ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE:	Green Sturgeon Population Characteristics In Oregon
PROJECT NUMBER:	F-178-R
JOB NUMBER:	1
JOB TITLE:	Green Sturgeon Population Characteristics In Oregon
PROJECT PERIOD:	1 October 2001 – 30 September 2002

Prepared by: Ruth A. Farr
Thomas A. Rien

Oregon Department of Fish and Wildlife
17330 Southeast Evelyn Street
Clackamas, OR 97015

This project was financed in part with the Federal Aid in Sport Fish Restoration Act (Wallop-Breaux) funds through the U. S. Fish and Wildlife Service.

CONTENTS

PAGE

ABSTRACT i

INTRODUCTION 1

METHODS 1

Umpqua River 2002 Field Sampling 1

Other Activities 2

RESULTS 6

Umpqua River 2002 Field Sampling 6

Other Activities 6

DISCUSSION 6

Plans for Next Year 16

ACKNOWLEDGEMENTS 16

REFERENCES 19

APPENDIX A. Rogue River 2002 Sampling 21

APPENDIX B. A catch Index for Green Sturgeon Harvested in lower Columbia River Commercial Fisheries 30

APPENDIX C. Green Sturgeon Growth Rates Estimated from Recapture Data 40

ABSTRACT

During March through August 2002, we used gill nets to capture adult and sub-adult green sturgeon *Acipenser medirostris* and white sturgeon *Acipenser transmontanus* in the Umpqua River, Oregon. All fishing effort occurred between river kilometers 5.3 to 39.4 and 164.8 to 165.6. We set 139 static gill nets for an average 1.0 hour and captured 34 individual green sturgeon (94-192 cm fork length, FL) and 13 individual white sturgeon (113-163 cm FL). We deployed 10 drifted gill nets for an average 0.4 hours and captured 3 individual green sturgeon (147-170 cm FL). All unmarked sturgeons were tagged with spaghetti and passive integrated transponder (PIT) tags.

Field staff from Oregon Department of Fish and Wildlife's Gold Beach office sampled green sturgeon in the Rogue River. Ninety-six unmarked green sturgeon (133-204 cm FL) were captured in gill nets and beach seines. Ninety-four of the unmarked sturgeon were tagged with spaghetti tags and 77 were tagged with PIT tags. Of these, 23 were recaptured once and 3 were recaptured twice. Sixteen of these fish were radio tagged, sonic tagged, or both. In addition, four were satellite tagged for tracking by Wildlife Conservation Society staff. Four juvenile green sturgeon were captured during beach seine sampling.

Lower Columbia River green sturgeon catch rates in commercial fisheries appear to be either stable or increasing. We used regressions of log-transformed catch rates (LTCR) to describe trends in lower Columbia River catch rate using landing ticket data. Regressions of LTCR on year for the periods 1981-2000 and 1981-1993 had weak correlation coefficients, shallow positive slopes (increasing at less than 0.08 fish/landing ticket/year), and were significant. The regression of LTCR on year for the period 1994-2000 was not significant.

We were able to interpret ages of 24 green sturgeon from pectoral fin-spine sections and therefore estimated parameters of von Bertalanffy growth functions (VBGF) using these and previously collected data. We examined Columbia River recapture data for 78 green sturgeon (90-157 cm fork length) at large 365-1,492 d to describe growth. The average growth rate for all recaptured fish was 3.94 cm/year. Linear regression of growth on years at large described: Growth (cm FL) = 3.43 * (years at large). Regression of annual growth increment (AGI) on median fork length while at large (FL) described: AGI = 18.93 - 0.12 * FL. We were able to estimate alternative parameters of a VBGF based on these analyses.

INTRODUCTION

Relatively little is known about the biology and life history of green sturgeon *Acipenser medirostris* and there is widespread concern and uncertainty regarding its status. Green sturgeon are classified as a species of special concern by the U.S. Fish and Wildlife Service and California Department of Fish and Game. As "rare" in Canada, but have no special status in Washington or Oregon. In June 2001, green sturgeon were petitioned for listing under the Endangered Species Act (EPIC 2001), and in December 2001, the National Marine Fisheries Service initiated a status review to determine if action is warranted (Federal Register 2001).

The harvest of green sturgeon in Oregon has been managed without the benefit of a comprehensive statewide investigation of population status. Most green sturgeon harvest occurs in the lower Columbia River, Oregon and Washington, and in Willapa Bay and Gray's Harbor, Washington.

In 1999, the Oregon Department of Fish and Wildlife (ODFW) initiated a multi-year project to increase the understanding of green sturgeon population characteristics, distribution, and status in Oregon. The specific objectives of the project are to:

1. Summarize and analyze existing information on green sturgeon.

2. Describe characteristics of adult populations in the Columbia, Umpqua, and Rogue rivers.

3. Describe spawning and recruitment in the Umpqua and Rogue rivers.

This report documents current progress toward these objectives**.** Emphasis is placed upon field activities performed on the Umpqua River during spring and summer 2002**.**

METHODS

Umpqua River 2002 Field Sampling

The Umpqua River Basin is located in Douglas County in southwestern Oregon and stretches from the Cascade Mountain crest to the Pacific Ocean at Reedsport, Oregon (Figure 1). The North and South Umpqua rivers and their tributaries combine to form the main stem Umpqua River about 11 kilometers (km) northwest of Roseburg, Oregon. The drainages of the North and South Umpqua rivers together make up about two-thirds of the greater basin drainage, and each river is about 170 km long. The main stem Umpqua River flows in a northwesterly direction another 180 km to the ocean. Together, the three rivers form one of the longest coastal basins in Oregon, approximately 340 km in length; with a drainage area of over 12,200 km^2. Major tributaries of the main stem Umpqua River include the Calapooya River (river kilometer [rkm] 164), Elk River (rkm 78), Scholfield Creek (rkm 18), and the Smith River (rkm 18). The estuary of the Umpqua River is one of largest on the Oregon coast and has a large seawater wedge that extends inland to Scottsburg, Oregon at rkm 45 (Johnson et al. 1994). Most field sampling for green sturgeon and white sturgeon *Acipenser transmontanus* was conducted from April through August 2002 in the lower 60 km of the Umpqua River from below Reedsport to

Mill Creek (Figure 2). We also sampled one day near km 164 at the mouth of the Calapooya River.

Large-Mesh Experimental Gill nets

From April through August 2002, we sampled one week per month to deploy 139 static gill nets between rkm 5.3 and 165.6 and 10 drifted gill nets between rkm 15.1 and 15.9 (Table 1; Figure 2). Static nets were fished an average of 1.0 h/set and drifted nets an average of 0.4 h/set during daylight hours. All nets were 3.0-m deep and 61.0-m long. Nets were constructed of 23.5-cm stretched-measure multi-strand monofilament. Static nets were fished in suitable areas of deep, slow moving water or at slack tide for up to 1.6 h. Drifted nets were fished on the running tide for up to 0.7 h.

Fish Processing

We measured fork length (FL) and total length to the nearest 1 cm, and examined all fish for tags and marks. All sturgeon were tagged with both a passive integrated transponder (PIT) tag and an external spaghetti tag. The second left lateral scute was removed to indicate the fish was implanted with a PIT tag (Rien et al. 1994) and the tenth right lateral scute was removed to indicate that the fish was handled in 2002. Tissue samples were taken from the pectoral fins and stored in ethyl alcohol for subsequent genetic analyses. A pectoral fin-spine section was collected from one fish for age analysis. Unlike white sturgeon, green sturgeon are prone to prolonged bleeding when fin spines are removed so not every fish was sampled.

Other Activities

Two experienced readers estimated ages for green sturgeon collected from the Rogue River, Umpqua River and Oregon coastal estuaries during 2001-02. Using techniques developed for white sturgeon (Rien and Beamesderfer 1994; Brennan and Cailliet 1989), we counted annular rings in pectoral-fin spine sections. These data were added to older data sets aged by various agencies and ODFW (Farr et al. 2001).

We used nonlinear regression (SAS Institute 1988 a and b) to derive von Bertalanffy equations ($L_t = L_\infty \, (1-e^{-k\,(t\,-\,t_0)})$) to described FL at age for green sturgeon. We standardized t_0 (the theoretical age at length 0) to the value estimated for all fish combined.

We plotted set times and catch against the tide table for sets done near the tide gauge to assess differences in catch by tide stage.

We analyzed historical data from an Umpqua River commercial landings report by plotting a simple regression of green sturgeon commercial landing data by year 1928-1946.

Green sturgeon were captured and tagged by field staff in ODFW's Rogue Watershed District and Wildlife Conservation Society (Appendix A). We conducted an analysis of commercial catch rate in the lower Columbia River based on landing tickets and green sturgeon harvest (Appendix B). We used recapture data from Lower Columbia River tagging studies (1985-1999) to estimate growth rate (Appendix C).

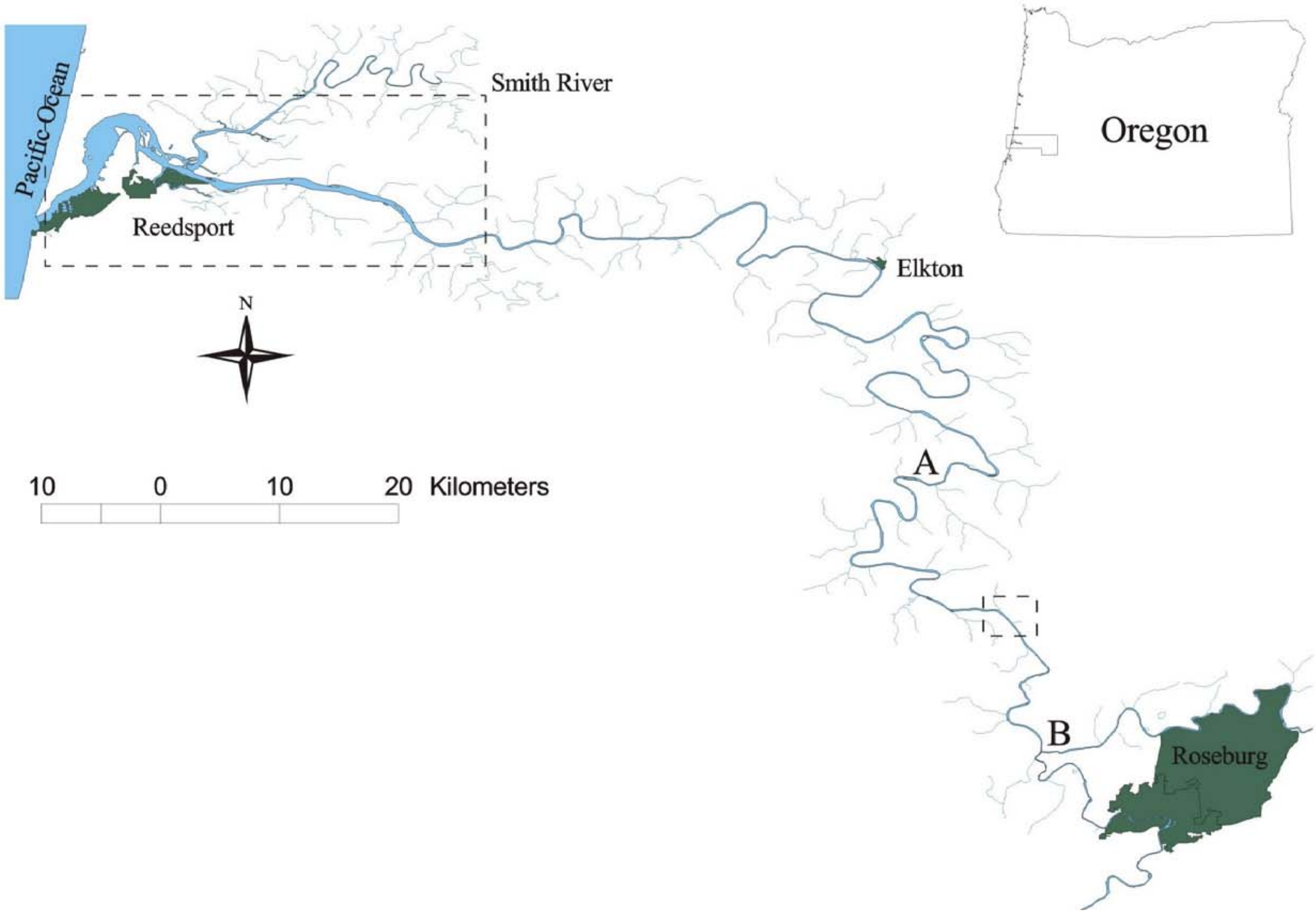


Figure 1. Umpqua River Basin, Oregon. Sample areas bounded by dashed lines. Location of juvenile green sturgeon recovery (A). Location of angler-caught adult green sturgeon (B).

