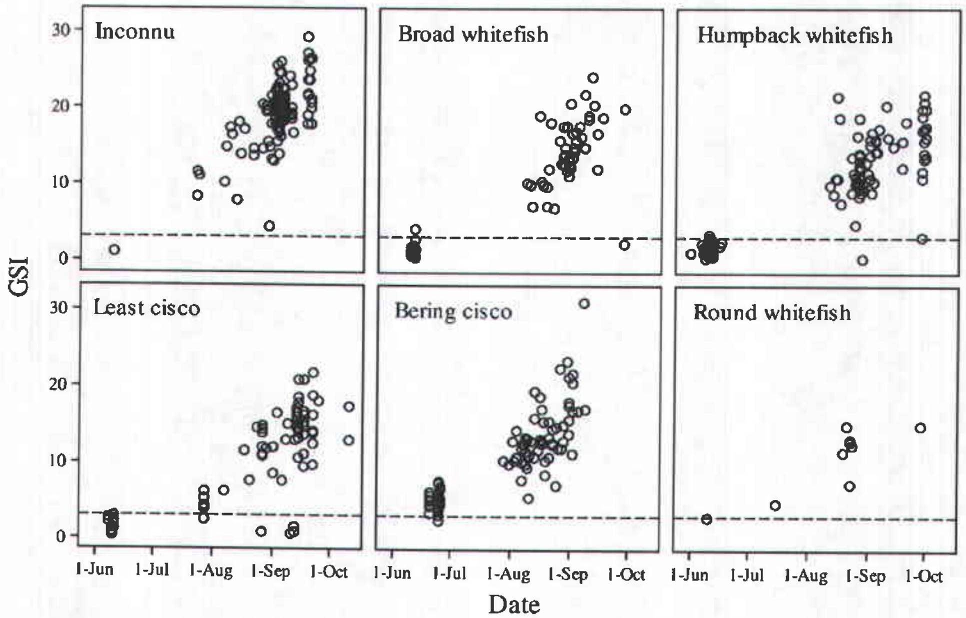

FIGURE 6.—Gonadosomatic indices (GSIs) for female coregonine fish sampled in all collection locations in the Yukon River drainage 1,200 or more river kilometers from the Bering Sea. Female fish with GSI values greater than 3 (horizontal dashed lines) in the late summer and fall were mature and preparing to spawn.

from each collection region in which anadromous individuals were detected. We present the Sr distribution graphs from the individuals with the highest maximum Sr concentrations within species and collection region groups.

Results

We captured six coregonine species during field sampling activities, including inconnu, broad whitefish, humpback whitefish, least cisco, Bering cisco, and round whitefish. Not all species were present in all locations, nor were all species that were present found in abundance. The GSI values of nearly all female fish of all species were substantially greater than 3 in the late summer and fall (Figure 6), indicating that sampled fish were predominantly mature and preparing to spawn.

Six species were captured at the lower Yukon River collection location. Round whitefish were found in very low numbers and were not considered for anadromy testing. Anadromous inconnu, broad whitefish, humpback whitefish, least cisco, and Bering cisco were detected in the examined samples (Table 1; Figure 7).

Six species were captured at the middle Yukon River collection location. Round whitefish were found in very low numbers and were not considered for anadromy testing. Inconnu, broad whitefish, humpback whitefish, least cisco, and Bering cisco were seasonally abundant. Brown (2000) showed previously that anadromous inconnu migrate to spawn in this collection location so they were not analyzed further. Anadromous broad whitefish, humpback whitefish, and Bering cisco were detected (Table 1; Figure 7). All least cisco tested were classified as nonanadromous.

Five species were captured at the upper Yukon River collection location, but no species were abundant there at any season. Least cisco were not captured there. Humpback whitefish and round whitefish were found in very low numbers and were not considered for anadromy testing. Anadromous Bering cisco were detected (Table 1; Figure 7). All inconnu and broad whitefish tested were classified as nonanadromous.

Five species were captured at the Koyukuk River collection location. Bering cisco were not captured at that site. Round whitefish were found in very low numbers and were not considered for anadromy testing. Anadromous inconnu, broad whitefish, humpback whitefish, and least cisco were detected (Table 1; Figure 7).

Five species were captured at the lower Tanana River collection location. Bering cisco were not captured there. Anadromous inconnu, broad whitefish, humpback whitefish, and least cisco were detected (Table 1; Figure 7) and all round whitefish tested were classified as nonanadromous.

Humpback whitefish and round whitefish were captured at the upper Tanana River collection location,

TABLE 1.—Yukon River drainage anadromy classification results for inconnu (IN), broad whitefish (BWF), humpback whitefish (HBWF), least cisco (LC), Bering cisco (BC), and round whitefish (RWF).

Collection location	Distance from the sea (km)	Species	Sample size	Anadromous fish	
				Number	Percent
Lower Yukon River	1,200	IN	12	12	100
		BWF	12	10	83
		HBWF	10	9	90
		LC	10	4	40
		BC	12	12	100
Middle Yukon River	1,700	IN[a]			
		BWF	10	3	30
		HBWF	20	5	25
		LC	24	0	0
		BC	7	7	100
Upper Yukon River	2,000	IN	10	0	0
		BWF	8	0	0
		BC	3	3	100
Koyukuk River	1,600	IN	10	8	80
		BWF	12	11	92
		HBWF	12	10	83
		LC	12	2	17
Lower Tanana River	1,300	IN	10	2	20
		BWF	10	8	80
		HBWF	10	4	40
		LC	10	2	20
		RWF	10	0	0
Upper Tanana River	2,000	HBWF	10	0	0
Chandalar River	1,800	BWF	10	0	0
Porcupine River	2,000	IN	10	0	0
		BWF	10	0	0
		HBWF	10	0	0

[a] Anadromous inconnu were previously shown to be present at the middle Yukon River collection location (Brown 2000).

but round whitefish were found in very low numbers and were not considered for anadromy testing. All humpback whitefish tested were classified as nonanadromous (Table 1).

Broad whitefish and round whitefish were captured at the Chandalar River collection location. Round whitefish were found in very low numbers and not considered for anadromy testing. All of the broad whitefish that were tested were classified as nonanadromous (Table 1).

Five species were captured at the Porcupine River collection location, but Bering cisco were not captured there. Round whitefish were found in very low numbers and were not considered for anadromy testing. Anadromous least cisco were not detected among the 24 fish tested from the middle Yukon River collection location 300 km downstream, so they were not considered for anadromy testing at the Porcupine River location. All inconnu, broad whitefish, and humpback whitefish tested were classified as nonanadromous (Table 1).

