MOVEMENTS OF WI-KITE STURGEON IN LAKE ROOSEVELT

Final Report

1988-1991

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Background:

The following experimental work was undertaken through contract with Bonneville Power Administration to gather information useful for addressing the migration potential of white sturgeon (*Acipenser transmontanus*) as described by Section 903 (e) of the Fish and Wildlife Program. The issue that prompted the study was interest in the influence of the reservoir water management scheme on sturgeon distribution, and ultimately on reproductive activity. Research on distribution of the species in reservoir/river systems was initiated in conjunction with stock identification research on white sturgeon of the Columbia River (Setter and Brannon, 1992). Sturgeon caught for tissue samples and then released provided the opportunity to assess movement patterns by applying sonic tags and then monitoring signal locations over the following months. The behavior of tagged sturgeon was interpreted to be representative of the population within the reservoir/river system, and thus indicated something about relative stability of local distributions of the fish within specific areas of Lake Roosevelt.

Introduction:

Historically, white sturgeon moved throughout the Columbia River system, ranging freely from the estuary to the headwaters, with the possible exception of limited passage at Cascades, Celilo and Kettle Falls during spring floods. Construction of Rock Island Dam in 1933, followed by Bonneville in 1938 and Grand Coulee in 1941, completely disrupted sturgeon migratory opportunity, and with the 17 successive Columbia and Snake river dams constructed over the next 32 years an entirely different river system was created for the species. Sturgeon caught between dams were essentially isolated populations with severely limited reproduction potential. Some reservoirs ran from dam to dam with no river habitat remaining, while other reaches had various lengths of free running river, but drastically reduced from historical situations. However, if reservoirs provide habitat for sturgeon use, and therefore compensate to some degree for river loss, the major limiting factors associated with population viability may be reduced spawning success, either from lack of suitable area or poor incubation environments.

The most upstream impoundment of the Columbia River in the United States is Lake Roosevelt, behind Grand Coulee Dam (Fig. 1). As a storage reservoir with 129 square miles of surface area at full pool, a substantial grazing range is available to sturgeon if they are inclined to use the reservoir as habitat. While the river environment above Lake Roosevelt provides much more habitat and spawning area for sturgeon than most other Columbia reservoir systems, if sturgeon don't use Lake Roosevelt the capacity of the system to sustain a large sturgeon population would be understandably limited, and much reduced from the pre-dam era.

There has been a general uncertainty about the factors responsible for differences in the seasonal and annual migration patterns of white sturgeon in the Columbia River. It had not been shown whether landlocked upriver white sturgeon undergo a spring/summer upstream movement as found in the lower Columbia (Bajkov 1951). Coon et al (1977) suggested that movements in the Snake River may be due to a habitat preference for flowing water in contrast to that of impoundments. Larger sturgeon within the Snake River showed less net movement than smaller fish. Haynes et al (1978) also found size related movement patterns by white sturgeon in the mid-Columbia Intermediate sized fish moved less, while smaller fish showed a tendency for downstream movement and larger fish stronger upstream movement. Additionally, they suggested that sturgeon reside in shallower water during periods of high activity (summer) and deeper in the winter.