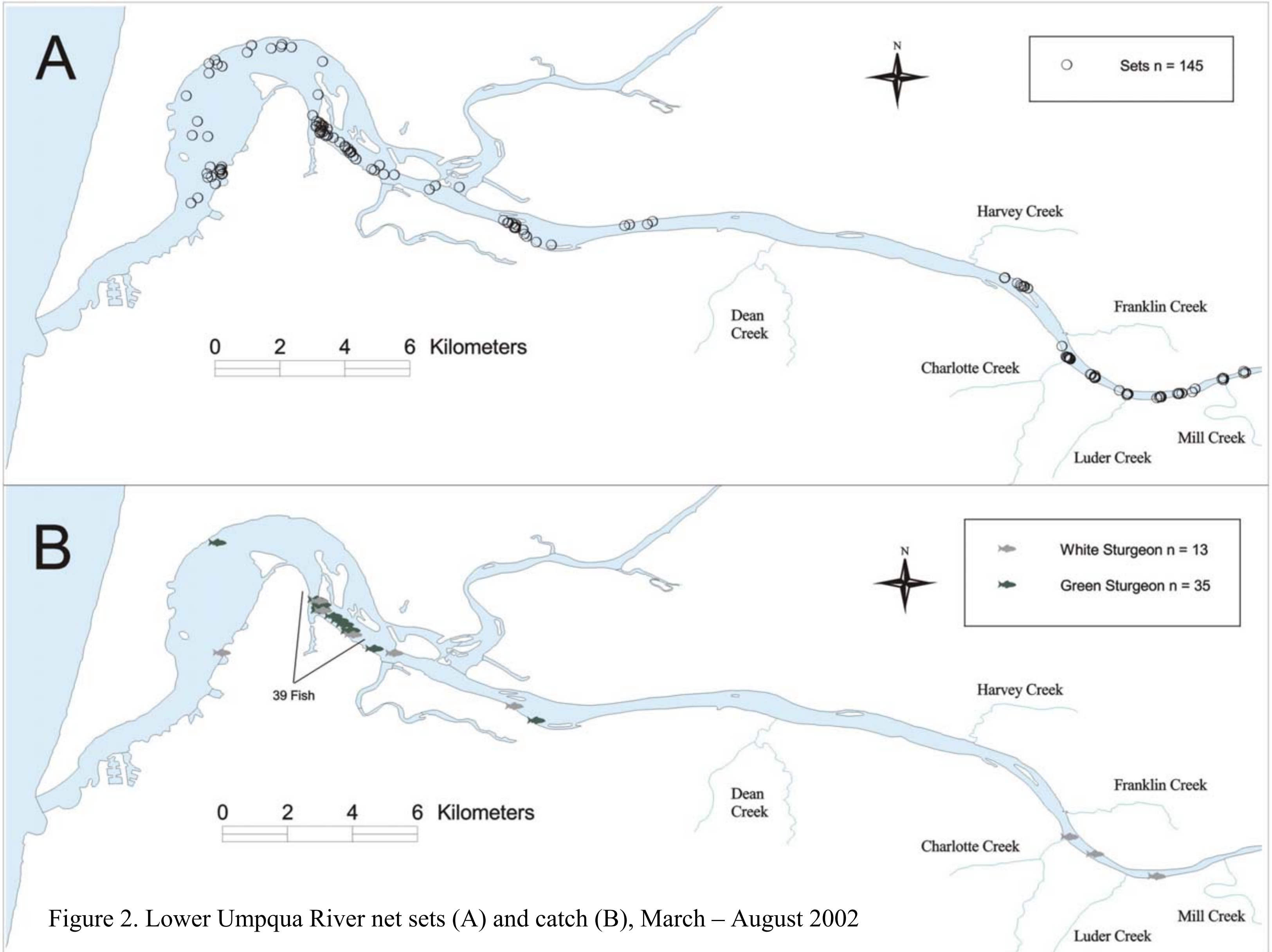


Figure 2. Lower Umpqua River net sets (A) and catch (B), March – August 2002

Table 1. Effort (sets) and catch for all gears by week, Umpqua River, Oregon, 2002. To clarify trends, catch columns are not zero-filled.

	Static Gill Net Catch			Drifted Gill Net Catch			
Day/Week	# of Sets	Green Sturgeon	White Sturgeon	# of Sets	Green Sturgeon	White Sturgeon	Incidental Catch
15-Apr	3			0			
16-Apr	7	1					
17-Apr	8						
18-Apr	8						
Week 1 Total	26	1	0	0	0	0	0
13-May	2						
14-May	10						
15-May	8						2 [a] / 2 [b]
16-May	7		4				
17-May	5						
Week 2 Total	32	0	4	0	0	0	4
10-Jun	3	6					1 [a]
11-Jun	10	1	2				
12-Jun	10	1	2				
13-Jun	10						
14-Jun	5						
Week 3 Total	38	8	4	0	0	0	1
15-Jul	2						
16-Jul	7	5		3	2		
17-Jul	12	10	2	4			
18-Jul	8						
Week 4 Total	22	15	2	7	2	0	0
12-Aug	3			3	1		
13-Aug	10		1				
14-Aug	7	8	2				2 [a]
15-Aug	4						
Week 5 Total	21	8	3	3	1	0	2
Totals	139	32	13	10	3	0	7

[a] Adult chinook salmon

[b] Juvenile harbor seal

RESULTS

Umpqua River 2002 Field Sampling

Thirty-three unmarked green sturgeon (113-192 cm FL) were captured between rkm 9.8 and 20.9 (Tables 2 and 3; Figure 2), one of which was recaptured. In addition, we recaptured one green sturgeon (94 cm FL) that had been tagged in February 2002 during yearly coastal estuary sampling conducted by ODFW (Whistler et al. 1999). It was at large two months, was recaptured in the same place it had been originally tagged, and had not grown.

Thirteen unmarked white sturgeon (113–163 cm FL) were captured from rkm 5.9 and 37.2 (Tables 2 and 3; Figure 2), none were recaptured. In addition, we recaptured one white sturgeon (147 cm FL) that had been tagged in March 1998 during coastal estuary sampling (Whistler et al. 1999). It was at large 51 months, was recaptured 13 km upriver of where it was tagged and had grown 59 cm. Eight DNA samples were collected from white sturgeon

During sampling we caught five adult chinook salmon (three dead and two released alive). We also caught 2 juvenile harbor seals (one dead, one released alive).

Other Activities

We assigned ages to 24 green sturgeon (33-168 cm FL; Tables 4-6). Growth curves were generated for male, female, and all fish aged. In addition, a growth curve was generated for fish aged by ODFW since 2000 (Figure 3). All green sturgeon DNA samples collected are shared with genetics programs at University of California, Davis, and at the U. S. Fish and Wildlife Service laboratory in Ashland, Oregon (Table 7).

Catch rates did not appear to be affected by the timing of the sets in a tide sequence or the amount of exchange (Figure 4).

Historic commercial landings of green sturgeon in the Umpqua River from 1928-1946 showed a decline in landings (Figure 5).

DISCUSSION

This year's field sampling was directed at identifying areas of the Umpqua River that contain adult and sub-adult green sturgeon. Generally we found most green sturgeon from Reedsport (km 11) downstream while white sturgeon were found throughout the sampling area. We did not consistently catch green sturgeon until June, which coincides with local angler observations that green sturgeon moved into the river later this year than past observations. This may be because 2002 was a low water year (Figure 6).

We were able to interpret ages of 24 green sturgeon from pectoral fin-spine sections. We urge caution in applying these results because of uncertainty with ageing techniques (Farr et al. 2001). Because of rapid growth in juveniles and a very small sample size for age-0 fish, the t_0 value appears unreasonably small. A search of green sturgeon and other North American sturgeon species showed our value was within the range of other published values of –3.450 to 0.972 (DeVore et al. 2000; Morrow et al. 1998). We believe more age-0 samples would change this value.

Table 2. Effort (hours) and catch by sampling week for gill nets used to capture green and white sturgeon, Umpqua River, Oregon, 2002.

Gear		Effort		Catch	
Week	Sets	Hours	STD	Green Sturgeon	White Sturgeon
Drifted Gill Nets					
4	7	2.82	0.19	2	0
5	3	1.25	0.07	1	0
	10	4.07	0.16	3	0
Static Gill Nets					
1	26	25.28	0.11	1	0
2	32	32.22	0.03	0	4
3	38	38.50	0.11	8	4
4	22	22.63	0.07	15	2
5	21	20.50	0.10	8	3
	139	139.13	0.09	32	13

Table 3. Catch of green sturgeon per unit effort for all gears by river kilometer, Umpqua River, Oregon, 2002. A dash (--) indicates no fishing effort

	River Kilometer Section				
Gear Week	0.0 - 9.9	10.0 - 19.9	20.0 - 29.9	30.0 - 39.9	102.0 - 102.9
Static Gill Net					
1	0.11	0.00	0.00	0.00	--
2	0.00	0.00	0.00	0.00	--
3	0.00	0.78	0.10	0.00	--
4	0.00	1.50	0.00	0.00	--
5	--	1.14	--	0.00	0.00
	0.05	0.71	0.06	0.00	0.00
Drifted Gill Net					
4	--	0.29	--	--	--
5	--	0.33	--	--	--
		0.30			

Table 4. Age frequency distribution for green sturgeon <220-cm FL collected from Puget Sound, Columbia River, Yaquina Bay, Winchester Bay, Coos Bay, and Rogue River, 1949–2002. To clarify trends, this table is not zero-filled.

	Fork length interval (cm)													
Age	0-19	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	Mean length	STD	N
0	2	2										24.6	10.0	4
1														0
2		1										36.0		1
3				3	1							72.8	10.0	4
4				6	2							76.4	6.7	8
5				1	4							80.0	10.1	5
6				1	4							86.2	6.3	5
7				3	8	6						94.3	14.5	17
8				1	5	8	1					104.5	15.2	15
9						9	3					116.5	6.4	12
10					2	8	6					113.6	11.2	16
11					1	9	10					118.7	9.0	20
12						8	7					119.7	8.4	15
13						7	5	4				127.1	13.1	16
14					1	3	6	3				127.0	14.3	13
15						3	6	2				129.8	15.1	11
16						8	5	2	2			128.8	18.0	17
17						1	3	5	1			140.6	15.7	10
18						3	3	4	1			131.6	16.2	11
19							2	11	1			146.9	8.2	14
20							1	5	2			150.5	11.7	8
21							2	6	2	1		151.7	17.3	11
22								6	3	1		154.0	13.6	10
23							1	1	1			150.3	11.2	3
24								4	3			155.7	7.4	7
25							1	7	6			155.6	12.8	14
26									4	1		168.0	9.0	5
27								3	1			150.8	7.5	4
28								3	2	1		164.7	12.6	6
29							1	3	1			148.8	11.2	5
30								1				141.0		1
>30								4	9	5	1	171.3	16.3	19
All ages	2	3	0	15	28	73	63	74	39	9	1	128.1	30.4	307

Table 5. Age frequency distribution for male green sturgeon <220-cm FL collected from Puget Sound, Columbia River, Yaquina Bay, Winchester Bay, Coos Bay, and Rogue River, 1949–2002. To clarify trends, this table is not zero-filled.

	Fork length interval (cm)													
Age	0-19	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	Mean length	STD	N
0														0
1														0
2														0
3														0
4														0
5														0
6														0
7														0
8					1	3	1					111.4	12.9	5
9							1					131.0		1
10						4	4					117.5	10.6	8
11					1	4	4					117.2	10.5	9
12						1	2					122.0	5.6	3
13						1	1	3				139.4	13.2	5
14							2	2				136.8	12.6	4
15							2	1				144.3	11.0	3
16							2	1				137.7	4.5	3
17						1	1	2	1			141.4	20.1	5
18							2	3				134.8	11.1	5
19								6	1			149.4	7.0	7
20								2	2			158.0	11.2	4
21								1				150.0		1
22									1			162.0		1
23														0
24								1	1			151.0	12.7	2
25							1	1	1			152.0	16.5	3
26														0
27								1	1			151.0	12.7	2
28								1				155.0		1
29														0
30								1				141.0		1
>30									1			165.0		1
All ages	0	0	0	0	2	14	23	26	9	0	0	135.6	18.3	74

Table 6. Age frequency distribution for female green sturgeon <220-cm FL collected from Puget Sound, Columbia River, Yaquina Bay, Winchester Bay, Coos Bay, and Rogue River, 1949–2002. To clarify trends, this table is not zero-filled.

	Fork length interval (cm)													
Age	0-19	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	Mean length	STD	N
0														0
1														0
2														0
3														0
4														0
5														0
6														0
7						3						110.7	4.6	3
8						5						114.2	2.9	5
9						8	2					115.8	4.4	10
10					1	1	1					110.3	16.0	3
11							6					126.0	3.8	6
12							1					133.0		1
13							2	1				132.7	8.0	3
14							1					139.0		1
15							2	1				135.0	14.4	3
16						1			2			149.7	33.9	3
17								2				149.0	7.1	2
18									1			164.0		1
19								1				147.0		1
20														0
21								1	2			163.3	8.7	3
22									2			165.0	0.0	2
23														0
24								1				159.0		1
25									3			169.0	8.0	3
26									2			164.5	0.7	2
27								1				149.0		1
28									1			166.0		1
29									1			166.0		1
30														0
>30									2		1	178.0	20.9	3
All ages	0	0	0	0	1	18	15	8	16	0	1	137.5	24.3	59