The prevalence of anadromy among regions of the drainage was illustrated in the plots of CVI versus maximum Sr concentration (Figure 8). In four of five collection regions in which anadromous fish were detected, anadromous individuals from several species were present. Only at the upper Yukon River collection location was there a single anadromous species among those present, Bering cisco. Nonanadromous coregonines of at least some species were present in all collections. Fish classified as anadromous had CVI and maximum Sr concentration values that ranged from just above critical point levels to maximum values as high as 20.6 CVI and 14,611 mg/kg. This resulted in plots with data concentration regions near the origin that dispersed broadly towards the upper right (Figure 8, top row). In regions where few or no anadromous fish were detected, the plots contained data concentrated at the origin (Figure 8, bottom row). Otolith core regions of all fish, that is, those classified as anadromous and nonanadromous, had Sr concentrations below 1,700 mg/kg, reflecting their natal origins in freshwater (see examples of anadromous fish in Figure 7).

Discussion

Anadromous Fish Distribution

It is clear from these data that several species of anadromous coregonines migrate from the mouth of the Yukon River upstream as far as 1,600 km or more into the drainage (Figure 9). Migrations of this magnitude

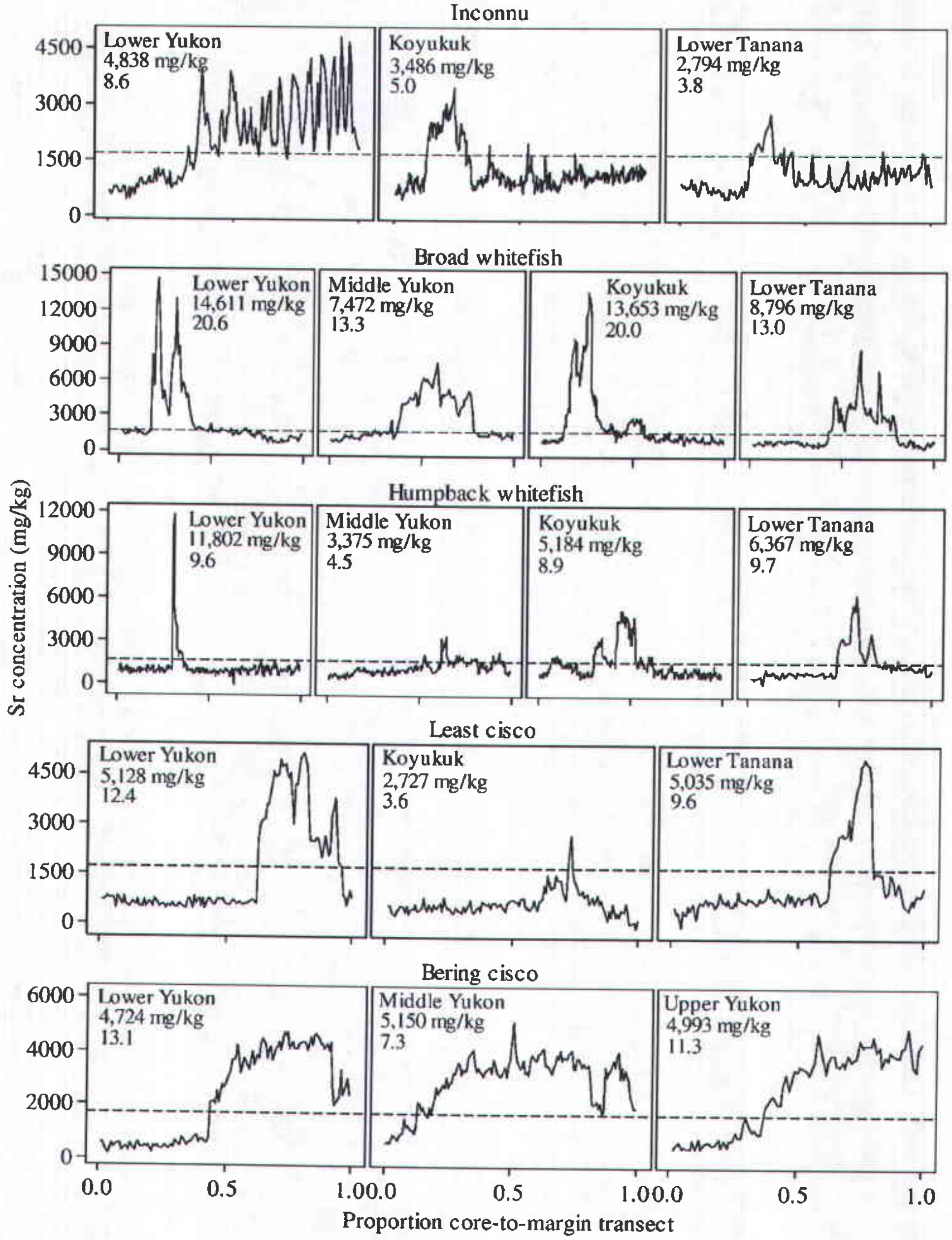

FIGURE 7.—Otolith Sr distributions of the anadromous coregonines with the highest Sr concentration levels from each of the collection regions. In each graph the collection region, maximum Sr concentration, and CVI are indicated. The horizontal dashed line denotes a Sr concentration of 1,700 mk/kg.

for coregonine species, with the exception of inconnu, are unprecedented in the literature. Prasolov (1989), Bogdanov et al. (1992), and Shestakov (1991, 2001) undoubtedly understood that extensive coregonine spawning migrations were occurring in the Ob and Anadyr rivers in northern Asia. Similarly, Reist and Bond (1988) knew that coregonine species were migrating upstream in the Mackenzie River in northern Canada. Specific migrations of anadromous components of coregonine populations, however, were not documented in these systems. Our findings indicate that most coregonine species in the Yukon River are making migrations similar in magnitude to those of Pacific salmon species *Oncorhynchus* spp., which has not been seriously considered before.