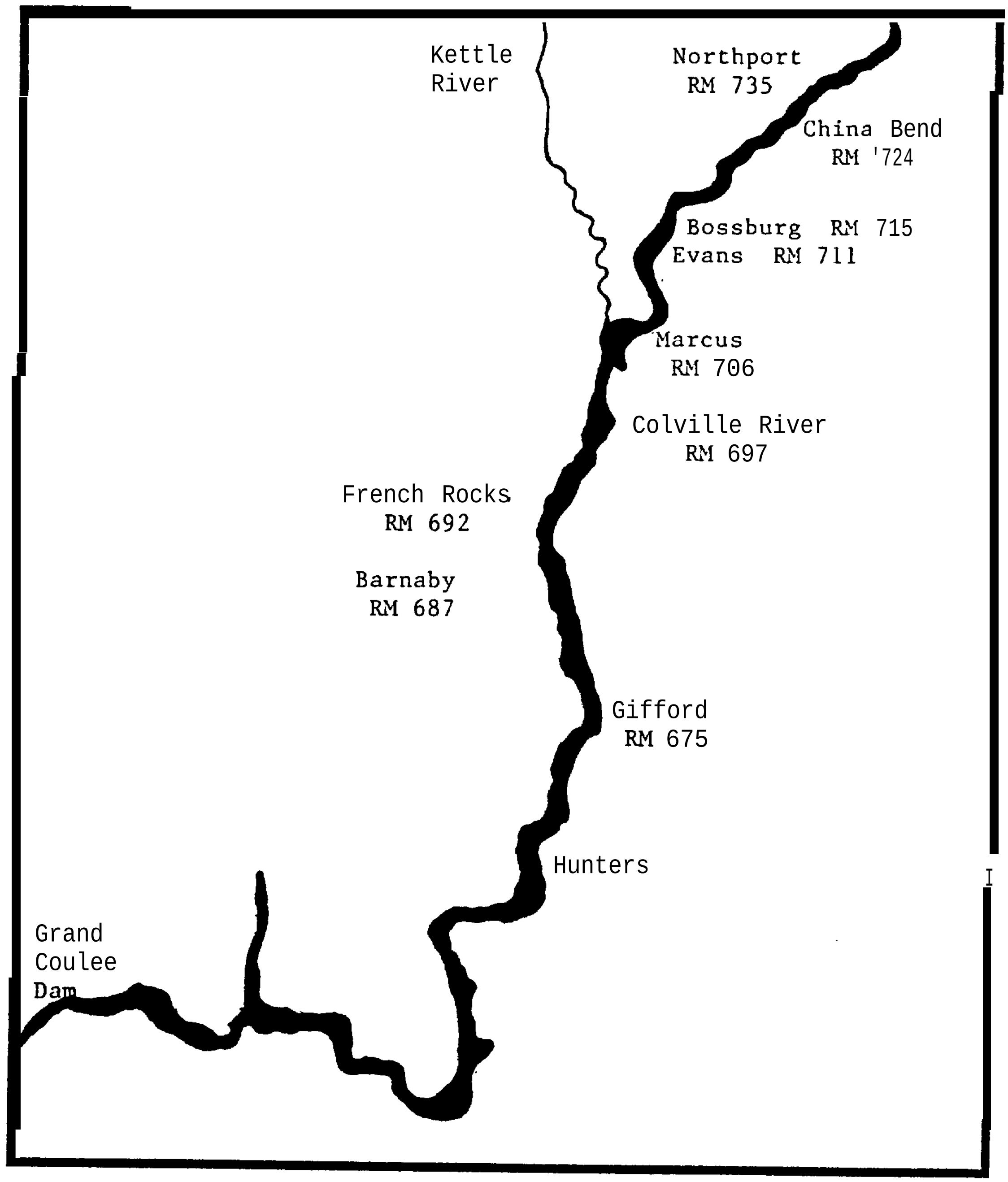


Figure 1. Map of Lake Roosevelt from Grand Coulee Dam to US/Canada border with distances between locations shown as river miles (RM) from mouth of Columbia River.

Tracking studies in other river systems on various sturgeon species (Buckley & Kynard, 1985; McCleave et al, 1977; Shubina, 1971; Hurley et al., 1987; Apperson and Anders, 1991) have provided specific information on daily and seasonal migrations, which is helpful in identifying potential spawning areas used by sturgeon. Strong indications of localized, random movement within a home range was noted by several investigators. Recent work (Apperson and Anders, 1991) on white sturgeon in the Kootenai River suggest that pre-spawning females may overwinter near the site they will use for spawning. Post-spawn females seemed to prefer overwintering downstream in Kootenai Lake. White sturgeon males in the Kootenai were found to overwinter in both locations presumably for similar reasons as the females.

In general, it appears that sturgeon spawner aggregations from early spring to mid-summer depend most heavily on the timing of increasing water temperature. Also, sport fishing for white sturgeon in Lake Roosevelt has always been most productive in early spring through the summer. The early spring catch is likely due to rising water temperatures which seem to stimulate fish to start feeding and leave the deep pools where they are believed to have over-wintered. Coinciding with'this is the annual spring reservoir drawdown for salmonid smolt passage and runoff control, which may encourage sturgeon to remain in pools due to lower water levels. The summer period, when the reservoir is usually at full pool, provides access to broader and shallower areas for obtaining food resources. The study on sturgeon movement in Lake Roosevelt was an attempt to define habitat use in such a reservoir/river system.