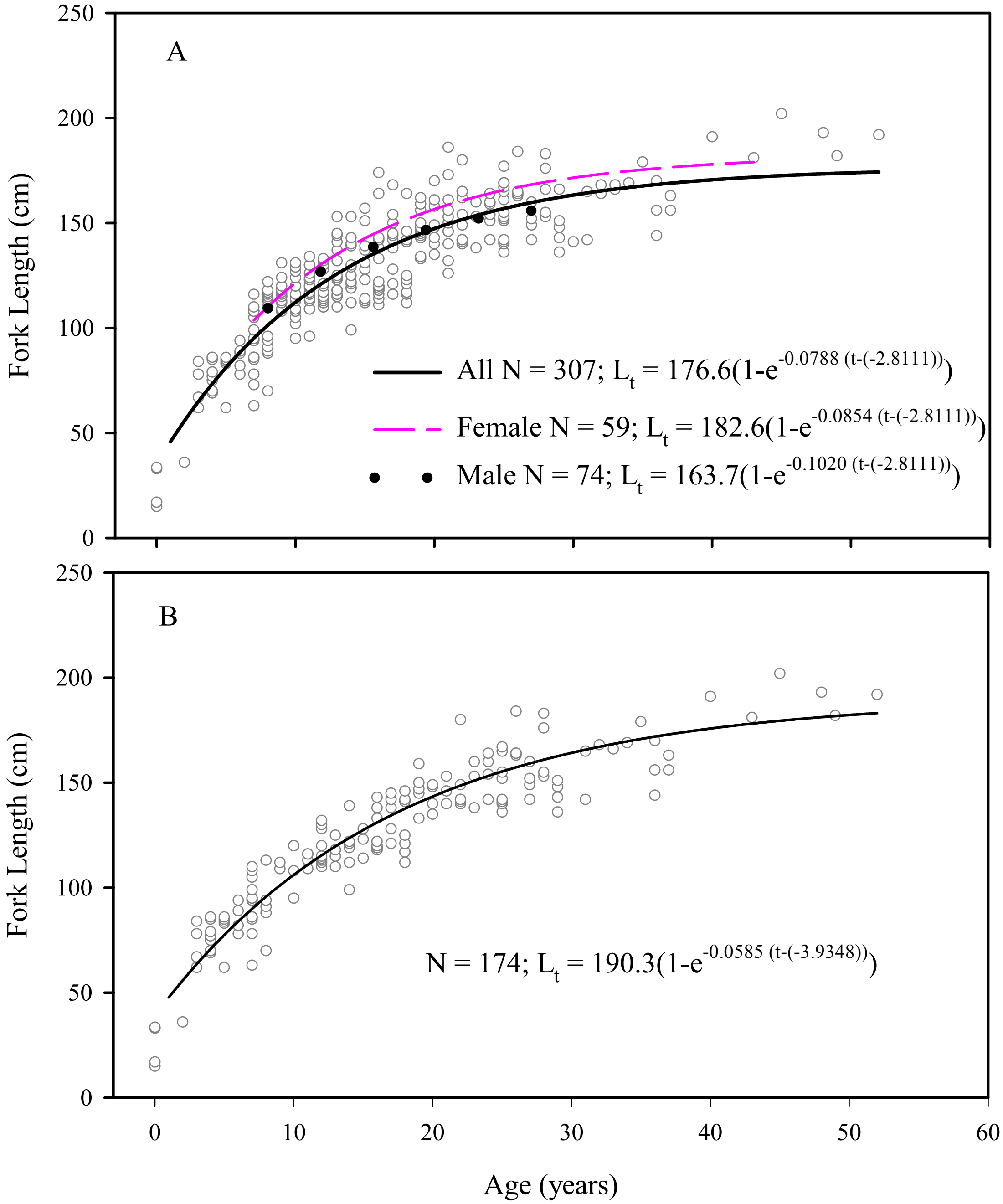


Figure 3. Von Bertalanffy growth curves for green sturgeon. (A) All aged fish (B) fish aged by ODFW. t = age (years); where L_t = FL (cm) at age t.

Table 7. Sumary of green sturgeon tissue samples collected by ODFW staff for genetic assay, 2000 - 2002.

Year	Green Sturgeon		Intermediate[a]
Location	Adult and Sub-adult	Juvenile	Adult
2000			
Coos Bay, OR	1		
Pacific Ocean off Newport, OR	4		
Rogue River, OR	66	10	
Tillamook Bay, OR	6		
Umpqua River, OR	106		
Yaquina Bay, OR	11		
2001			
Rogue River, OR	49	5	
Coos Bay, OR	8		
Lower Columbia River, OR	160		
Umpqua River, OR	20		
Yaquina Bay, OR	5		1
2002			
Rogue River, OR	76		
Coos Bay, OR	2		
Umpqua River, OR	57		
Yaquina Bay, OR	8		
Sum	579	15	1
Minimum Total Length (mm)	380	135	1,060
Maximum Total Length (mm)	2,250	335	1,060

[a.] This fish (most likely a green sturgeon) had morphological and meristic characteristics intermediate between white and green sturgeon.

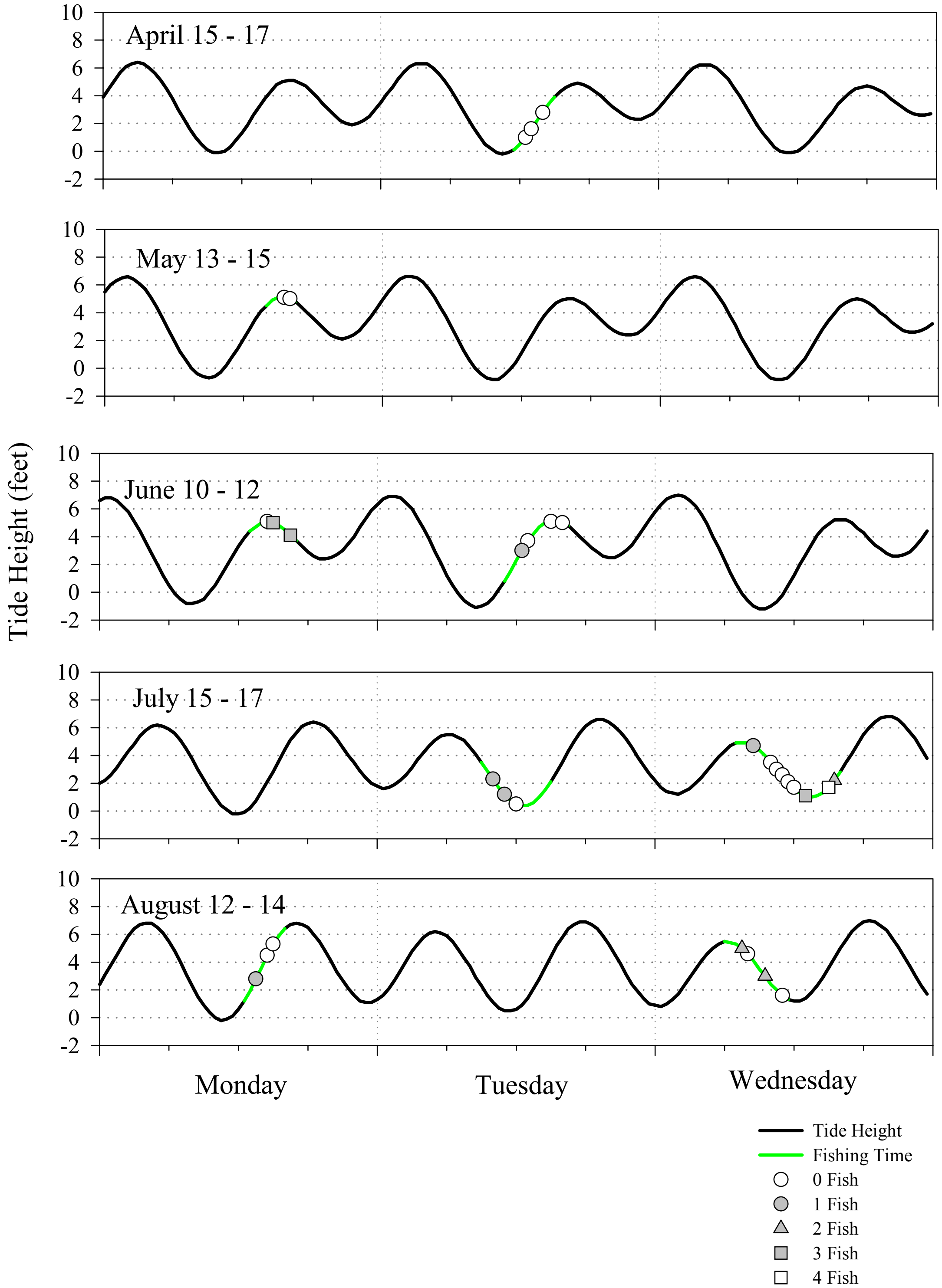


Figure 4. Tides and catches of green sturgeon on the Umpqua River, Oregon near river kilometer 14.5 for April through August 2002. Includes drifted and static net sets.

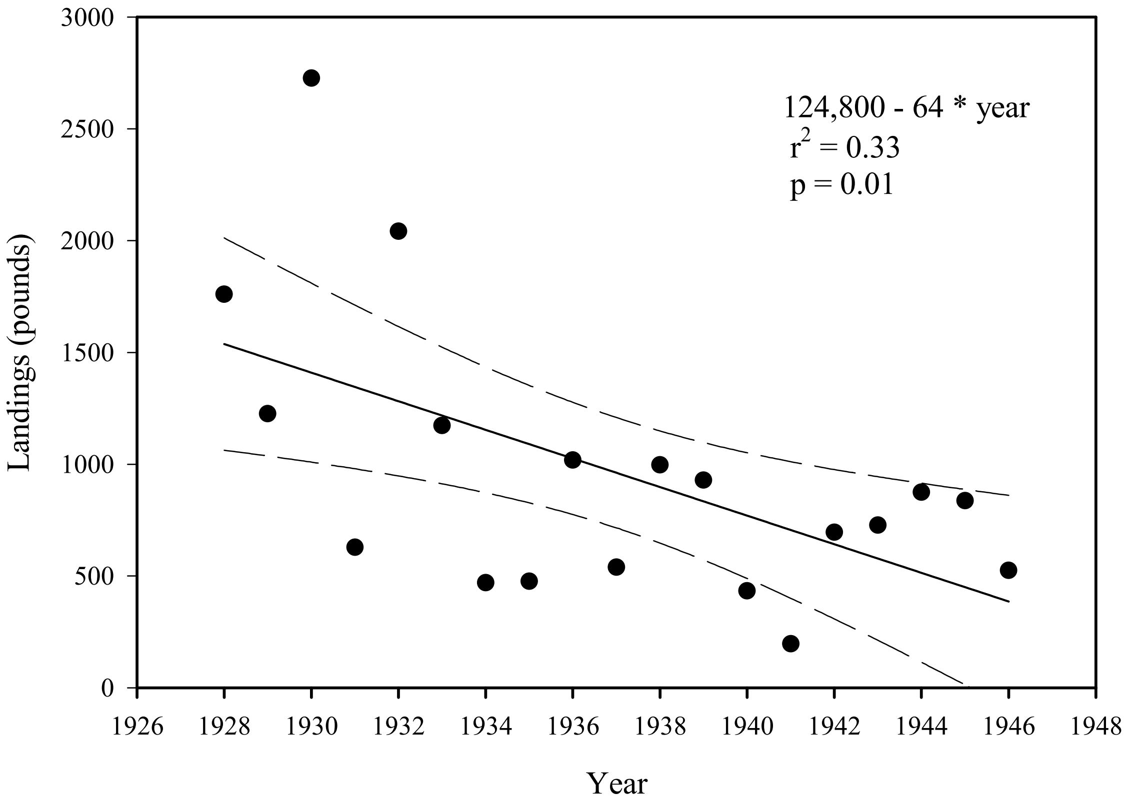
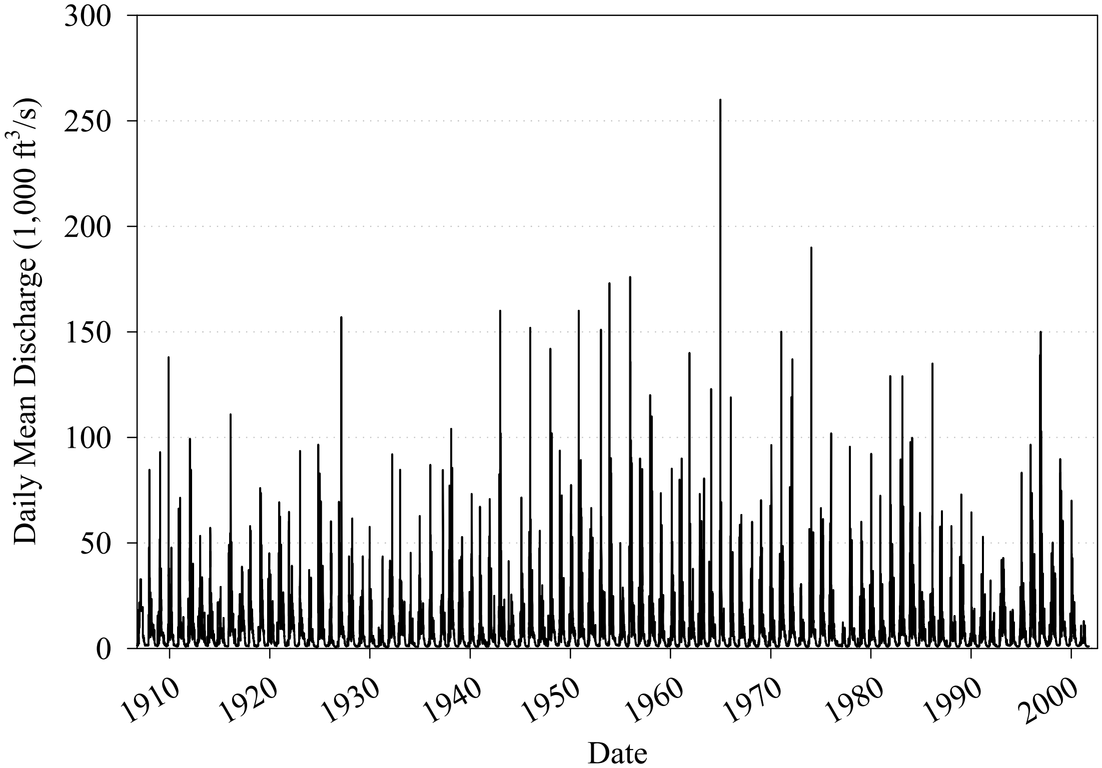


Figure 5. Trend in green sturgeon commercial landings from the Umpqua River, Oregon, 1928-1946.

We attempted to obtain historical data that had documented green sturgeon as incidental catch. We found commercial landings for the Umpqua River from 1928-1946 that ranged from 7-104 fish (converted from pounds landed divided by 26.3; FCOO and OSGM. 1946; Figure 5). It is noted in the text that landings appeared to be declining. We have no data to compare effort with the landings.