The predominance of elevated GSI values in female

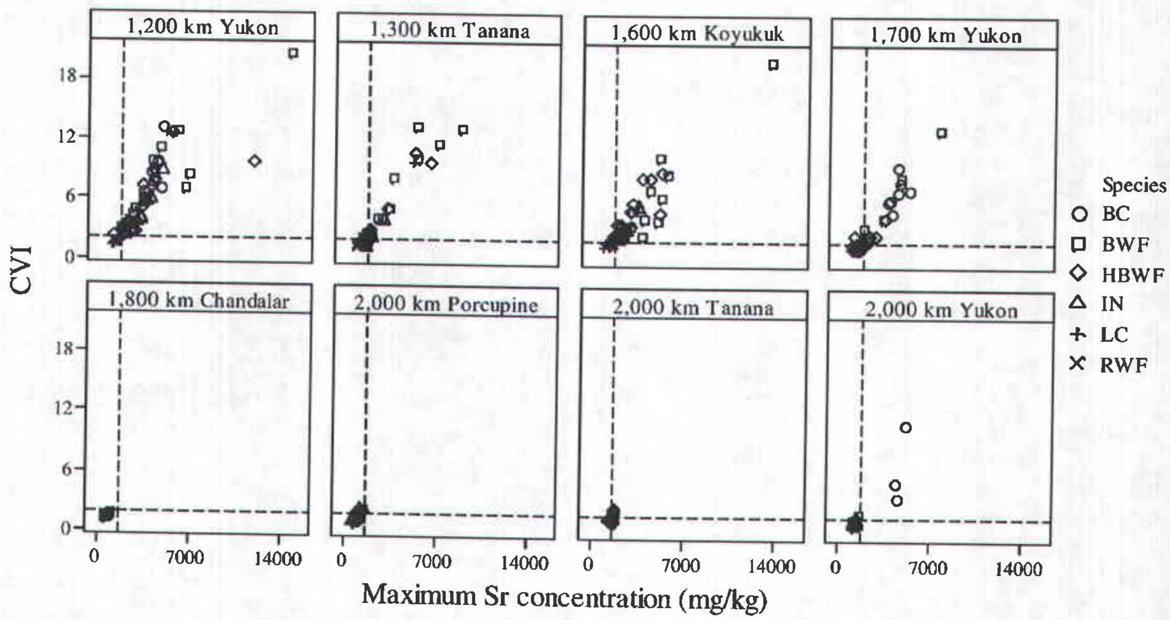

FIGURE 8.—Plots of the coefficient of variation index (CVI) versus the maximum Sr concentration of the coregonine fishes in each collection region, identified here in terms of distance from the sea and river basin. Points for fish classified as anadromous lie above the horizontal dashed lines (CV > 2) and to the right of the vertical dashed lines (maximum strontium concentration > 1,700 mg/kg). Species codes are as follows: BC = Bering cisco, BWF = broad whitefish, HBWF = humpback whitefish, IN = inconnu, LC = least cisco, and RWF = round whitefish.

fish of all species (Figure 6) indicated that most samples were taken from populations engaged in spawning migrations. Few coregonine spawning destinations have been identified, so the actual upstream migration distances of anadromous coregonines may be greater than presented here. It is not clear whether the distance itself limits further upstream migration, or if it is simply that suitable spawning habitats occur in those regions of the drainage. Future investigations will focus on identifying spawning destinations, which will allow true migration distances to be determined, identify user groups in the drainage, and permit stock-specific assessments to be conducted.

Stephenson et al. (2005) used dart tags and otolith chemistry to document the presence of anadromous inconnu in the Liard River, 1,800 km upstream from the mouth of the Mackenzie River. Their finding represents the longest documented migration of anadromous inconnu in North America. We identified anadromous inconnu in the Yukon River drainage as far as 1,700 km upstream from the sea (Figure 9). Our results were consistent in most cases with Alt's (1977) assessments, which were based on many years of dart tagging and sampling data. A notable exception to Alt (1977) was his contention that inconnu in the Tanana River were nonanadromous and localized, but our data indicated that some anadromous inconnu were present in that system.

Chang-Kue and Jessop (1992, 1997) used tagging data to identify broad whitefish migrations from the Mackenzie River delta to spawning areas as far as 630 km from the Beaufort Sea and lake whitefish migrations into the Mackenzie and Arctic Red rivers as far as 500 km from the sea. The upstream migrations of anadromous broad whitefish and humpback whitefish in the Yukon River drainage, up to 1,700 km from the sea (Figure 9), are more extensive than any previously reported. If similar sampling and otolith chemistry techniques were applied to populations in the large northern Asian rivers and in the Mackenzie River, anadromous migrations of similar distances probably would be identified.

Lindsey (1963) contended that Alaska whitefish were present in upstream regions of the Yukon River drainage based on modal gill raker counts from various collections. Morrow (1980) subsequently defined their range in the drainage as being upstream from approximately 600 river km from the sea, and humpback whitefish downstream of this point. Our data indicate that there is no range barrier between these two forms. They are either sympatric across much of the drainage or the taxonomic distinctions between

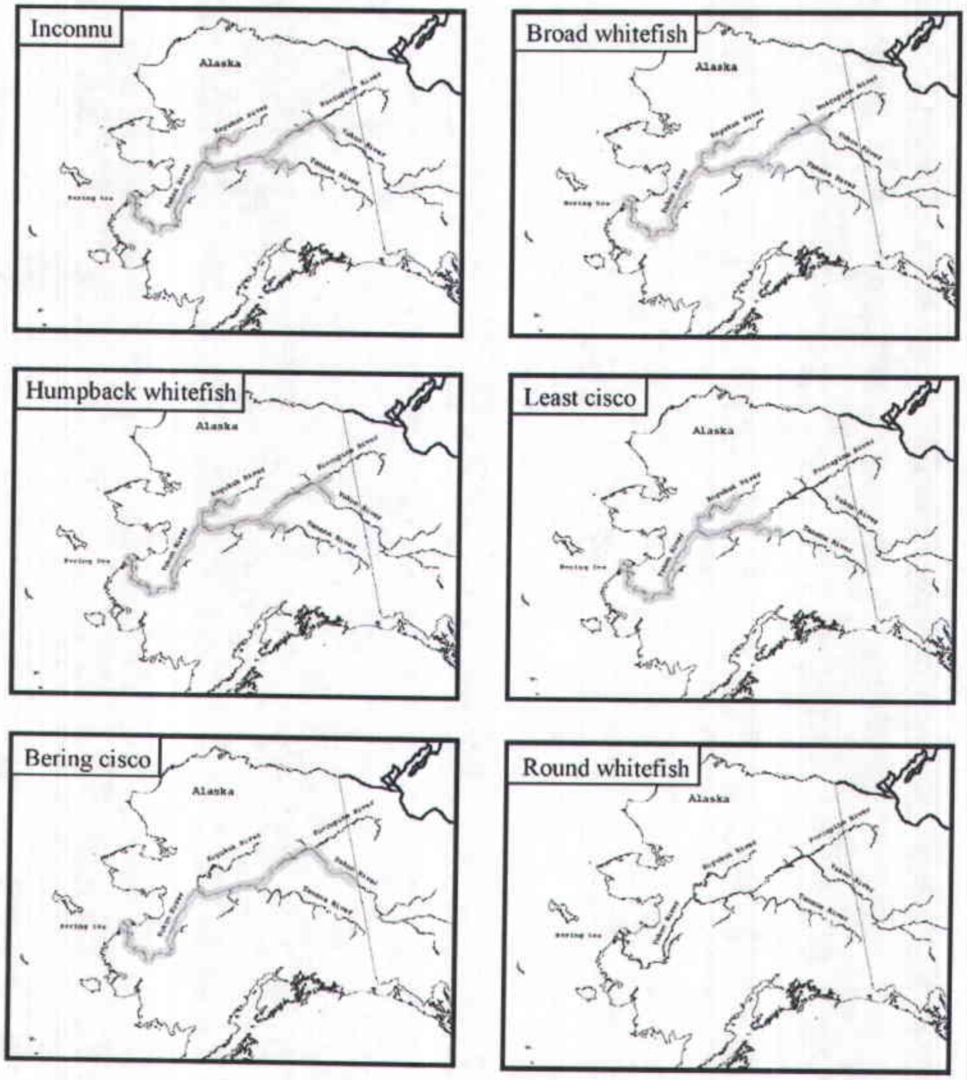

FIGURE 9.—Maximum extent of anadromous migrations for coregonine species in the Yukon River drainage based on otolith chemistry analysis (shaded areas).

them are more complicated than previously thought. This issue should eventually be revisited and resolved.