Materials & Methods:

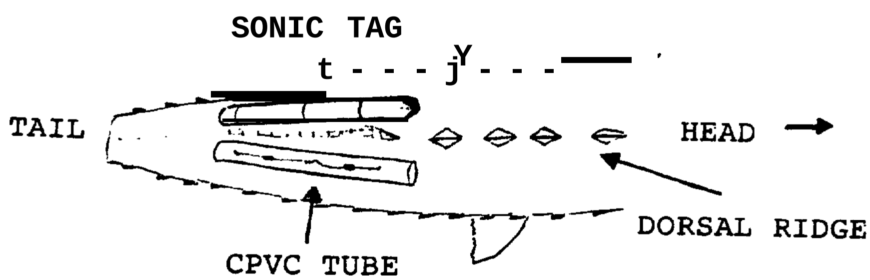
Tagging

Columbia River white sturgeon used in the study were fish captured by setlines in research on stock identification (Setter and Brannon, 1992). Setlines were polypropylene 3/8 or 1/2 inch rope, 200 ft in length with gangions clipped every 20 ft on which baited hooks were attached. Frozen salmon and trout were the most successful bait, thawed just before being placed on the hook. Captured fish selected for tagging were at least 48 inches long to eliminate potential problems with the size of the tag. The fish was kept in the water beside the 18 foot aluminum boat used to set and recover fishing gear, and released immediately after tagging.

Sonic tags manufactured by Smith-Root of Vancouver, Washington were used for the study. Sonic tags were selected over radio tags because of a better signal recovery efficiency from a boat. The sonic tag resembled a plastic cigar in size and shape and was sealed with clear epoxy resin twice. Twisted strand trolling wire used for attaching the tag to the fish was rapped around the tag at three locations and embedded in the second coat of epoxy to keep it securely connected to the tag. The tags were placed at the base of the dorsal fin and attached via the wire fed through the flesh at the base of the fin and tied to a PVC tube resembling the tag on the opposite side of the dorsal fin (Fig. 2). After placement, the flesh invasion points were rinsed with nitrofurazone to minimize infection while the wound healed.

The tags were coded with a unique manufacturing number which we utilized as the tag number. Table 1 shows the important specifications of the individual tags used during this study. Six different frequencies were utilized in combination with three pulse rates. All tags were equipped with batteries to maintain an active transmitting life of one year. Tags were activated and the signal tested prior to placement on each fish. Data for 1988 was more comprehensive as signal recovery and receiver problems hindered data collection

OVERHEAD VIEW OF STURGEON TORSO SHOWING SONIC TAG PLACEMENT



WIRE IS ATTACHED TO SONIC TAG IN THREE PLACES,
PUT THRU FISH FLESH BELOW DORSAL FIN,
AND CRIMPED ON OUTSIDE OF CPVC TUBE.

Figure 2. Drawing showing relative placement of the sonic tag on white sturgeon

during late 1989 and 1990.

Monitoring

A Smith-Root sonic tag receiver with a frequency range of 25-80 khz was borrowed from the National Marine Fisheries Service in Seattle, Washington. A hydrophone mounted to a six foot piece of 1/2 inch iron pipe was connected to the receiver via coaxial cable and a BNC connector. The BNC connector was a weak link in the design and the solder between the coaxial cable and the BNC connector pin was often severed in the field. In addition, the sonic receiver was powered by a rechargeable battery that was at its best during the first 4-6 hours of use. Background noise with the older receiver was periodically detected and unable to be filtered out. Above and beyond the physical limitations imposed by the quality of the receiver, the environment (i.e. weather) was usually the main deterrent for good data collection.