We were not able to find any reference to sturgeon in reports of American shad, *Alosa sapidissima,* and striped bass, *Morone saxatilis*, studies, which were common on the south coast. We did find incidental mention of green sturgeon in notes from commercial American shad fisheries in 1977. In Coos Bay, during spring gillnet sampling, incidental green sturgeon catches were recorded for a period of 13 years (Table 8). Many of these fish were probably younger than 3 years old based on their size (Table 4). This may indicate some spawning in the Coos Bay system or at least the importance of the bay for juvenile rearing habitat. We found a newspaper clipping from the News Review, Roseburg, Oregon dated 3 May, 1979 that has a story and picture of a 178-cm green sturgeon that was caught at River Forks Park (km 164), Umpqua River (Figure 1). We have a sample of a juvenile green sturgeon (approximately 10 cm) regurgitated from a smallmouth bass, *Micropterus dolomieu,* caught 30 July, 2000 at km 134, Umpqua River (Figure 1).



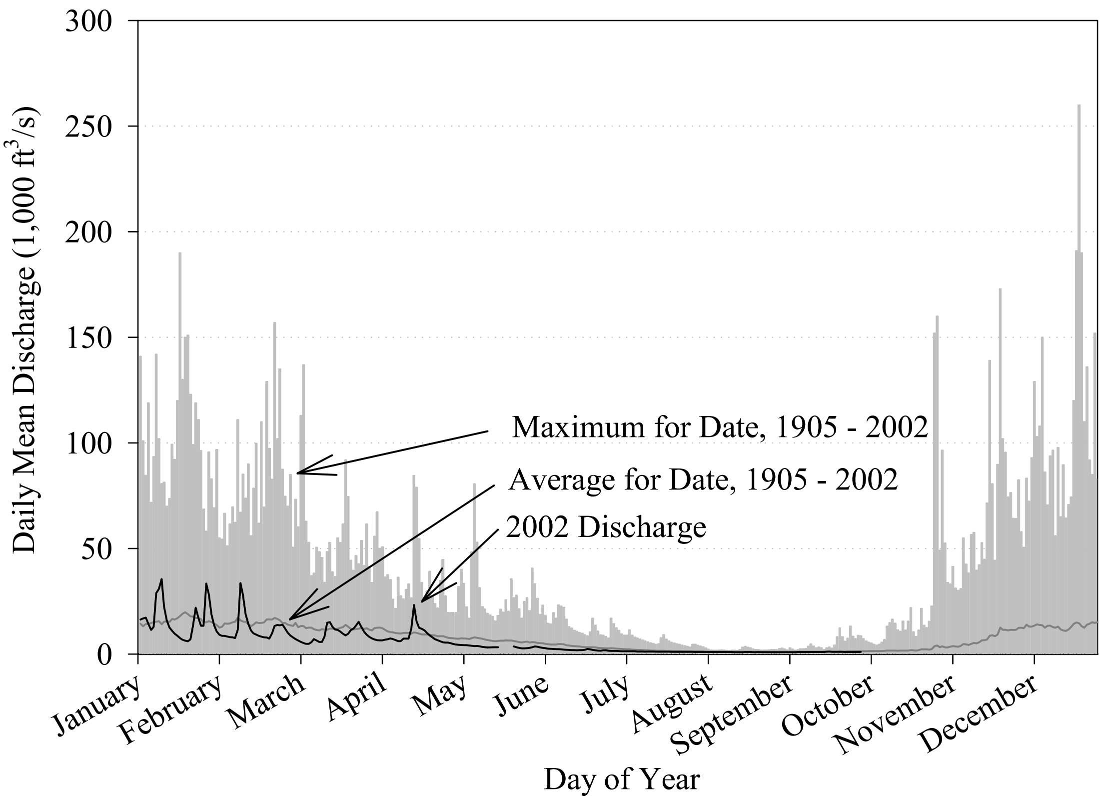


Figure 6. Umpqua River discharge near Elkton, Oregon, 1905-2001. (Top) Mean by date. (Bottom) 2002 daily mean discharge and the average and maximum daily means by day of year. Source: U. S. Geologic Survey (http://water.usgs.gov/usa/nwis/sw).

Table 8. Incidental catch of green sturgeon during spring gill net sampling in Isthmus Slough, Coos Bay, Oregon April–June, 1980–1992. Effort ranged from 4–9 net sets a year.

Year	Catch	Size Range (cm TL)
1980	2	~ 46, ~46
1981	2	58, 65
1982	7	Not measured
1983	12	38 to 61
1984	0	--
1985	1	66
1986	3	61, 46, 85
1987	1	46
1988	1	56
1989	1	53.5
1990	2	49, 61.5
1991	0	--
1992	1	84

Plans for Next Year

Field sampling plans for 2003 will emphasize effort to collect juvenile green sturgeon above tidal influence in the Umpqua River. We will use an underwater camera, beach seine, and possibly an electroshocker or gill nets. We will also use gill nets to attempt to capture adult green sturgeon in the Siuslaw River, Coquille River and Coos Bay. We will work with local guides to collect stomach samples from harvested green sturgeon along the coast. The ODFW Gold Beach Office will do limited gillnetting to attempt to capture adult green sturgeon for sonic tag implantation by the Wildlife Conservation Society (WCS). WCS will be working under a separate contract to monitor adult movements in the Rogue River.

ACKNOWLEDGEMENTS

Dave Loomis, Sam Moyer, Fabian Carr, and Dave Harris of ODFW's Roseburg office supplied us with river information, staff for sampling, and historical records on green sturgeon from their files. Michele Hughes, Travis Eoff, and Jody Gabriel of ODFW's Clackamas office assisted with sampling. Mike Gray and Chris Stevens of ODFW's Charleston office assisted us

with historical data and gear re-location. Nadine Craft with ODFW's Charleston office, Todd Hannah of The Oregon Angler Guide Service, and Dan Erickson of WCS volunteered to help us with field sampling. Terry Jarmain of Umpqua River Guide Service and Todd Hannah of The Oregon Angler Guide Service provided invaluable information about catches and areas to fish in the Umpqua River. Russ Stauff, John Weber, and staff of ODFW's Gold Beach Field office assisted by gillnetting, tagging and collecting DNA samples from the Rogue River.

Kevleen Melcher and Tom Neill with ODFW's Columbia River Management section conducted estuary sampling, supplied pectoral-spine samples for ageing, and DNA samples.

Dan Erickson, with WCS, radio tagged fish, collected samples, and tracked potential spawning fish through radio telemetry in the Rouge River.

REFERENCES

Brennan, J. S., and G. M. Cailliet. 1989. Comparative age-determination techniques for white sturgeon in California. Transactions of the American Fisheries Society 118:296-310.

DeVore, J. D., B. W. James, D. R. Gilliland, and B. J. Cady. 2000. Report B. Evaluate the success of developing and implementing a management plan for white sturgeon in reservoirs between Bonneville and McNary dams in enhancing production *and* Describe the life history and population dynamics of subadult and adult white sturgeon upstream of McNary Dam and downstream from Bonneville Dam. Pages 41-74 *in* D.L. Ward, editor. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. April 1998–March 1999 Annual Progress Report to Bonneville Power Administration, Portland, Oregon.

EPIC. 2001. Petition to list the North American Green Sturgeon (Acipenser medirostris) as an endangered or threatened species under the Endangered Species Act. Petition To National Marine Fisheries Service by Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California, petitioners.

Farr, R. A., M. L. Hughes, and T.A. Rien. 2001. Green Sturgeon Population Characteristics In Oregon. Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R.

FCOO and OSGM. 1946. Division of Research Library, Oregon Fish Commission, The Umpqua River Study. A Joint Report by The Fish Commission of Oregon and The Oregon State Game Commission. From the library at Umpqua Watershed District office, Oregon Department of Fish and Wildlife, Roseburg, Oregon.

Federal Register. 2001. Endangered and threatened wildlife and plants: 90-day finding for a petition to list green sturgeon as threatened under the Endangered Species Act. 14 December 2001, pages 64793-64794.

Johnson, O. W., R. S. Waples, T. C. Wainwright, K. G. Neely, F. W. Waknitz, and L.T. Parker. 1994. Status review of Oregon's Umpqua River sea-run cutthroat trout. NOAA Technical Memorandum NMFS-NWFSC-15.
Source: http://www.nwfsc.noaa.gov/pubs/tm/TM15/techmemo15.html

Morrow, J. V., J. P. Kirk, K. J. Killgore, and S. G. George. 1998. Age, growth, and mortality of shovelnose sturgeon in the Lower Mississippi River. North American Journal of Fisheries Management, 18: 725-730.

Rien, T. A. and R. C. P. Beamesderfer. 1994. Accuracy and precision of white sturgeon age estimates from pectoral fin rays. Transactions of the American Fisheries Society 123:255-265, 1994.

Rien, T. A., R. C. P. Beamesderfer, and C. A. Foster. 1994. Retention, recognition, and effects on survival of several tags and marks for white sturgeon. California Fish and Game 80:161-170.

SAS (Statistical Analysis Systems). 1988a. Procedures guide; version 6.03 edition. SAS Institute, Cary, North Carolina.

SAS (Statistical Analysis Systems). 1988b. SAS/STAT user's guide; version 6.03 edition. SAS Institute, Cary, North Carolina.

Whisler, J., T. Neill, K. Melcher. 1999. Sturgeon Tagging Project in Select Coastal Estuaries 1998. Oregon Department of Fish and Wildlife, Columbia River Management, Clackamas, OR.

APPENDIX A.

Rogue River 2002 Sampling

ABSTRACT

During February through December 2002, gill nets and beach seines were used to capture adult and juvenile green sturgeon *Acipenser medirostris* and white sturgeon *Acipenser transmontanus* in the Rogue River, Oregon. We set 181 gill nets for an average 0.8 h and captured 96 individual green sturgeon (133-204 cm fork length, FL) and 4 individual white sturgeon (174–206 cm FL). Most adult sturgeons were tagged with spaghetti and passive integrated transponder tags and 16 adult green sturgeon and two adult white sturgeon were fitted with a radio and/or a sonic tag at capture by Wildlife Conservation Society staff. Beach seining conducted in an unrelated study captured four juvenile green sturgeon, and16 individual adult green sturgeon (141–194 cm FL) in 708 sets fished mid July through October at rkm 12.9.

METHODS

Rogue River 2002 Field Sampling

The Rogue River is located in southwest Oregon and flows 346 kilometers from its headwaters near Crater Lake to the Pacific Ocean at Gold Beach (Figure 1). Field sampling for green sturgeon *Acipenser medirostris* and white sturgeon *Acipenser transmontanus* was conducted from late February through December 2002 in the lower 40 km of the Rogue River from Gold Beach to Copper Canyon.

Large-Mesh Experimental Gill nets

From February through December 2002, we deployed 181 gill nets between the Highway 101 bridge (rkm 1.7) and Copper Canyon (rkm 39.4). Nets were fished an average of 0.85 h/set (Appendix A Table 1) during daylight hours. Effort was not randomly distributed over the study area (Appendix A Table 2). All nets were 3.0-m deep. Nets were constructed of 23.5-cm stretched-measure multi-strand monofilament in 30.4-m and 61.0-m lengths. The nets were both statically fished in suitable areas of deep, slow moving water for up to 2.2 h and drifted through areas of higher currents for up to 10 minutes.

Beach Seine

In an unrelated study, beach seining was conducted to capture juvenile salmonids. They did 708 beach seine sets (45 sets/week for 15 weeks minus one day of only 3 sets). Sampling was conducted by Gold Beach District staff of Oregon Department of Fish and Wildlife (ODFW) at Huntley Park (rkm 12.9) with a 141.7-m long by 5.7-m deep beach seine with 1-cm square mesh net (Weber 2002).

Fish Processing

Each unmarked adult sturgeon captured was measured to the nearest 1 cm fork length (FL) and total length, and examined for tags and marks. Most sturgeons were tagged with both a passive integrated transponder (PIT) tag and an external spaghetti tag. The second left lateral scute was removed from each fish implanted with a PIT tag (Rien et al. 1994). The tenth right scute was removed to indicate that the fish was handled in 2002. Tissue samples were taken from the pectoral fins and stored in ethyl alcohol for subsequent genetic analyses. After processing, 18 fish were given to Wildlife Conservation Society (WCS) staff for radio tagging, sonic tagging, or both. In addition, 4 fish (including one recaptured sonic tagged fish) were fitted with satellite archival pop-off tags by WCS. Juvenile green sturgeon were counted. No lengths or DNA were taken.