Reist and Bond (1988) reported that upstream spawning migrations of least cisco occur in the Mackenzie River, but their destinations were not known. Anadromous least cisco were identified as far as 1,600 km upstream from the sea in the Yukon River drainage (Figure 9). Surprisingly, anadromous individuals were not identified in the middle Yukon River collection location despite an extensive testing effort and the presence of anadromous individuals of several other species (Table 1; Figure 7; Brown 2000). These findings suggest that there is a subtle, species-specific aspect to the dynamics of downstream distribution of coregonine larvae each spring.

Bering cisco were captured only in main-stem Yukon River habitat, where they were abundant throughout the lower and middle collection locations. Our failure to capture Bering cisco in the tributary drainages suggests that they restrict their migrations to the main stem. All tested fish were classified as anadromous, including individuals collected 2,000 km from the sea (Table 1). DeGraaf (1981) reported the first Canadian record of a Bering cisco captured in the Yukon River 2,150 km from the sea. No juvenile Bering cisco have been documented in the drainage, so presumably this was also an anadromous fish. These data suggest that all Bering cisco in the drainage are anadromous, which is consistent with our understanding of the life history of their closest relative, the Arctic cisco of the Mackenzie River drainage (McPhail 1966; Reist and Bond 1988).

Round whitefish were present in all collection locations but relatively abundant in only one, and no tested fish were classified as anadromous (Table 1). There was no indication from sampling activities that migrations of round whitefish were occurring except in the lower Tanana River sampling region. For example, during the entire project in the lower Yukon River region, when thousands of individuals from other species were captured, only a single round whitefish was observed. Round whitefish were similarly scarce in all other regions except the lower Tanana River. Spawning migrations of anadromous round whitefish have been reported in the relatively small rivers flowing into James and Hudson bays of Canada (Morin et al. 1982), although migration distances were not detailed. Our data suggest that if spawning migrations of anadromous round whitefish occur in the Yukon River drainage, they do not extend as far upstream as our collection locations.

Otolith Chemistry Analysis.—In a controlled laboratory experiment, Zimmerman (2005) showed that the otolith Sr concentration of several species of juvenile salmonids rose significantly between freshwater and saltwater treatments of salinity as low as 6.3‰. Additionally, he found that different salmonid species incorporated Sr at different rates and cautioned against using critical-point values established for one species to judge the anadromy of another. Furthermore, he suggested that it was not possible to predict the absolute salinity of water the fish inhabited based on otolith Sr levels, but that it was possible to determine as many as two levels of salinity, low and high, consistent with the findings of Howland et al. (2001) for inconnu.

In this study we were interested only in whether individual fish were anadromous or nonanadromous. Babaluk et al. (1997) classified unknown life history samples of Arctic char into anadromous and nonanadromous categories by visually matching patterns of otolith Sr distribution with known life history samples. This subjective classification method is effective because the Sr-distribution patterns in otoliths of anadromous and nonanadromous samples are very distinctive. We sought, however, to develop a numerical basis for life history classification. Classification based solely on critical levels of Sr concentration or Sr:Ca levels is not considered to be universally valid because of species-specific Sr incorporation rates (Zimmerman 2005) and variable chemistry within freshwater systems (Kraus and Secor 2004). The distinctive Sr-distribution patterns of nonanadromous (low variability and low levels of Sr) and anadromous (high variability and high maximum levels of Sr) individuals are thought to be valid across species and systems, with possible exceptions discussed by Kraus and Secor (2004). Yukon River water chemistry (Figure 2), however, indicated that those exceptions were not pertinent to this study. Howland et al.'s (2001) analytical method provided a numerical approach to evaluate the two main patterns apparent in graphs of otolith Sr distribution. Our modification of their method appeared to be as effective as a visual analysis of the Sr distribution graphs at classifying anadromous and nonanadromous individuals within the collections. We also explored the utility of linear and quadratic discriminant analyses using CVI and maximum Sr concentration data, but those procedures appeared to misclassify anadromous coregonines with low to moderate levels of Sr. A larger sample of data from known life history individuals would improve the effectiveness of those methods. Other approaches to the problem of classifying unknown samples among life history categories may eventually prove to be more useful and objective than those used here.

Acknowledgments

This project would not have been possible without substantial assistance from many different organizations and individuals living and working throughout the Yukon River drainage. Support for this project was provided by the U.S. Fish and Wildlife Service (Fairbanks Fish and Wildlife Field Office and the Office of Subsistence Management), the Alaska Department of Fish and Game, and the University of Alaska Fairbanks, Advanced Instrumentation Laboratory. Rural fishers, and agency employees who contributed samples and gathered data for the project include Chrissy Apodaca, Steven Bergman, Charlie Campbell, Bill Carter, Pete Cleary, Dick Cook, Dave Daum, Cheryl Dion, Tim Henry, Charlie House, Joanna Jagow, Paul Jagow, Linda Johnson, Gina Kang, Dennis Kogl, Lauri Larson, Mike Sager, Sonja Sager, Tevis Underwood, and Stan Zuray. Two anonymous reviews of an earlier draft helped to focus and refine the manuscript. These contributions are greatly appreciated.

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2005 Nowitna River Inconnu Radio Telemetry Study

Principal Investigator: Randy J. Brown, USF&WS-Fairbanks Fish and Wildlife Office

Objectives:

1) Determine if some inconnu feeding in the lower Nowitna River in June spawn in the upper Nowitna River drainage;
2) Determine if some inconnu feeding in the lower Nowitna River in June migrate to one of the other known spawning areas in the Yukon River drainage;
3) Determine if some inconnu feeding in the lower Nowitna River in June overwinter in the lower Nowitna River or the Yukon River near the mouth of the Nowitna River;
4) Determine if some inconnu present in the lower Nowitna River in June show fidelity to seasonal habitats;
5) Identify spawning periodicity of inconnu present in the lower Nowitna River in June based on the annual presence of radio-tagged fish on spawning areas over the course of four spawning seasons.

Justification: The Fishery Management Plan for the Nowitna National Wildlife Refuge (U.S. Fish and Wildlife Service 1991) specifically states that population studies of inconnu should be considered high priority research. Inconnu are present in the lower Nowitna River drainage during the spring and summer, and they are known to spawn in the Sulukna River, an upper drainage tributary of the Nowitna River. Alt (1985) suspected that inconnu present in the lower drainage in spring and summer were part of the Sulukna River spawning population, but no evidence supporting this believe have been produced. Additionally, dart tags deployed on inconnu in the lower drainage have been recaptured at various locations along the Yukon and Tanana rivers (Alt 1974, 1975), suggesting that inconnu present in the lower drainage during spring and summer may be members of other inconnu spawning populations. At present there appears to be a surge in guided sport fishing activities in a number of wetland regions of the Yukon River drainage, including the lower Nowitna River, and inconnu are taken in subsistence gillnet and fishwheel fisheries all along the Yukon River (Crawford 1979; Bergstrom et al. 1999; Borba and Hamner 2001), so it would be beneficial to know if multiple inconnu spawning populations utilize the Nowitna River. This project is designed to detect the presence of multiple spawning stocks during June, and will provide substantially more data regarding seasonal habitat use and inconnu life history as well.