Table 1. Smith-Root Sonic Tag Technical Specification Criteria

Tag Number	Frequency PPS	Pulse Per Second
728	47	1
8128	47	2
9138	47	3
348	49	1
448	49	2
548	50	3
148	50	1
2728	50	2
648	51	3
748	51	21
848	51	3
948	52	3
	54	1
1110	54	2
12128	54	3

Monitoring from the boat involved placing a hydrophone below the water surface and slowly rotating it 360” to detect any signal being transmitted from within approximately 0.5 miles. Signal recovery was limited or enhanced by weather conditions at the reservoir. Blowing wind with high chop lowered signal recovery while calm conditions increased the recovery distance. The tag monitoring routine was to scan the river between Northport and Gifford for recovery of signals emitted by the tagged fish at bi-weekly or monthly intervals. Monitoring would concentrate on the areas where the fish were last detected, and scanning would then proceed if signals were not intercepted close to the previous location. Tag life appeared to be longer for the sonic tags installed during 1988 based on interception results. The winter of 1989 low temperatures could have limited the battery life since only few interceptions were made during the winter.

White sturgeon captured at three areas had sonic tags attached during the period from April 1988 - June 1990. The three areas chosen for tagging were representative of areas where white sturgeon tended to congregate, based on prior fishing experience. Sixteen tagged sturgeon were released; six at Marcus (RM 706), five at China Bend (RM 724), and five at Gifford’s Ferry (RM 675). The fishing around Gifford’s Ferry was the southernmost location where sturgeon had been captured, and represented the mid-reservoir area. Marcus represented the low water reservoir/river interface in the study area and the location where the largest number of fish were captured in the stock identification research. China Bend was in the upper region or the reservoir/river interface, and except at maximum reservoir height represented the typical river reach, and the northernmost area where a large number of fish were captured. Sturgeon were tagged at two sites during the initial year, with the third site (Gifford) added during the second year (Table 2). Fish were not tagged until late spring in both years because of difficulty in capturing fish earlier.

Table 2. Location and date of tag placement on white sturgeon.

Fish No.	Tag No.	Date	Location	River Mile
1	148	4/03/88	Marcus	708
2	2728	4/09/88	Marcus	708
3	248	5/14/88	Marcus	708
4	348	7/14/88	China Bend	724
5	448	7/14/88	China Bend	724
6	548	7/14/88	China Bend	724
7	948	8/28/88	Marcus	706
8	728	5/25/89	Gifford	675
9	8128	5/25/89	Gifford	675
10	9138	5/26/89	Gifford	675
11	1112	8/28/89	Gifford	675
12	1110	8/28/89	Gifford	675
13	848	9/23/89	China Bend	724
14	748	9/23/89	China Bend	724
15	648	6/07/90	Marcus	708
16	12128	6/07/90	Marcus	708

Fish locations were marked on a map based on the boat location at the surface when the hydrophone angle indicated the boat was directly overhead. In the process of fixing the site of the signal the location would be circled to locate the general position of the fish. The depth where the fish was located was identified using a depth finder with the transducer mounted on the rear of the boat.

Sediment samples

Sixteen sites from the Colville River (RM 699) to North Gorge (RM 7 19) were sampled during 1991 with a dredge to compare river bottom composition with substrate size associated with sites preferred by sturgeon. A Peterson dredge was used which sampled 225 cm^2 of surface. Each sample was collected, stored in a plastic bag and dried prior to screening. A graded series of eleven sieves from 0.124 microns to 25.4 microns were used to quantify samples. Duplicate samples were taken from each site (Table 3).

Table 3. Substrate sampling locations and depth.

Location	River Mile	Depth (Ft)	Sample
Colville River	699	100	A
		120	B
Below Colville R.	699.5	120	A
		120	B
Sherman Creek	700	100	A
		80	B
Boat Launch	701	100	A
		112	B
Below Kettle R.	706	70	A
		68	B
Kettle River	707	90	A
		85	B
Lower Marcus Flats	707.5	35	A
		35	B
Marcus Plats	708	40	A
		35	B
Marcus Channel	709	85	A
		90	B
Mile Marker	710	70	A
		70	B
Below Evans	712	70	A
		70	B
Evans	713	72	A
		70	B
Bossburg (right bank)	716	70	A
		70	B
Bossburg (left bank)	716	72	A
		70	B
Power Line	718	85	A
		50	B
North Gorge	719	35	A
		35	B