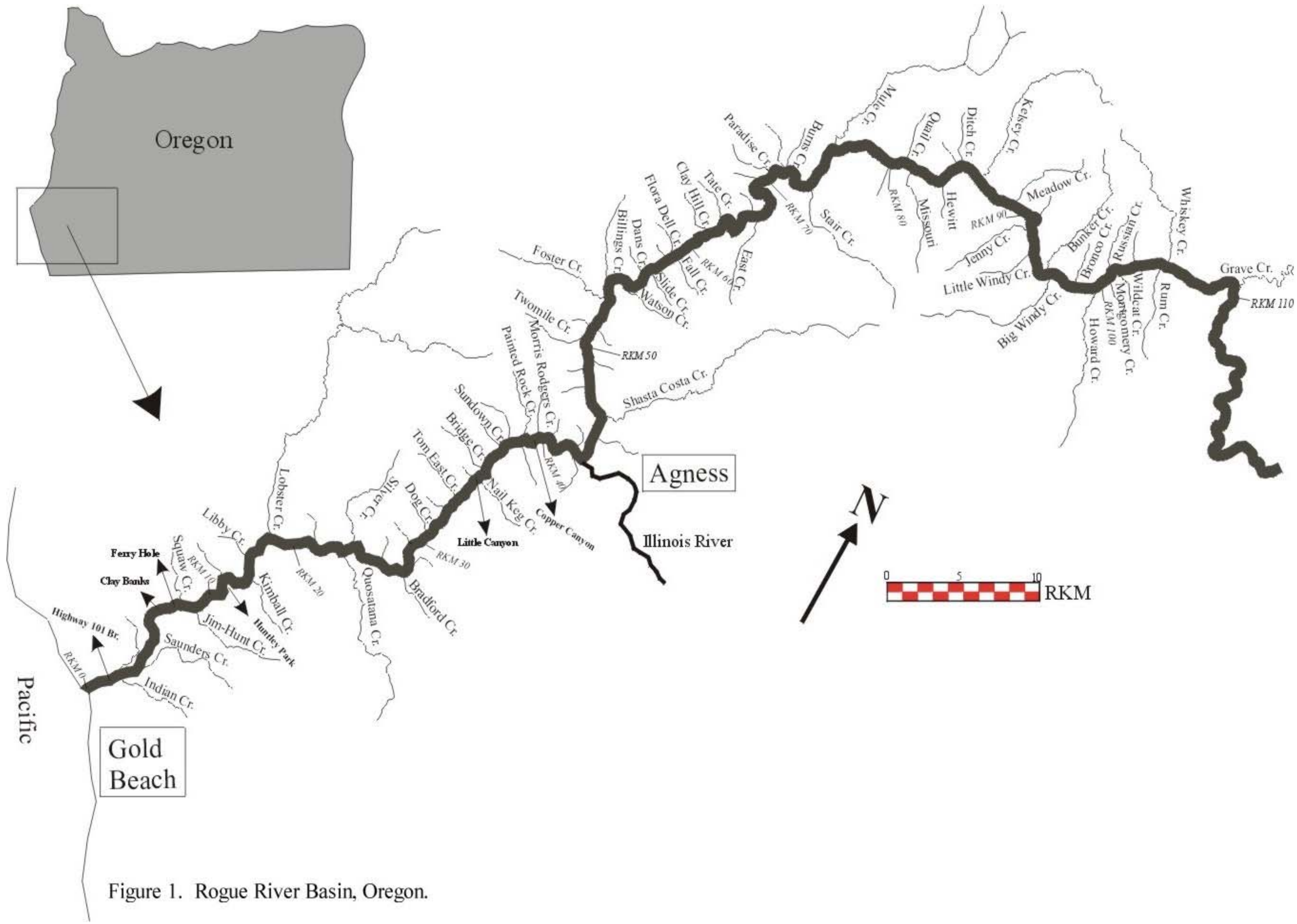


Figure 1. Rogue River Basin, Oregon.

Appendix A Table 1. Effort (h) and catch by sampling week for gill nets used to capture green and white sturgeon, Rogue River, Oregon, 2002.

		Effort (hours)		Catch	
Week	Sets	Total	STD	Green Sturgeon	White Sturgeon
February 25	5	5.00	0.00	0	0
March 4	6	5.83	0.04	0	0
March 11	4	4.10	0.05	0	0
March 18	6	5.95	0.02	0	0
March 25	6	6.00	0.00	0	0
April 1	6	6.25	0.40	0	0
April 8	9	6.50	0.44	0	1
April 15	3	3.00	0.00	0	0
April 22	18	17.10	0.15	1	0
April 29	7	6.83	0.05	6	0
May 6	7	7.27	0.11	2	0
May 13	8	8.00	0.00	1	0
May 20	5	5.05	0.01	2	0
May 27	3	3.07	0.04	4	0
June 3	3	2.87	0.08	3	1
June 10	3	3.00	0.00	4	0
June 17	3	3.00	0.00	4	0
June 24	3	1.50	0.00	3	0
September 9	5	2.67	0.13	4	0
September 16	11	7.95	0.29	7	0
September 30	2	1.00	0.00	5	0
October 7	16	7.92	0.23	3	0
October 14	6	4.92	0.49	8	0
October 21	3	1.17	0.10	4	0
October 28	13	8.42	0.36	10	0
November 4	5	4.20	0.18	18	1
November 11	7	6.20	0.20	0	1
November 18	6	5.80	0.13	6	1
December 2	2	3.17	0.82	13	1

Appendix A Table 2. Effort (h) and catch by river kilometer for gill nets used to capture green sturgeon and white sturgeon, Rogue River, Oregon, 2002.

		Effort (hours)		Catch	
River Kilometer	Sets	Total	STD	Green Sturgeon	White Sturgeon
0 - 10	33	32.85	0.04	0	0
10.1 - 20	140	113.70	0.32	107	6
20.1 - 30	2	1.17	0.19	0	0
30.1 - 40	6	6.00	0.00	1	0

RESULTS

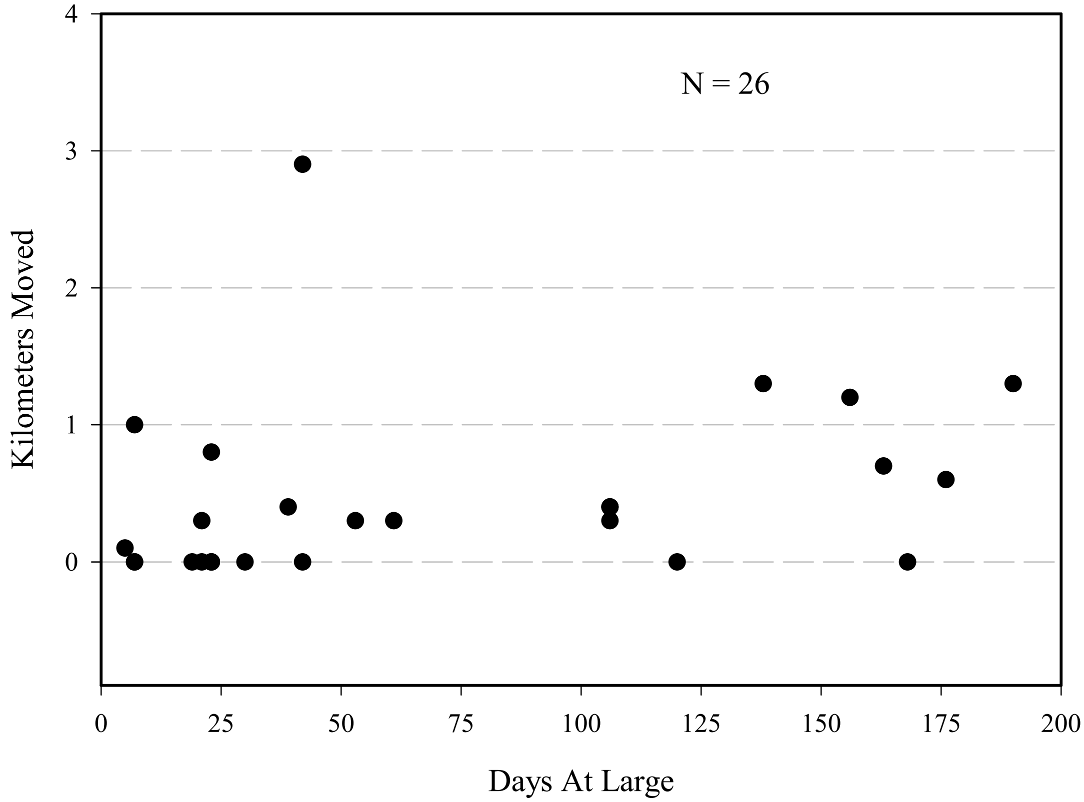
ODFW captured 108 adult and sub-adult green sturgeon (133-204 cm FL) in gill nets and 17 adult and sub-adult green sturgeon (141-194 cm FL) in beach seines including 23 recaptured once and 3 recaptured twice over the study period. ODFW collected 95 DNA samples. Sixteen of the fish were radio tagged, sonic tagged or both. Four fish were satellite tagged. Tracking was done by WCS staff. Four juvenile green sturgeon were captured in beach seines. These fish were counted and released. No data were collected.

We captured 6 adult and sub-adult white sturgeon (174–206 cm FL) in gill nets including one recaptured in the study period and one recaptured from tagging in the Rogue River in 2000. Two were radio or sonic tagged for tracking by WCS staff. Five DNA tissue samples were collected.

DISCUSSION

Fish showed little movement over the study period with 81% moving less than one kilometer (Appendix A Figure 2). The white sturgeon tagged in 2000 was recaptured 1.3 km from its original tagging site. This trend may only be indicative of a small portion of the population as most (77%) of the sampling effort was done in a fairly short reach (10 km) of river, and effort was not random over the entire sampling area (Appendix A Table 2).

Juvenile green sturgeon captured in beach seines over the last several decades are strong evidence that spawning occurs fairly regularly in the Rogue River (Rien et al. 2000). This year, juvenile green sturgeon were again collected. This may indicate that spawning occurred in the Rogue River in 2002. Still, we were not able to directly document sturgeon spawning or spawning sites.



Appendix A Figure 2. Distance moved and days at large for recaptured spaghetti tagged green sturgeon, Rogue River, Oregon 2002.

Plans for Next Year

Field sampling plans for 2003 will be limited to gillnetting in the Rogue River at specific sites to collect fish for telemetry by WCS. The WCS will be working under a separate contract to monitor adult movements and attempt to capture eggs.

REFERENCES

Rien, T. A., R. C. P. Beamesderfer, and C. A. Foster. 1994. Retention, recognition, and effects on survival of several tags and marks for white sturgeon. California Fish and Game 80:161-170.

Rien, T. A., L. C. Burner, R. A. Farr, M. D. Howell, and J. A. North. 2000. Green Sturgeon Population Characteristics In Oregon. Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R.

Weber J. 2002. The Annual Rogue Seine Report. Oregon Department of Fish and Wildlife. Gold Beach, Oregon.

APPENDIX B.

A Catch Rate Index for Green Sturgeon Harvested in Lower Columbia River Commercial Fisheries

INTRODUCTION

The petition to list green sturgeon (EPIC 2001) and a recent publication (Musick et al. 2000) have interpreted declines in green sturgeon *Acipenser medirostris* harvest as evidence of a population decline (Appendix B Figure 1). However, catch data can be misleading if not interpreted in conjunction with fishing effort.

One measure of fishing effort is the number of commercial fishing days allowed. In the Columbia River, the overwhelming majority of green sturgeon are harvested during July through October (Appendix B Figure 2) in fisheries management Zones 1 and 2 (mouth to river mile 69, Appendix B Figure 3). The duration of gillnet fisheries has steadily declined over time. Prior to 1960, gillnetters were allowed 100+ days of fishing per year; 20 of those in August. Since 1992, fewer than 40 days per year have been allowed. In 1995 there were only 2 allowed dates. Since 1990, there have been an average of 2.3 fishing dates in August and 4.7 days in September (Appendix B Figure 4; WDFW and ODFW 2002).

We conducted an analysis to examine commercial catch rate based on landing tickets and green sturgeon harvest. Commercial fishery harvest is tracked by fish landing tickets in databases maintained by Oregon and Washington departments of fish and wildlife. Each fish sale generates a ticket documenting species and pounds purchased. Harvest numbers are generally recorded on tickets now, but past catches were estimated from average weight of sampled fish and pounds landed. Because a fish must be sold at a commercial buyer to generate a landing ticket, zero-catch days for individual fisherman are not represented in a summary of green sturgeon landing tickets. The target species in lower Columbia River fisheries is white sturgeon so the maximum of white or green sturgeon landing tickets is a reasonable surrogate for "sturgeon effort".

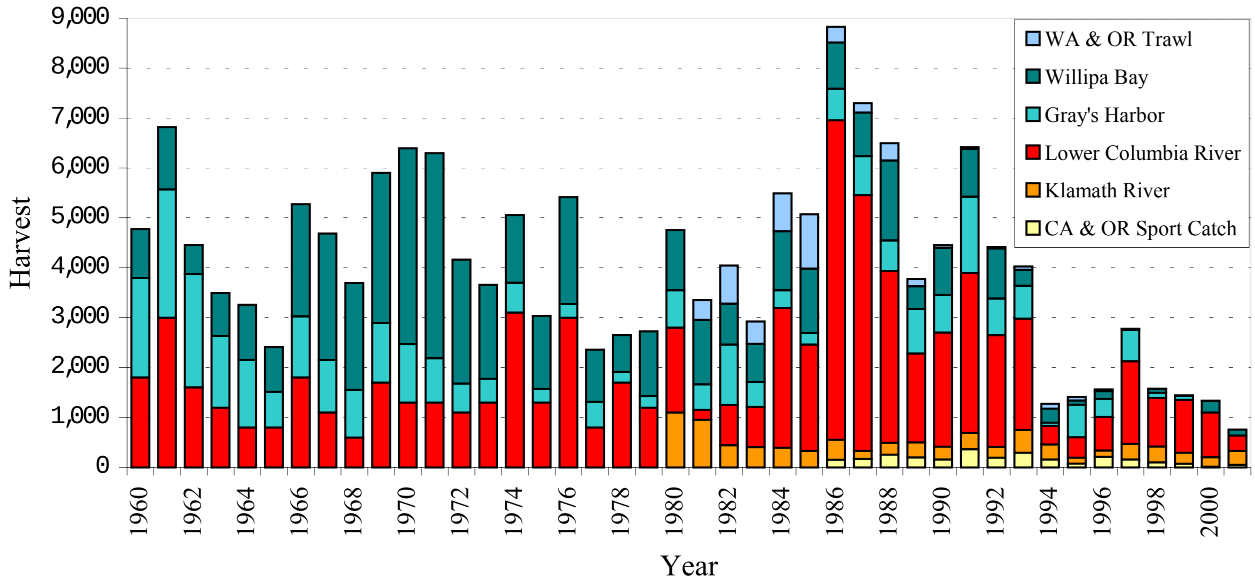
METHODS

We focused this analysis on commercial landings of green sturgeon from months (August through October) and geographical areas (Zones 1 and 2) that account for the majority of commercial harvest. The period August-October has accounted for more than 90% of all green sturgeon harvest since 1981. July was excluded because even though it has accounted for about 6% of all harvest, harvest was allowed in July in only one year (1986). Zones 1 and 2 have accounted for about 99% of all green sturgeon harvest.