Background: Yukon River inconnu *Stenodus leucichthys* are highly migratory within the drainage, and are known to be anadromous, venturing into marine water near the river's mouth (Brown 2000). They are subject to a winter subsistence fishery on the lower river (Crawford 1979), are harvested elsewhere in the drainage by sport and subsistence fishers (Bergstrom et al. 1999; Howe et al. 1999), and are taken incidentally by salmon fishers all along the river (Borba and Hamner 2001). In addition, fishers in the lower Yukon River have periodically considered establishing a commercial fishery for inconnu and other coregonid fish. Despite the fact that inconnu can be captured throughout much of the Yukon River drainage many aspects of their life history remain unclear. Major migration routes, migration timing, and important habitat areas for the species are only partly understood.

Five spawning areas have been specifically located in the drainage: two are in the upper Koyukuk River (Alt 1969); one is in the Chatanika River, a tributary of the Tanana River (Alt 1969); one is in the mainstem of the Yukon River upstream from the Porcupine River mouth (Brown 2000), and one is in the Sulukna River, a tributary of the Nowitna River (Figure 1). Alt (1987) proposed that there may be additional inconnu spawning areas in the upper reaches of the Yukon River drainage as well, but specific locations have not been identified. Recent radio-tagging work (USF&WS, unpublished data) and decades of sampling throughout the Yukon River drainage suggest that the five identified inconnu spawning areas may be all there are in the Alaska portion of the drainage. Movements of juveniles, rearing habitats, the behavior of non-spawning adults, spawning periodicity, and habitat fidelity are largely matters of speculation.

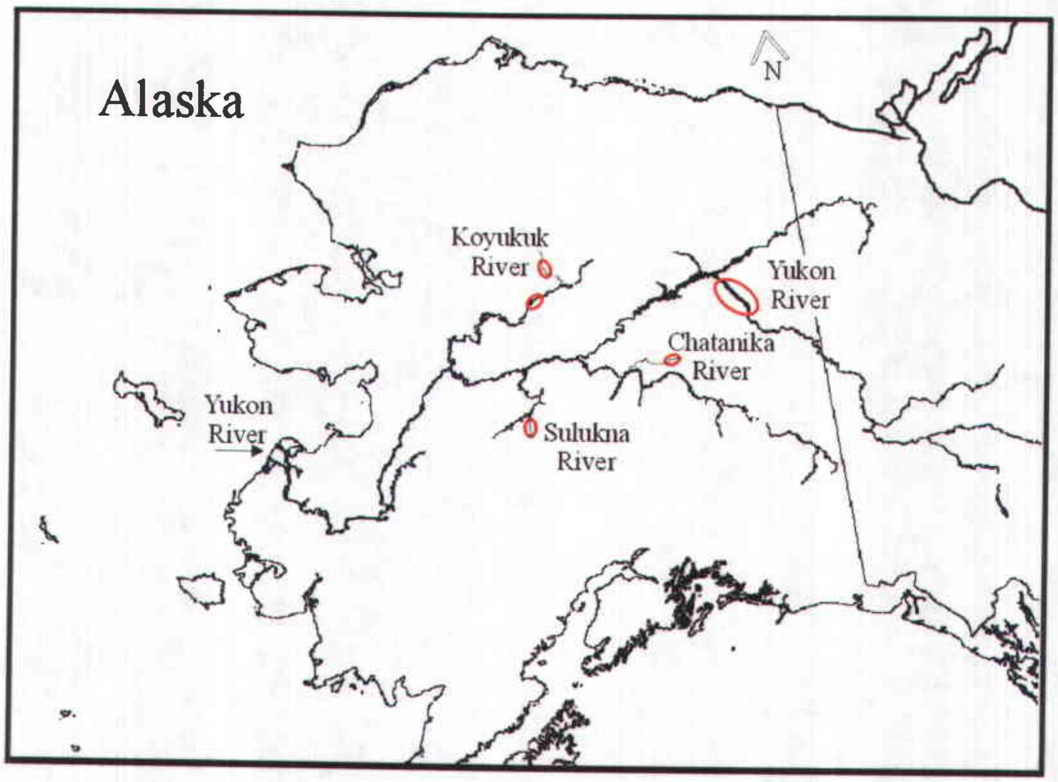

FIGURE 1.—The Yukon River drainage in Alaska. Red elipses mark known spawning areas for Yukon River inconnu.

Alt (1973, 1974, 1975, 1985) conducted several fisheries surveys in the Nowitna River during the 1970s and 1980s. Inconnu were observed during all surveys in the lower reaches of the river, which Alt (1985) described as being wide, slow, and meandering.

Inconnu tagged in the lower Nowitna River were recaptured as far away as the Chatanika River (Alt 1974), the mainstem Yukon River upstream from the Tanana River mouth, and in the Yukon River downstream from the Nowitna River (Alt 1975). On two September surveys he observed inconnu in or near the Sulukna River, an upper-drainage tributary of the Nowitna River (Figure 2), and judged them to be pre-spawning fish (Alt 1974, 1985). He proposed that they were preparing to spawn in the Sulukna River but acknowledged that he did not know specifically where. A radio telemetry study in the upper Nowitna River during fall 2003, conducted jointly by Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (USF&WS), Alaska Department of Fish and Game (ADF&G), and Tanana Chiefs Conference (TCC), confirmed that inconnu were spawning in the Sulukna River and determined that fish were spawning between 30 and 75 km upstream from its mouth (C. Kretsinger, BLM, unpublished data). Alt (1985) was convinced that inconnu spawning in the Nowitna River were members of a resident population that didn't stray far from the drainage. However, using otolith microchemical techniques, which have been shown by Howland (1997) and Brown (2000) to effectively identify anadromous individuals, it was discovered that some inconnu from the Sulukna River spawning population had been to sea (R. Brown, USF&WS, unpublished data). It seems reasonable to expect that some of the inconnu feeding in the lower Nowitna River are from the Sulukna River spawning population. It is also likely, given the tag relocation data described earlier (Alt 1974, 1975), that individuals from other spawning populations may be present there as well.

This study proposes to use radio telemetry to improve our understanding of the stocks present and vulnerable to fisheries each summer in the lower Nowitna River, and of their migrations and habitat associations. Long-duration radio transmitters will be implanted into 30 mature inconnu during June 2005. An additional 30 transmitters may be deployed in 2006 to increase the sample size if the work in 2005 is successful. Radio-tagged fish will be relocated at their spawning locations in late September and October, at their overwintering sites in January and February, and in their feeding habitats during May and June, for 3.5 years. Fidelity to spawning, overwintering, and feeding habitats will be evaluated based on the similarity of seasonal locations during the 3.5 year lifespan of the transmitters. Spawning frequency will be determined based on repeat locations obtained in spawning habitat for each fish.