Results:

Setline catch data was used as an indication of preferred habitat areas, but the relative numbers of fish caught did not represent proportional effort. Lines were set where there was success catching fish, and sites where fish weren't caught were not routinely revisited. Catch data over the three year period (Table 4), therefore, must be viewed with such qualification. The data shows that the habitat represented around Marcus (RM 708), the low water interface between reservoir and river, was extensively utilized by sturgeon. However, China Bend (RM 724) more typical of the river above reservoir influence, and the area off the Colville River (RM 699) well into the reservoir, showed good catches and were judged to also represent preferred habitat.

Table 4. Catch summary of sturgeon for 1988, 1989 and 1990.

	Catch by Area						
	Boundary Bay	Onion Cr	China Bend	Bossburg	Marcus	Colville River	Gifford
1988	1	2	16		6	19	
1989		4	2	3	52	10	7
1990					37		
Total	1	6	18	3	95	29	7

Results from the monitoring work indicated that tagged sturgeon tended to prefer those areas where the largest number of fish were caught by setlines. Tagged fish were found to spend time in nine distinct river locations within the reservoir/river system (Table 5). Marcus was the most preferred location in the study area. Nearly all the tagged sturgeon spent time in or passed through the Marcus area. Fish #14 was the exception, but this fish was only located on three different occasions before contact was lost, and insufficient data was gathered to determine the extent of movement.

Overall movement by river mileage was graphed separately for each fish (Appendix Figures 1-16). Excluding fish #14, all sturgeon captured and tagged at China Bend were downstream from their original capture site (RM 724) at the end of their tag battery life. Two traveled downstream and returned upstream, and two continued further down the reservoir. Fish #4 traveled down to the Bossburg area, while fish #5 traveled approximately 27 miles to French Rocks (RM 692). Fish #'s 6 and 13 traveled ten miles downstream to the Marcus Area. Six fish tagged in the Marcus area remained in this area through to the end of the study period, although local movements were observed. The five remaining fish were tagged in the Gifford area (RM 675). All five of the Gifford fish moved upstream during the subsequent tracking interval. Fish # 8, 9 and 10 moved upstream to the Marcus area, fish #1 1 and 12 moved upstream past Marcus to the Bossburg area. Only one of the five made an excursion back to the reservoir before returning to the river.

Table 5. Percent time tagged sturgeon spent in river areas.

Area	River Mile	Percent
North Port		2
China Bend	734 725	14
Bossburg	715	13
Evans		6
Marcus	706 710	55
Colville River	697	6
French Rocks	692	< 2
Bamaby	687	< 2
Gifford	675	3

Examining depth at which fish were located in relation to reservoir level, time and water temperature provided the most descriptive representation of factors influencing movement patterns (Appendix Figures 1- 16). An increase in water temperature in conjunction with time of year corresponded with movement into shallow water, and retreat into deeper water occurred with temperature decreases. Location, however, influenced the options that a fish may have available for depth selection. If very deep water was to be sought, the fish would have to be in the reservoir close to the old river channel. Fish that remained in the Marcus area during reservoir draw-down had little choice but to be in shallower water at that time. Similarly, if fish were in the upper river, maximum depth available was very much influenced by their location in the river. Apparently other environmental factors were of importance in fish distribution because tagged fish didn't reside in some river locations where deep holes were available. Although turbidity wasn't measured, and showed no correlation in sturgeon distribution in the Kootenai study (Apperson et al., 1989), visible turbidity increased during the spring and summer months, corresponding with temperature increases.

Substrate was another variable that no doubt influenced where the sturgeon selected temporary residence, but again substrate composition isn't a factor that one can isolate from other environmental variables in this particular study. Finer materials settle out where velocity reduction occurs in broad deep areas of the river, and thus some of the relationships suggested by bottom composition would also apply to other variables.

The percent of fines was very high at sites below or near river confluences (Fig. 3-6). Fine material usually dominated the quiet water and hard bottom was associated with higher velocity currents. Sites where sturgeon showed highest residence time (RM 699 and 708) was in very fine sediment (<. 124 micron sieve), corresponding with low velocities, but were also associated with areas close to the transition zones at the confluence of a river with the reservoir environment. Rock or hard bottom where the dredge was unable to penetrate was encountered at sites 11, 13,and 16 in higher velocity areas of the river section.