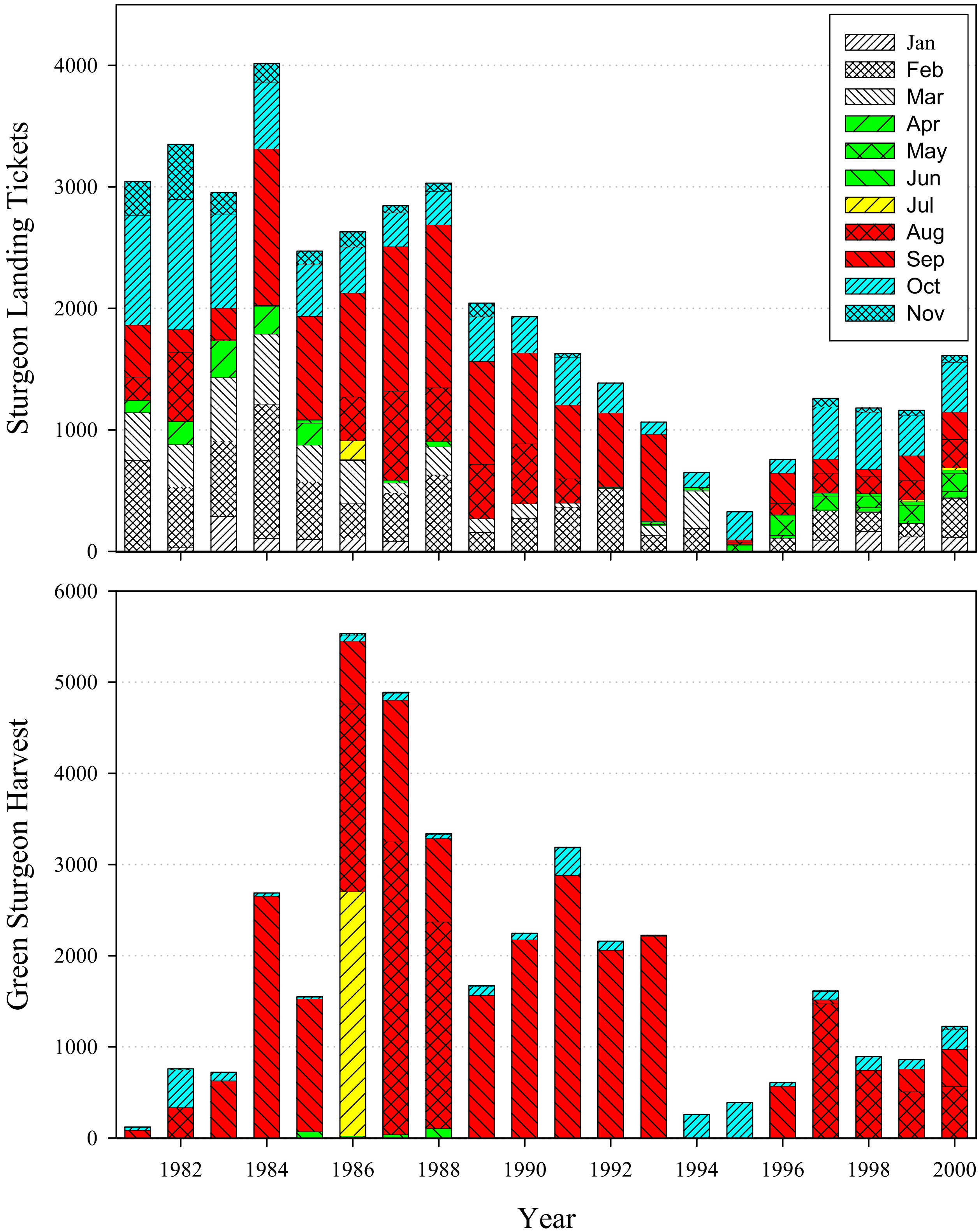
Commercial gill-net catch data are highly skewed (Appendix B Figure 5) so statistical analyses must either be based on non-parametric tests or transformed data. We used regressions of log-transformed catch rates (LTCR) to describe trends in catch rate:

LTCR=(log (green sturgeon landings+1))/sturgeon effort

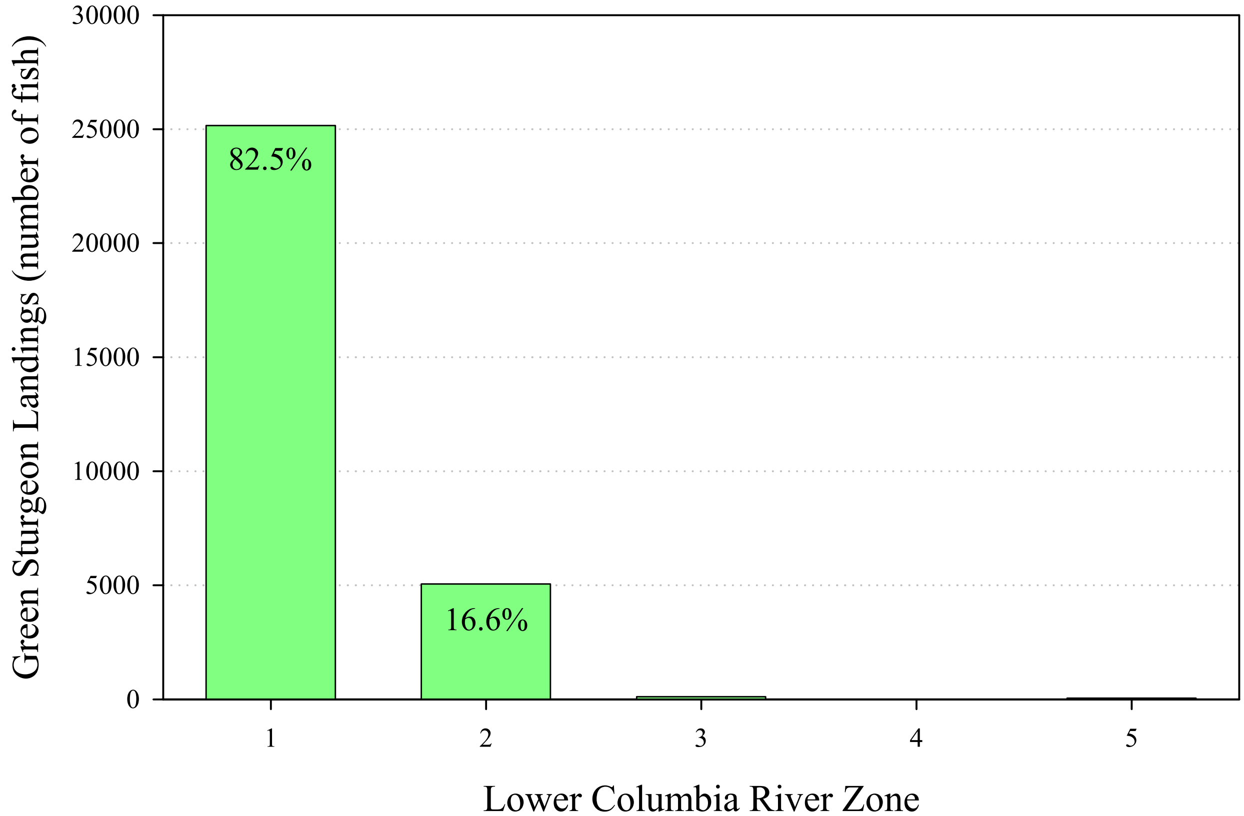
We ran separate regressions for the periods 1981-2000, 1981-1993, and 1994-2000 (slot sizes changed from 48-72 in. to 48-66 in. in 1994) to examine catch rate trends. Regressions were considered significant if $P \leq 0.05$.



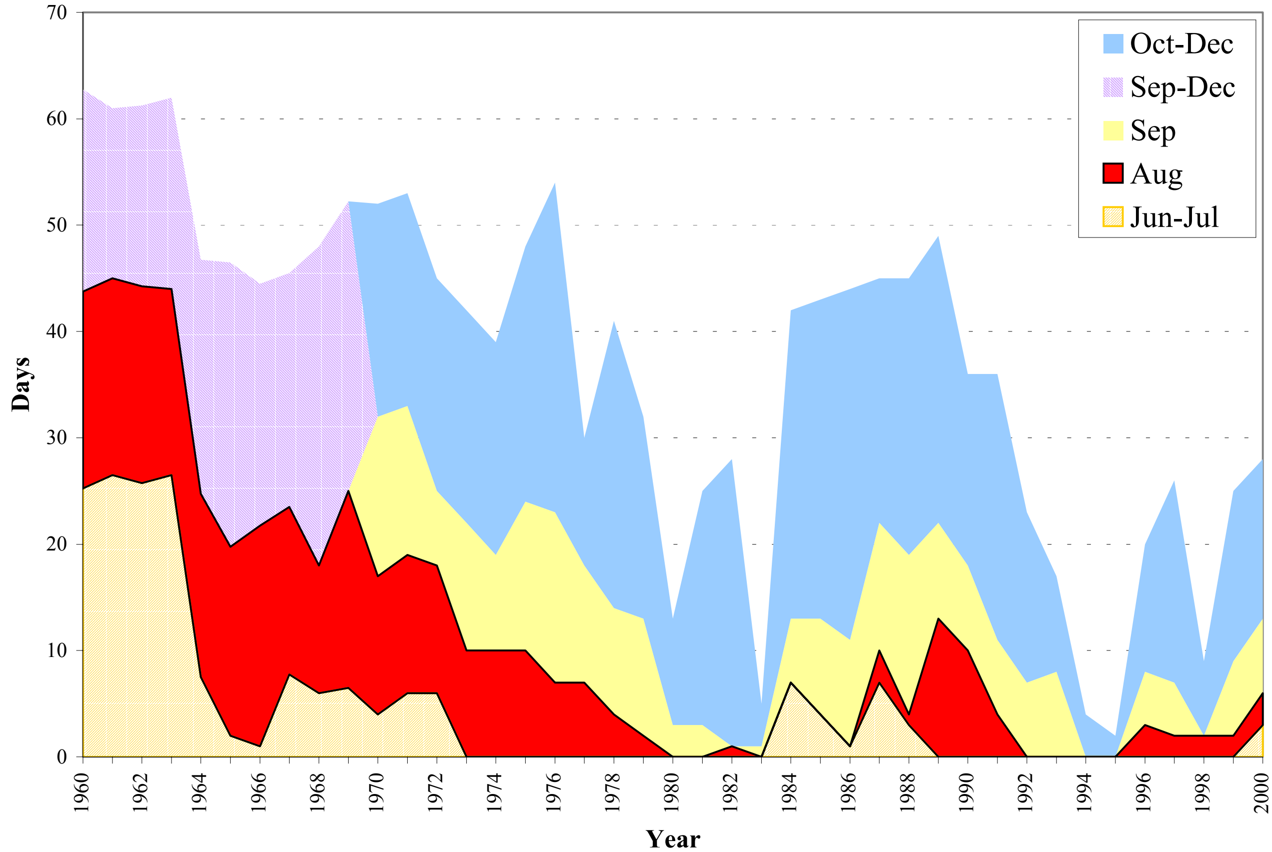
Appendix B Figure 1. Green sturgeon harvests in California, Oregon, and Washington, 1960-2001. Klamath River harvest and the Oregon/California sport harvest data were not available prior to 1980 and 1986. Data for years 2000 and 2001 are not complete.



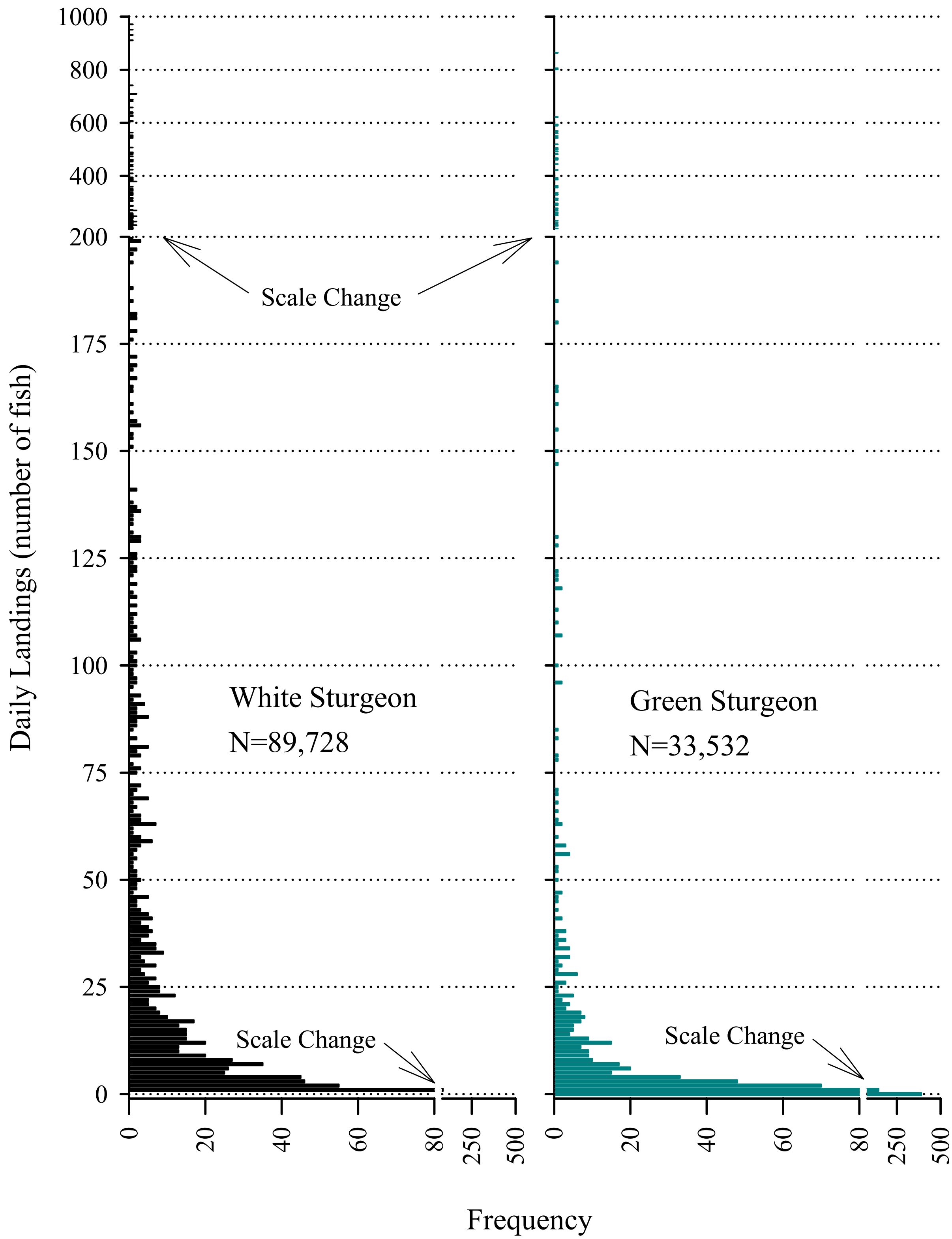
Appendix B Figure 2. Commercial landing tickets and harvest of Columbia River green sturgeon by month, 1981-2000.