Procedures: In June 2005, radio transmitters will be surgically implanted into 30 mature inconnu following the basic methods detailed in Brown et al. (2002) and Morris (2003). Based on length distributions from the Yukon and Sulukna rivers spawning populations (Brown 2000; C. Kretsinger, BLM, unpublished data), inconnu with fork lengths (FL) $\geq$70 cm will be judged to be mature, even though some females may still be immature at the minimum length (Figure 3). Transmitters are expected to be deployed on both spawners and nonspawners because early summer fish preparing to spawn are indistinguishable from those that are not. Inconnu are thought to spawn every two or three years once they become mature (Reist and Bond 1988), so the ratio of spawners to nonspawners may be on the order of 1:1 or 1:2 if the two groups mix proportionally in the lower Nowitna River. As such we might expect that 10 to 15 tagged fish could be present in spawning habitat during the first fall spawning season, and the others would be expected in spawning habitats in subsequent spawning seasons. If spawning frequency is every other year, then all tagged fish should be found on spawning habitats at least twice. If spawning frequency is every third year, then only those present on spawning habitats the first fall should be found again on spawning habitat during the fourth and final spawning season. All tagged fish should provide overwintering location data and feeding habitat data throughout the 3.5 years of tag operation.

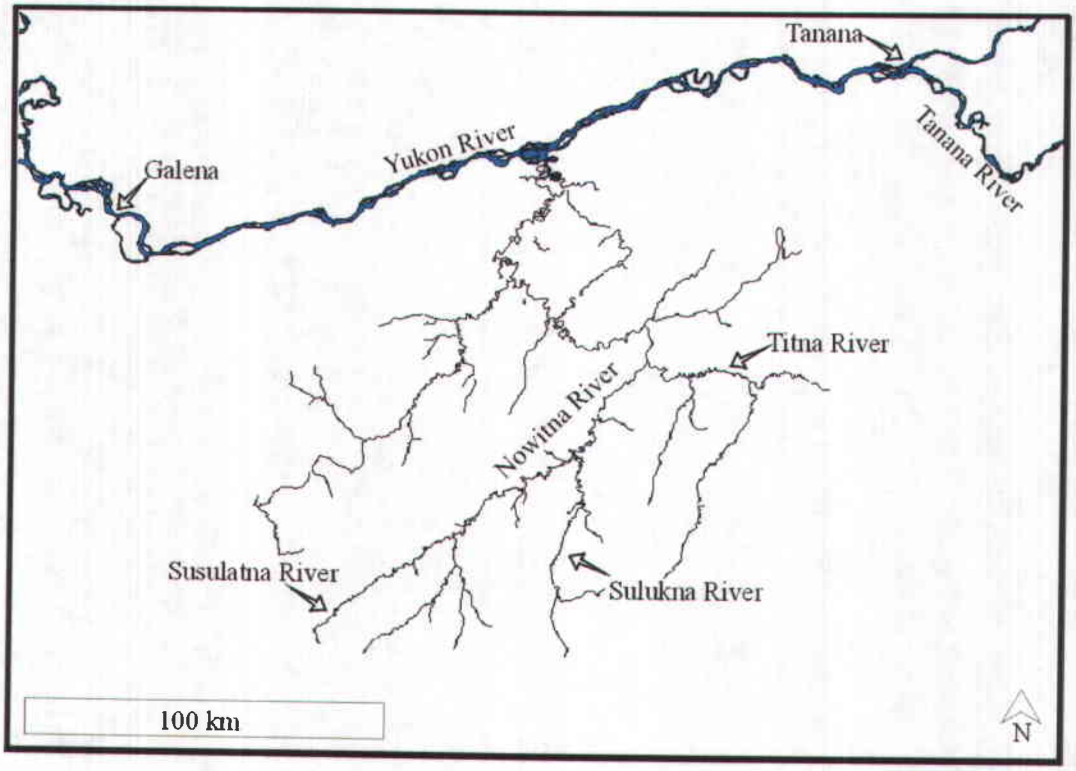

FIGURE 2.—The Nowitna River flows into the Yukon River from the south approximately 985 river km from the sea. An inconnu spawning area was located in the Sulukna River, a tributary of the Nowitna River.

Highly migratory fish are distinctly challenging subjects for radio-tagging projects. As a tagged fish moves farther and farther from the tagging location, the search area required to find the fish becomes exponentially larger. Therefore, the scope of the aerial surveys must be defined. Spawning surveys will begin in the upper Nowitna River drainage with searches of the Sulukna River, where we know spawning occurs, and continue to the Titna and Susulatna rivers, and the Nowitna River mainstem, where spawning may occur but has not been documented. The lower Nowitna River will be surveyed next to identify nonspawning fish that have remained there. If all radio-tagged fish are accounted for in these two surveys, no other flights will be needed during the first spawning season survey. If some radio-tagged fish are unaccounted for in the Nowitna River spawning season surveys, the Chatanika River (Alt 1969) and the Yukon Flats (Brown 2000) spawning areas will be surveyed. If some radio-tagged fish are still unaccounted for, the spawning areas in the upper Koyukuk River drainage (Alt 1969) will then be surveyed. These are all the known spawning areas in the Yukon River drainage, and it is thought that if radio-tagged fish from the Nowitna River are spawning on a particular year, they will be in one of these locations. Spawning surveys on subsequent years will follow a similar process of elimination.