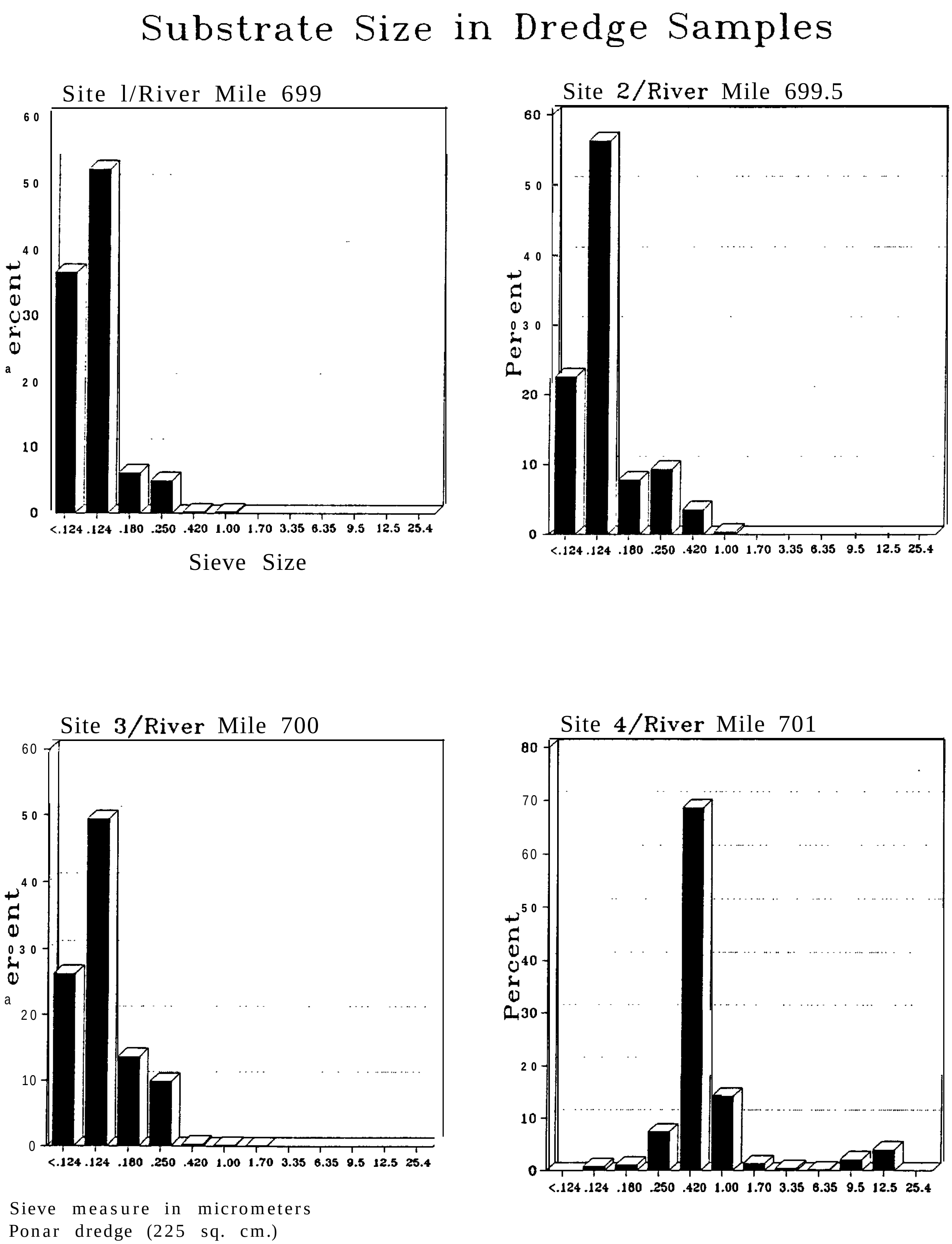