Appendix B Figure 3. Green Sturgeon landings by commercial fishing zone in the Lower Columbia River, 1981-2001. The zones shown are downstream from Bonneville Dam.



Appendix B Figure 4. Days open to commercial fishing in the Columbia River below Bonneville Dam, 1938-2000. Based on Table 13 in WDFW and ODFW (2002).



Appendix B Figure 5. Distribution of daily landings in lower Columbia River sturgeon fisheries. White sturgeon have no days with zero landings (target white sturgeon fishery).

RESULTS

Regressions of LTCR on year for the periods 1981-2000 and 1981-1993 had weak correlation coefficients, and shallow positive slopes (increasing at less than 0.08 fish/landing ticket/year), but were statistically significant. The regression of LTCR on year for the period 1994-2000 was not significant (Appendix B Table 1 and Appendix B Figure 6).

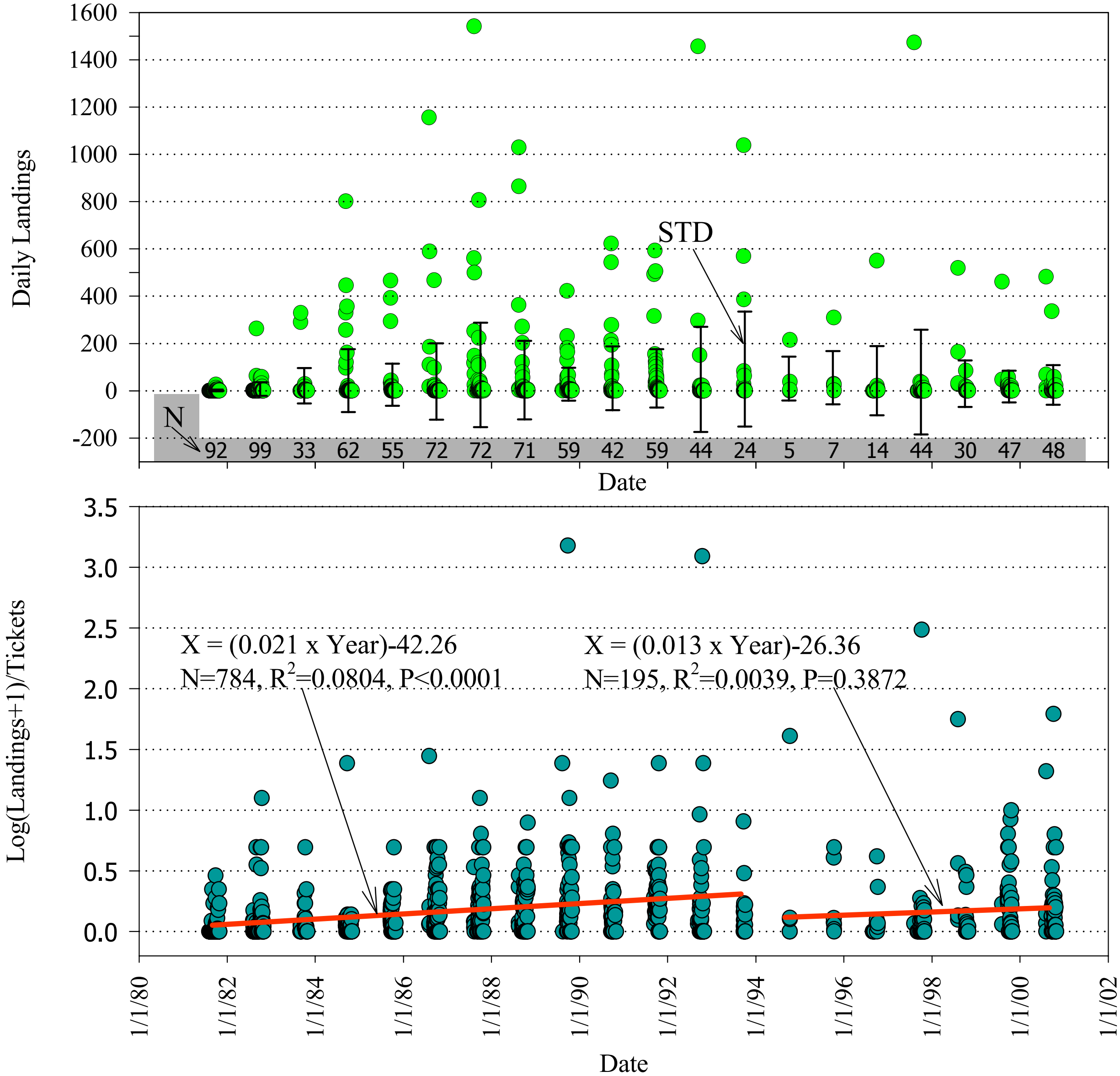
DISCUSSION

This analysis does not support a declining trend in Columbia River green sturgeon harvest rate. Catch rates appear to be either stable or increasing. While this index of catch rate may represent density of green sturgeon in the Columbia River estuary, it is less likely that green sturgeon density in the estuary is representative of the overall abundance of green sturgeon. We do not know why green sturgeon are using the estuary. There is no evidence of spawning or feeding in this area. Green sturgeon density in the Columbia River Estuary is likely related to an environmental cue that we have yet to identify. An understanding of factors influencing green sturgeon density in the estuary may help us infer population trends on a larger geographic scale.

Trends in catch rate should be interpreted with some potential biases in mind. Green sturgeon are harvested as bycatch during fisheries with allowed white sturgeon sales. Using bycatch data as an index of density presents unique concerns. White sturgeon and green sturgeon likely distribute themselves differently in response to various environmental cues. This may affect seasonal and annual variability in vulnerability to harvest. The species probably have different vulnerabilities to capture. Reporting bias is unlikely since all legal-sized green sturgeon are probably harvested, and while their value is less than white sturgeon, they do not count against the annual white sturgeon harvest guideline. The substantial disparity in commercial value of the two species means that both buyer and seller have a vested interest in correct identification. Identification bias is unlikely since white sturgeon and green sturgeon have distinct appearances and fishers easily distinguish them. Finally, the bycatch index may underestimate effort, and thus overestimate harvest rate, if zero-catch days are common for Columbia River gillnetters. We do not believe this is true.

Appendix B Table 1. Linear regression results for log-transformed catch rates on year over the periods 1981-2000, 1981-1993, and 1994-2000.

Years	1981-2000	1981-1993	1994-2000
N (Dates)	950	755	195
Slope	0.00832	0.02215	0.01328
y-intercept	-16.3819	-43.84608	-26.3641
R^2	0.0280	0.0826	0.0039
F value	27.28	67.79	0.75
Pr > F	<.0001	<.0001	0.3872



Appendix B Figure 6. Trends in green sturgeon catch rate and log-transformed catch rate from lower Columbia River commercial fisheries landings in Zones 1 and 2, August-October, 1981-2000. Sample size (N = landing tickets) is shown for each calendar year

REFERENCES

EPIC. 2001. Petition to list the North American Green Sturgeon (Acipenser medirostris) as an endangered or threatened species under the Endangered Species Act. Petition To National Marine Fisheries Service by Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California, petitioners.

Musick, J.A., M. M Harbin, S. A. Berkeley, G. H. Burgess, A. M. Eklund, L. Findley, R. G. Gillmore, J. T. Golden, D. S. Ha, G. R. Sedberry, H. Weeks, and S. G. Wright. 2000. Marine, Estuarine and Diadromous Fish Stocks at Risk of Extinction in North America (Exclusive of Pacific Salmonids). American Fisheries Society vol.25, No.11, pg. 6-30.

WDFW and ODFW. 2002. Status Report. Columbia River Fish Runs and Fisheries. 1938-2000. Washington Department of Fish and Wildlife (Olympia, Washington) and Oregon Department of Fish and Wildlife (Portland, Oregon).

APPENDIX C.

Green Sturgeon Growth Rate Estimated from Recapture Data

INTRODUCTION

Validation of an ageing technique requires data from known-age fish from the population and the range of ages under evaluation (Beamish and McFarlane 1983). Typically validation studies call for paired age structures collected from mark and recapture events or use of a chemical to impart a mark or label in the age structure, which is then collected after a known-period at large. Relative ages or the counts of annular rings formed after the label are used to determine validity of the technique.

Green sturgeon age determinations and von Bertalanffy growth parameters (L_∞ = the theoretical maximum size; t_0 = the x-intercept on plot of length at age or the theoretical age of a fish with length 0), and k = the growth coefficient) have been estimated from fin spines (Adair et al. 1983, Farr and Rien. this report) however, validation of the fin-spine method has not been reported for green sturgeon. Because green sturgeon are highly mobile species that cross state and national boundaries, obtaining age structures from known-age fish will require a long-term cooperative effort among several state, federal, and tribal agencies.

Corroboration of length-age relationships derived from age interpretation may be possible using length measurements from mark-recapture data. Two parameters of a von Bertalanffy growth relationship (L_∞ and t_0) can be derived using period at large and growth data from recaptured fish (Fabens 1965; Gulland 1983). In this exercise, we examined recapture data provided to National Oceanic and Atmospheric Administration Fisheries by Washington Department of Fish and Wildlife in response to an information request to address a petition to list green sturgeon as threatened under the Endangered Species Act (EPIC 2001).

METHODS

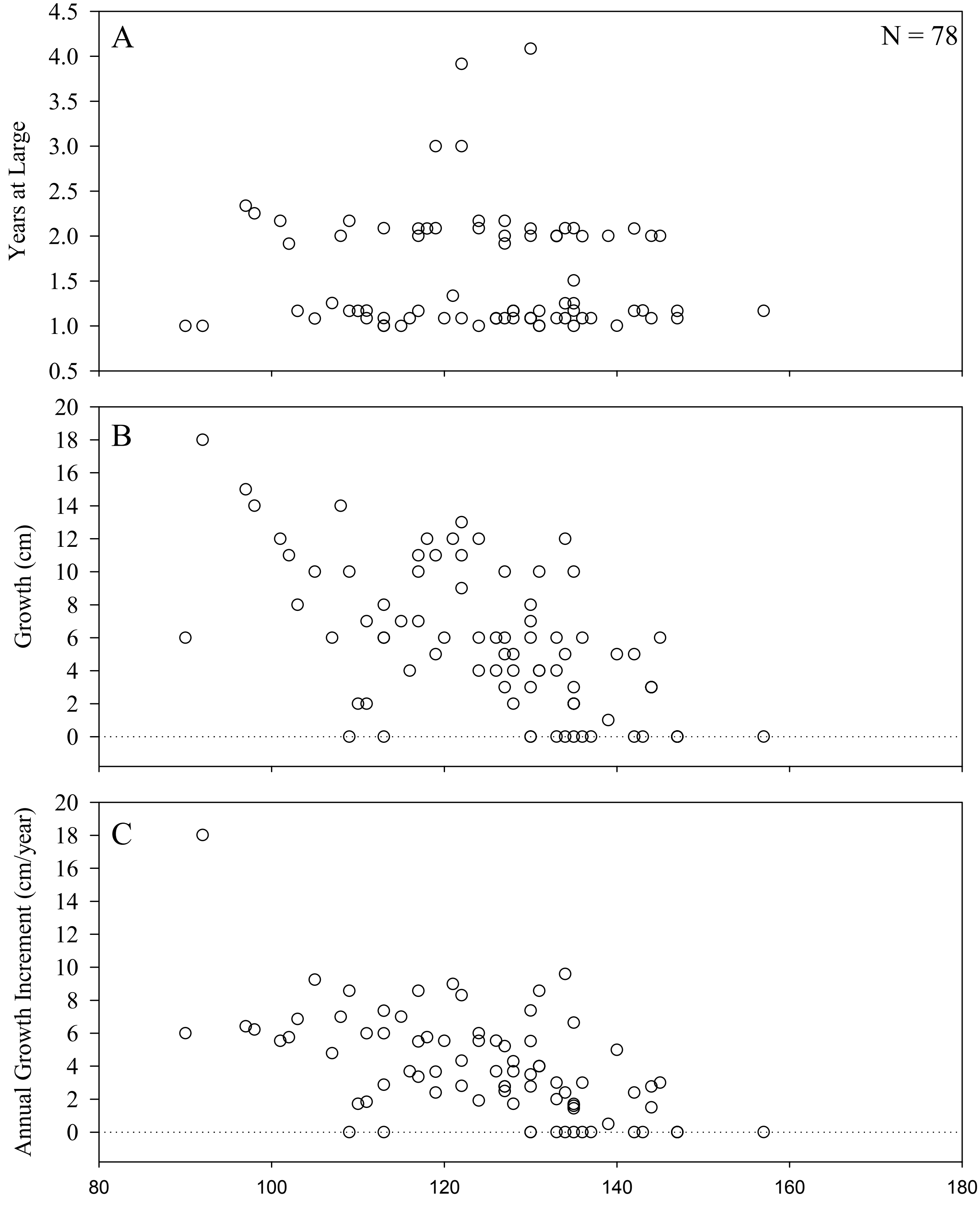
Over the period May 1985 through August 1999 green sturgeon were captured and tagged incidental to a Columbia River estuary white sturgeon tagging program (Watts and Whisler 1998). Fish were captured in gill nets and tagged with individually numbered spaghetti tags. Some of these fish were later recovered in later sampling or in monitored harvest. We identified 78 recaptured green sturgeon that were at large one or more years from Columbia River tagging data. Trained personnel measured all fish. Green sturgeon ranged 90-157 cm fork length and were at large 365-1,492 d (Appendix C Figure 1). Fish at large less than 365 d were excluded from analysis to moderate potential affects of seasonally variable growth.