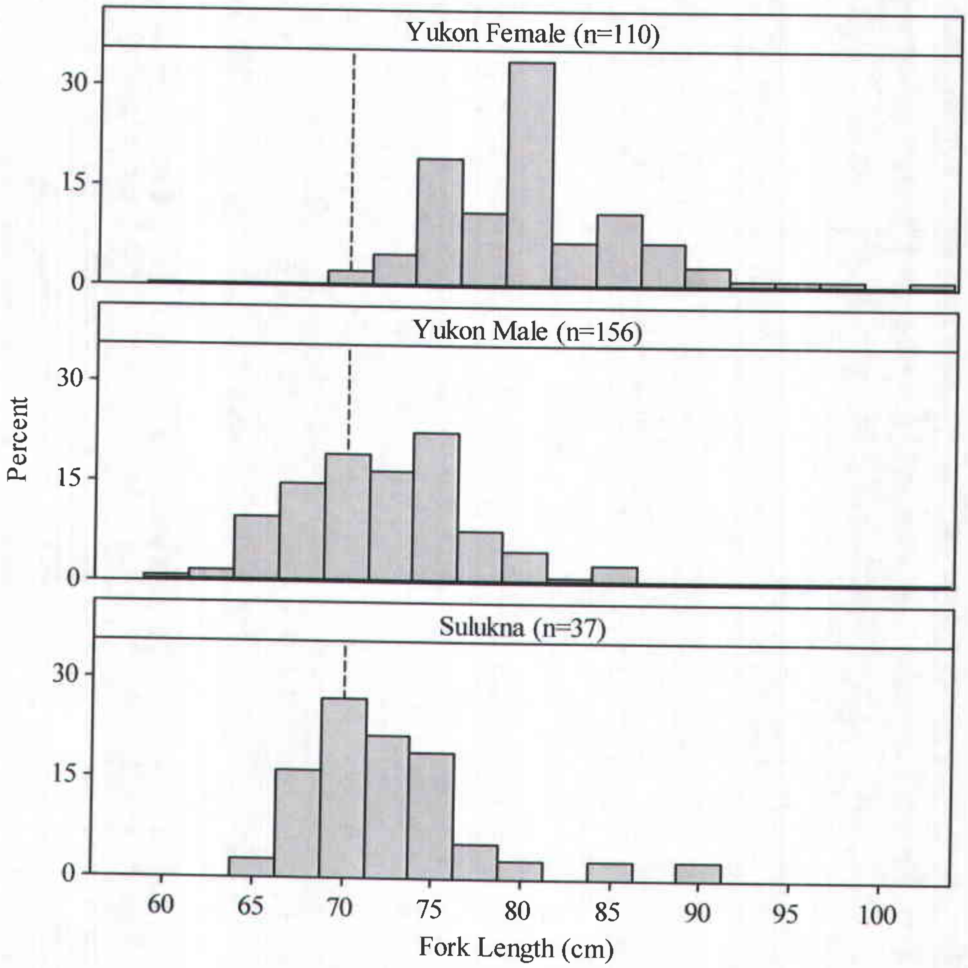

FIGURE 3.—Length frequency histograms of mature female and male inconnu from the Yukon Flats spawning population, and from mature individuals from the Sulukna River spawning population. The vertical dashed line is at FL = 70 cm.

Aerial surveys to locate overwintering and feeding habitats will be limited to the Nowitna River drainage and the Yukon River in the vicinity of the Nowitna River. The possibility of fish migrating to the mouth of the Yukon River or beyond for overwintering, and of migrating to other waterways in the Yukon drainage for feeding, prohibits surveys of all possible habitats. Essentially, we will either document that radio-tagged inconnu exhibit fidelity to the Nowitna River drainage for overwintering and feeding, or we will not.

Radio transmitters used in this study will operate on five frequencies compatible with transmitters being deployed in northern pike *Esox lucius* in the lower Nowitna River by ADF&G. There will be six digitally coded transmitters on each frequency. The radio tags weigh about 26 g in the air, and are 73 mm long and 16 mm in diameter. The transmitters will be programmed to operate for eight weeks during each of three seasons; spawning during September and October, overwintering during January and February, and feeding during May and June. During these periods they will transmit on a 12 hours on 12 hours off schedule. They will be dormant during other seasons of the year. They are expected to last for approximately 3.5 years with this operating schedule, providing the opportunity for locations during four feeding (tagging and three more) and spawning periods, and three overwintering periods for each fish.

Schedule:

Task	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
transmitter orders submitted, other field preparations	01/30/05		05/15/05			
transmitter deployment			06/15/05			
aerial surveys	02/01/06 02/01/07 02/01/08		06/10/06 06/10/07 06/10/08		09/25/05 09/25/06 09/25/07 09/25/08	
final report			05/31/09			

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Responsibility:

Brendan Scanlon and John Burr with the ADF&G will be in the lower Nowitna River in June 2005 implanting transmitters in northern pike. They have agreed to implant transmitters in inconnu they capture during their work. They will be conducting aerial surveys of the Nowitna River for their northern pike, and will collect and share location data for inconnu during these flights as well.

Randy J. Brown with the USF&WS will be directing aerial surveys to areas of the upper Nowitna River and other locations in the Yukon River drainage to locate radio-tagged inconnu that may have traveled far from the tagging area. Northern pike locations collected during non-ADF&G flights will be provided to the ADF&G researchers. The Koyukuk Nowitna National Wildlife Refuge has agreed to support up to two flights a year for the 3.5 years of the project, to spawning habitats in the upper Nowitna River drainage in late September, and to overwintering habitats in the lower Nowitna River and adjacent areas of the Yukon River in February. The Yukon Flats National Wildlife Refuge has agreed to support one flight a year to survey the inconnu spawning area in the upper Yukon Flats during early October. The Kanuti National Wildlife Refuge has agreed to support one flight a year to survey the inconnu spawning areas in the upper Koyukuk and Alatna rivers during late September or early October, if it is needed. The Fairbanks Fish and Wildlife Field Office is providing the transmitters and will be collecting and organizing the aerial survey data. Mr. Brown will be responsible for reporting on the inconnu project when it comes to conclusion. The estimated time of completion is May, 2009.

Carl Kretsinger with the BLM is particularly interested in inconnu use of the upper Nowitna River drainage, upstream from the National Wildlife Refuge boundary. He has agreed to support two aerial survey flights per year to locate spawning areas in the Nowitna River drainage.

This collaborative project is being conducted jointly by Randy J. Brown (USF&WS-FFWO), Brendan Scanlon (ADF&G, Fairbanks), John Burr (ADF&G, Fairbanks), and Carl Kretsinger (BLM-NFO). These agencies have different policies regarding operational plans and procedures, so this document serves as the organizing document for the project, identifying the roles and responsibilities accepted by the cooperators. It should be understood that the contributions of all the participants are critical to project success. The signatures below, however, pertain to the responsibility accepted by the USF&WS only. Primary responsibility for the USF&WS-Fairbanks FWO component of project operation and subsequent reporting lies with the principal investigator, Randy J. Brown.

Submitted by:______________________________ Date:________________________
Principal Investigator