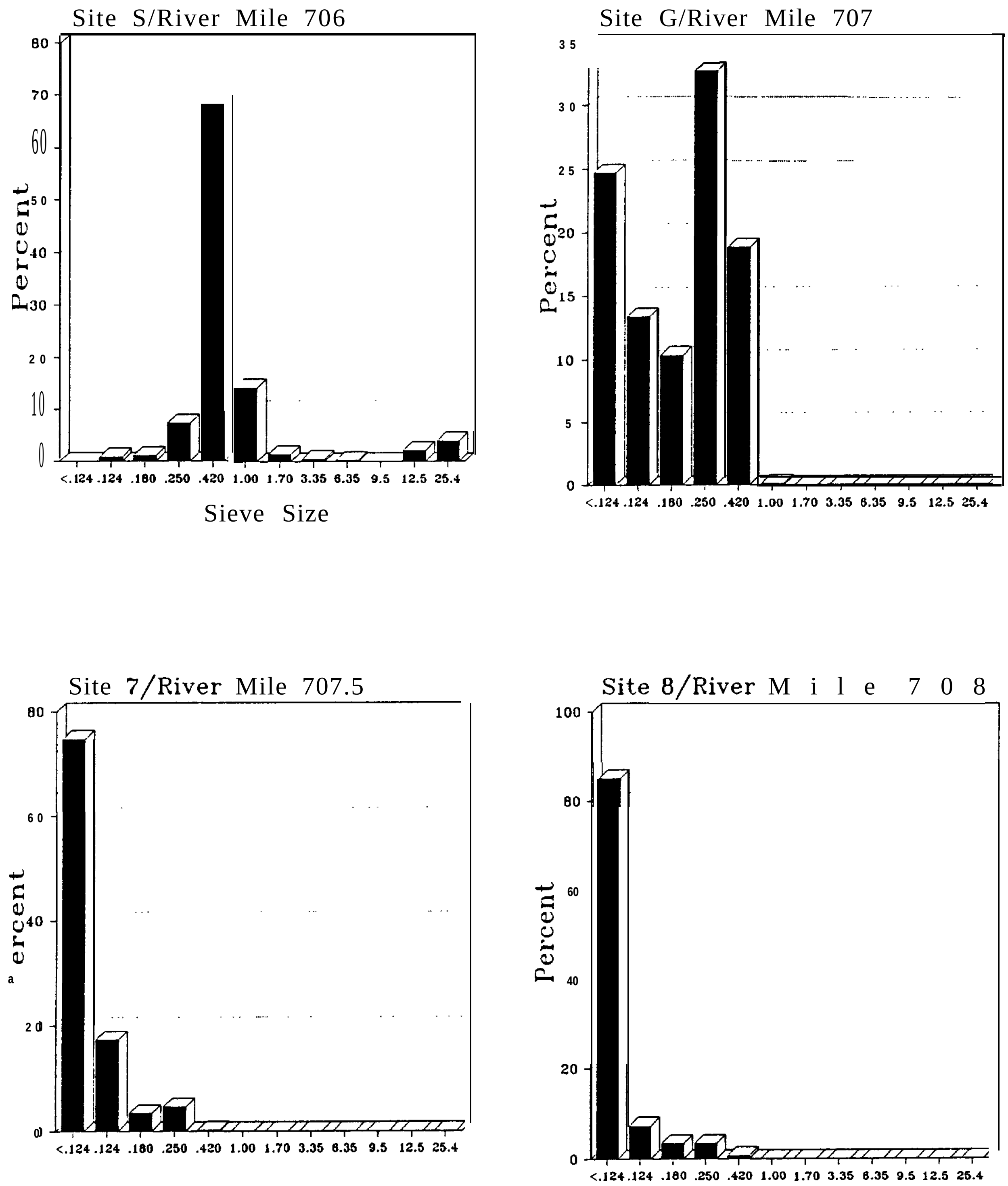