We calculated annual growth increments (AGI) for each of the 78 fish as:

AGI = change in fork length / (d at large / 365.25 d/year).

From these data we completed 5 simple analyses.

1) We calculated the mean AGI for all 78 fish.
2) We described the relationship between period at large and growth using linear regression (SAS 1988; PROC REG). The intercept was forced through the origin to reflect that a fish at large for zero days cannot grow.
3) We determined the relationship between AGI and median fork length while at large (MFL) using linear regression.



Appendix C Figure 1. Years at large (A), observed growth (B), and annual growth increment (C), for 78 green sturgeon marked and recaptured in the lower Columbia River, 1985–1999.

4) From the linear regression of AGI and MFL we derived estimates of L_∞ and k as:

L_∞ = x-intercept

k = -ln (slope + 1)

5) Finally we derived least squares estimates of L_∞ and k using SAS software (PROC GLM) and fitting data to Fabens (1965) equation:

$$L_{recapture} = L_{tag} + (L_\infty - L_{tag})*(1 - \exp(-k*T)$$

where:

$L_{recapture}$ = fork length at recapture

L_{tag} = fork length at tagging, and

T = years at large

RESULTS

Analyses provided the following estimates:

1) The average growth rate for all 78 recaptured fish was 3.94 cm/year.

2) Linear regression of growth on years at large, with the intercept forced through the origin, described:

   Growth = 3.43 * (years at large)
   (Appendix C Figure 2).

3) Regression of AGI on MFL described

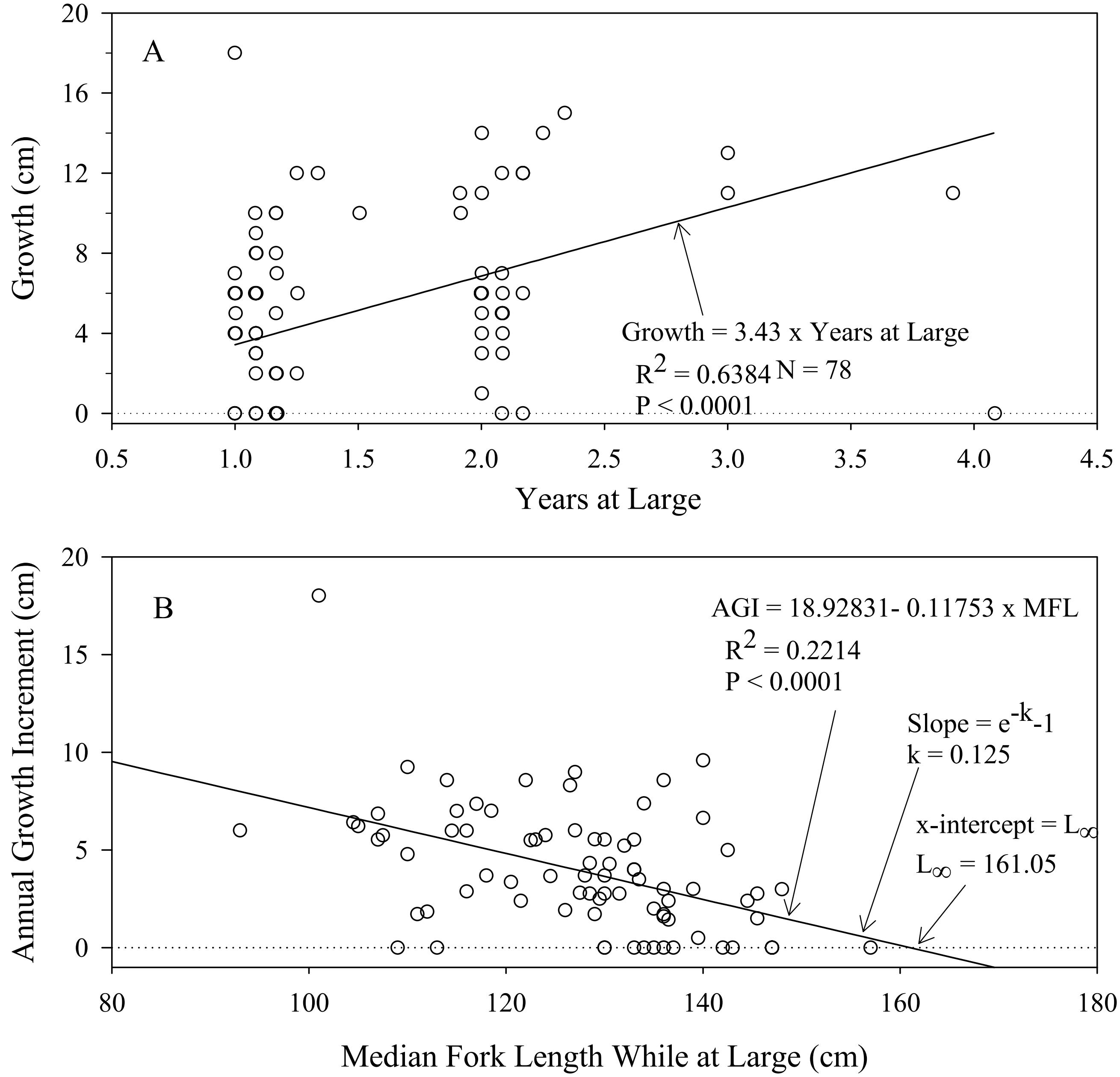
   AGI = 18.93- 0.12 * MFL
   (Appendix C Figure 2).

4) From this slope and x-intercept estimate L_∞ = 161.05, and k = 0.125.

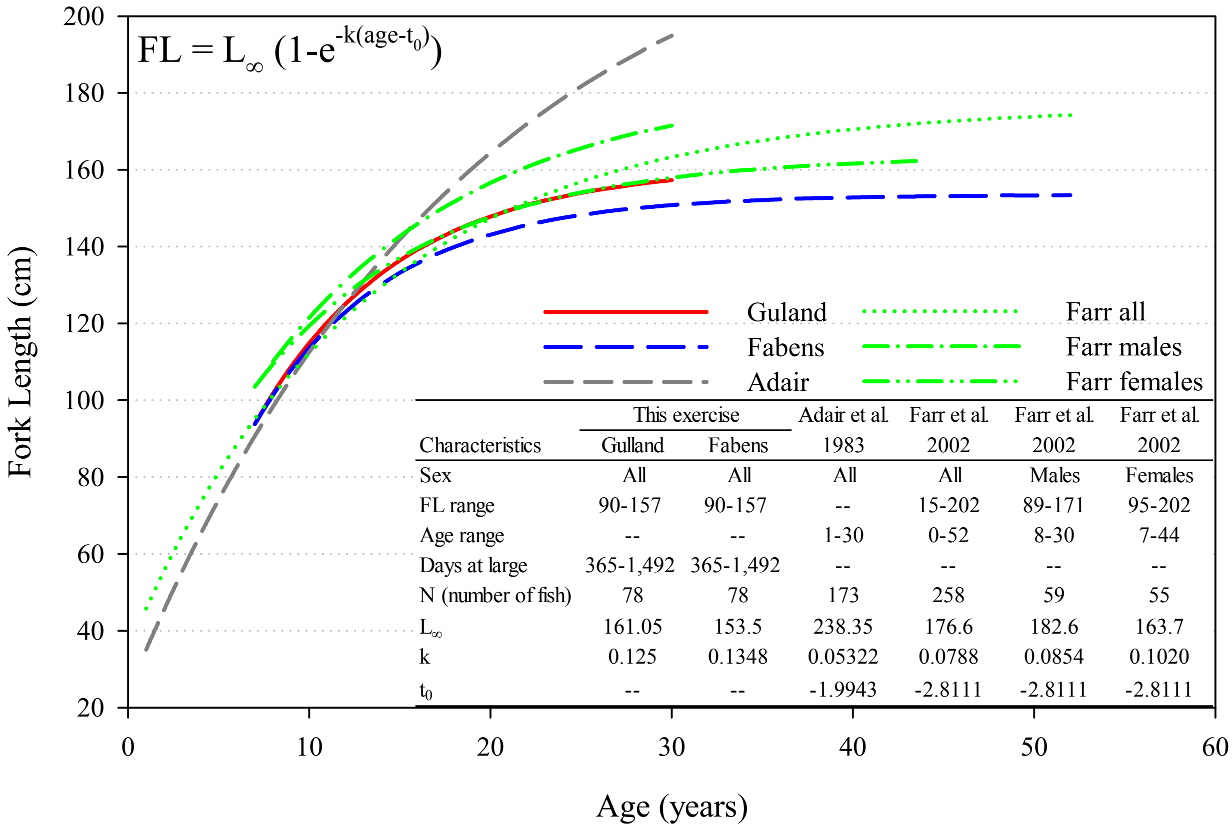
5) Using the method of Fabens we estimate L_∞ = 153.5, and k = 0.1348
   (Appendix C Figure 3).

DISCUSSION

Which age-length relationship best represents the true growth of green sturgeon? Each of the curves we have reported here has strengths and weaknesses. All estimates of growth rate based on Columbia River and Oregon/Washington coastal fisheries data alone are biased toward underestimates of L_∞ because over-legal sized fish are poorly represented in our data set, and because fish that grow rapidly out of the legal slot limit are unlikely to be recaptured. However ages based on the fin-spine method and based on recapture data had similar growth rates over the size range these fish came from. It is noteworthy that scientists at University of California, Davis, report phenomenal growth rates for juvenile green sturgeon in captivity; much faster than white sturgeon at the same facilities (personal communication with Joel van Eenennaam, University of California, Davis). The growth relationship generated by Adair et al. (1983) has fish in the most commonly captured size range growing substantially slower than this analysis or that reported in Farr and Rien (this report). The estimate for L_∞ reported by Adair is closer to the longest green sturgeon reported (233 cm FL; Nakamoto et al. 1995).



Appendix C Figure 2. Regressions of growth on years at large (A) and of median fork length while at large on annual growth increment (B) for 78 green sturgeon marked and recaptured in the lower Columbia River, 1985–1999.



Characteristics	This exercise: Gulland	This exercise: Fabens	Adair et al. 1983	Farr et al. 2002	Farr et al. 2002	Farr et al. 2002
Sex	All	All	All	All	Males	Females
FL range	90-157	90-157	--	15-202	89-171	95-202
Age range	--	--	1-30	0-52	8-30	7-44
Days at large	365-1,492	365-1,492	--	--	--	--
N (number of fish)	78	78	173	258	59	55
L_∞	161.05	153.5	238.35	176.6	182.6	163.7
k	0.125	0.1348	0.05322	0.0788	0.0854	0.1020
t_0	--	--	-1.9943	-2.8111	-2.8111	-2.8111

Appendix C Figure 3. Green sturgeon von Bertalanffy growth curves.

In applying results of various ageing analyses in population modeling, potential biases in each of the age-length relationships need to be considered in light of the potential affects those biases may have on modeling outcomes. Overestimates of growth rate may underestimate exploitation rates because fish will wrongly be assumed to have a briefer vulnerability to harvest. Theoretical derivations of natural mortality rate (M) may overestimate M if underestimates of L_∞, or if overestimates of k are employed. We suggest that modelers use a range of potential growth rates that encompasses findings in this analysis of recapture data as well as those derived by Farr and Rien (this report) and Adair et al. (1983) in sensitivity analyses to simulate population growth and persistence.

REFERENCES

Adair, R., W. Harper, J. Smith, S. Egers, and S. Klemp. 1983. Klamath River Fisheries Assessment Program. Annual Report 1982. U. S. Fish and Wildlife Service, Arcata, California.

Beamish, R. J., and G. A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Transactions of the American Fisheries Society 112:735-743.

EPIC. 2001. Petition to list the North American Green Sturgeon (Acipenser medirostris) as an endangered or threatened species under the Endangered Species Act. Petition To National

Marine Fisheries Service by Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California, petitioners.

Fabens, A. J. 1965. Properties and fitting of the von Bertalanffy growth curve. Growth 29:265-289.

Gulland, J. A. 1983. Fish stock assessment: a manual of basic methods. John Wiley and Sons, Chichester.

Nakamoto, R. J., T. T. Kisanuki, and G. H. Goldsmith. 1995. Age and growth of Klamath River green sturgeon (Acipenser medirostris). U.S. Fish and Wildlife Service and U.S. Forest Service.

SAS (Statistical Analysis Systems). 1988. Procedures guide; version 6.03 edition. SAS Institute, Cary, North Carolina.

Watts, J. W., and J. Whisler. 1998. The 1997 NEAP funded sturgeon project on the Lower Columbia River. Oregon Department of Fish and Wildlife, Clackamas, Oregon