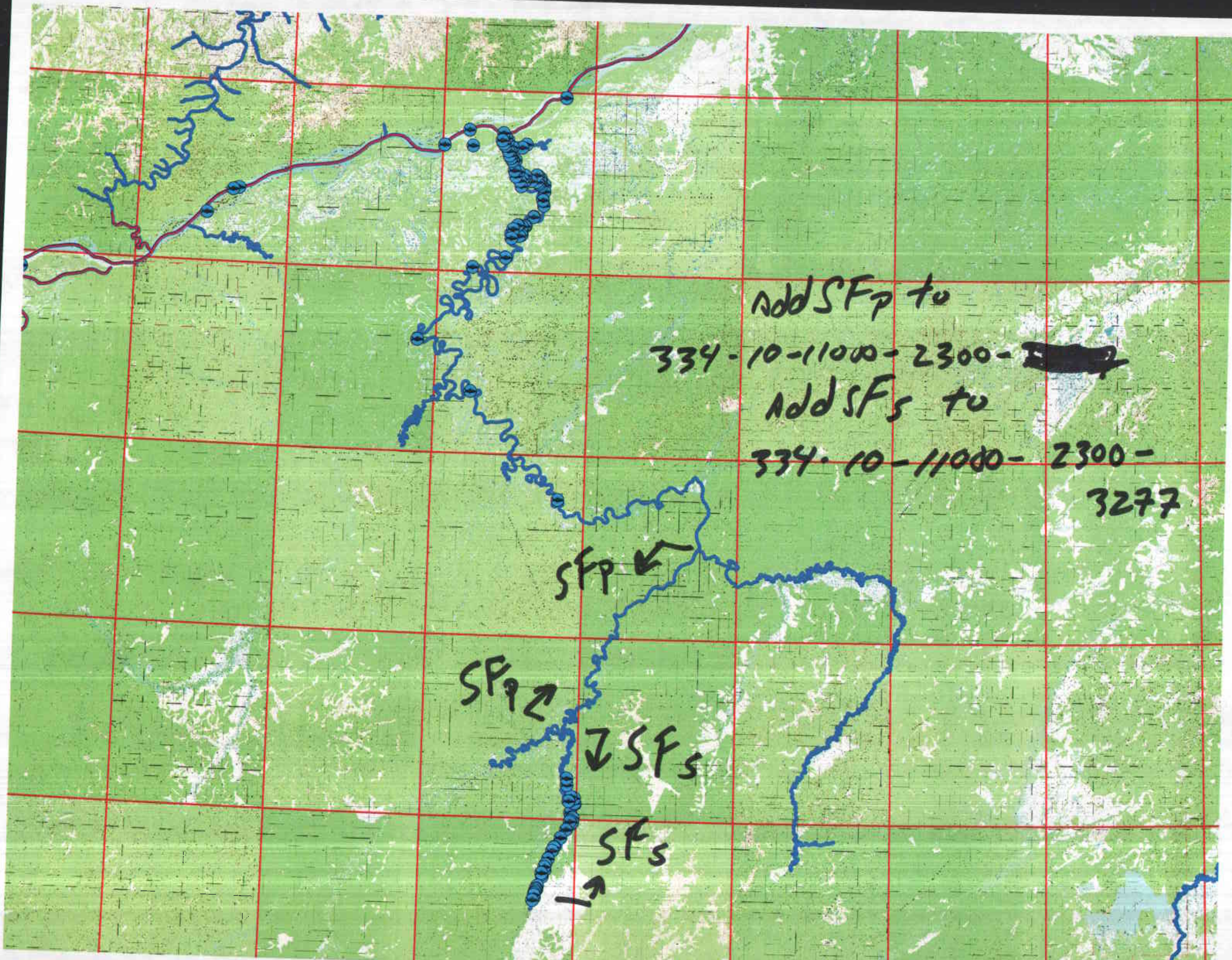
Approved by:______________________________ Date:________________________
Branch Chief

Approved by:______________________________ Date:________________________
Refuge Manager, Koyukuk Nowitna NWR

Approved by:______________________________ Date:________________________
Refuge Manager, Yukon Flats NWR

Approved by:______________________________ Date:________________________
Refuge Manager, Kanuti NWR

Reviewed by:______________________________ Date:________________________
Biometrician



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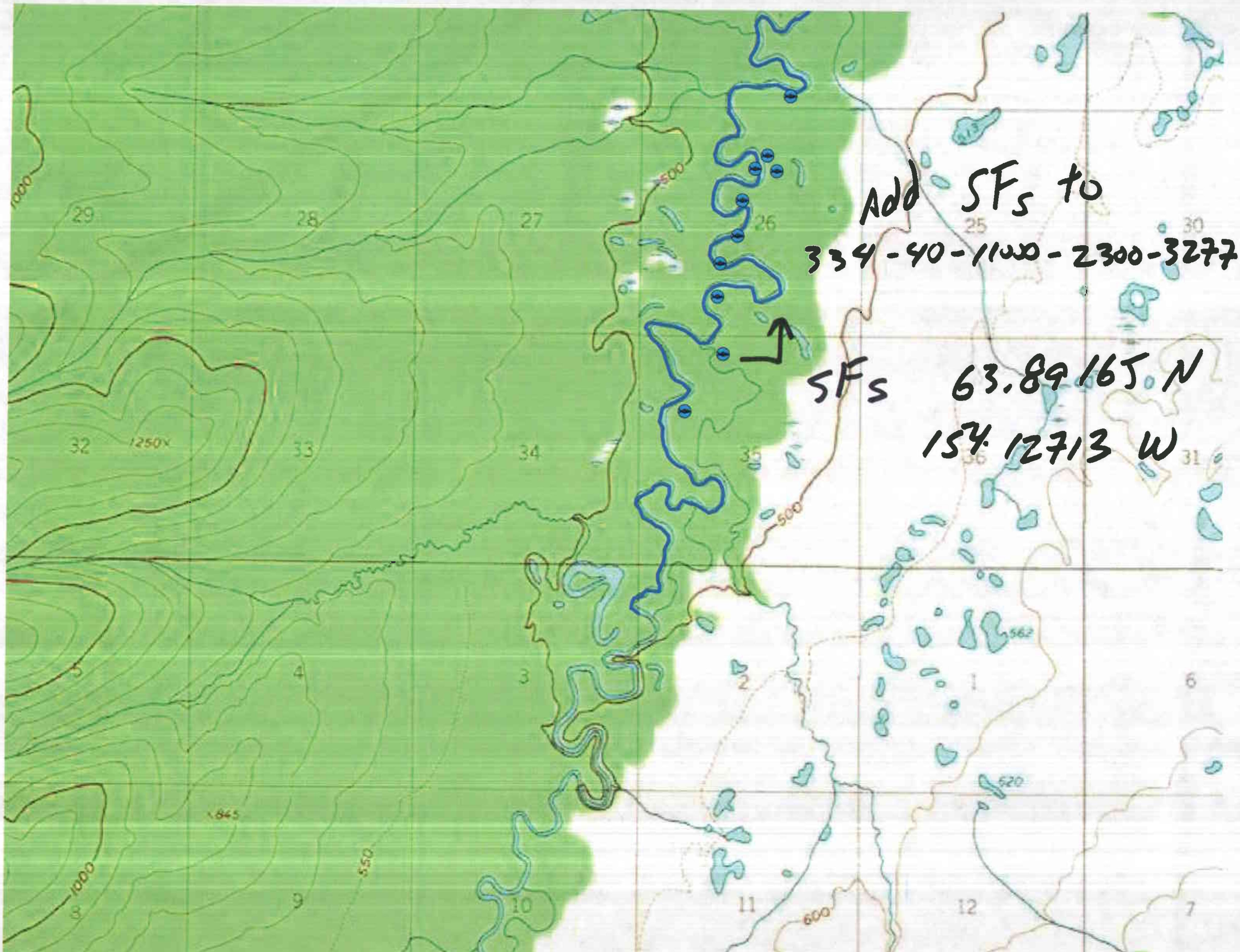
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