Figure 3. Substrate sizes in dredge samples taken from sample sites 1, 2, 3, 4 within Lake Roosevelt.

Substrate Size in Dredge Samples



Sieve measure in micrometers
Ponar dredge (225 sq.cm.)

Figure 4. Substrate sizes in dredge samples taken from sample sites 5, 6, 7, 8 within Lake Roosevelt.

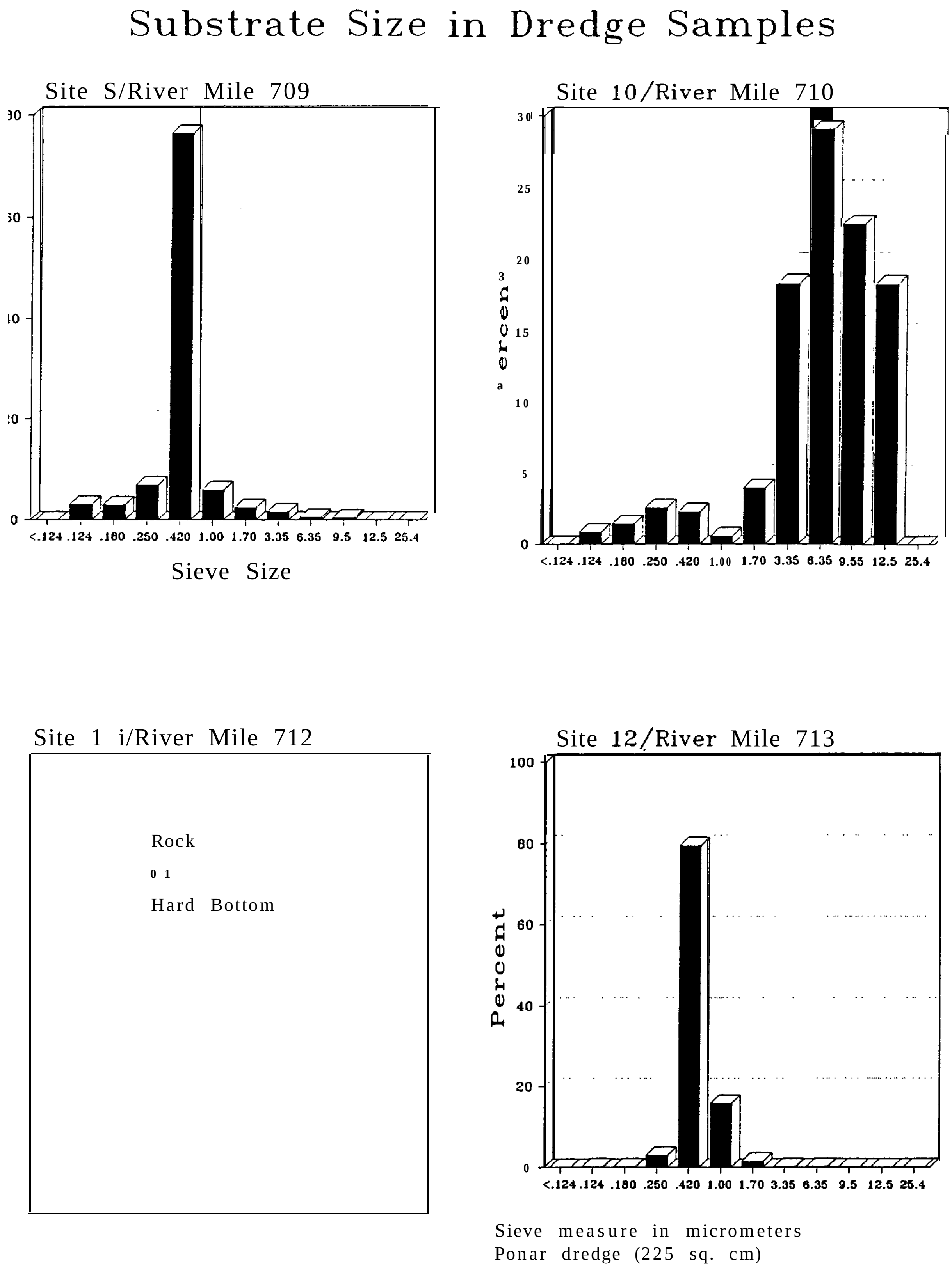


Figure 5. Substrate sizes in dredge samples taken from sample sites 9, 10, 11, 12 within Lake Roosevelt.

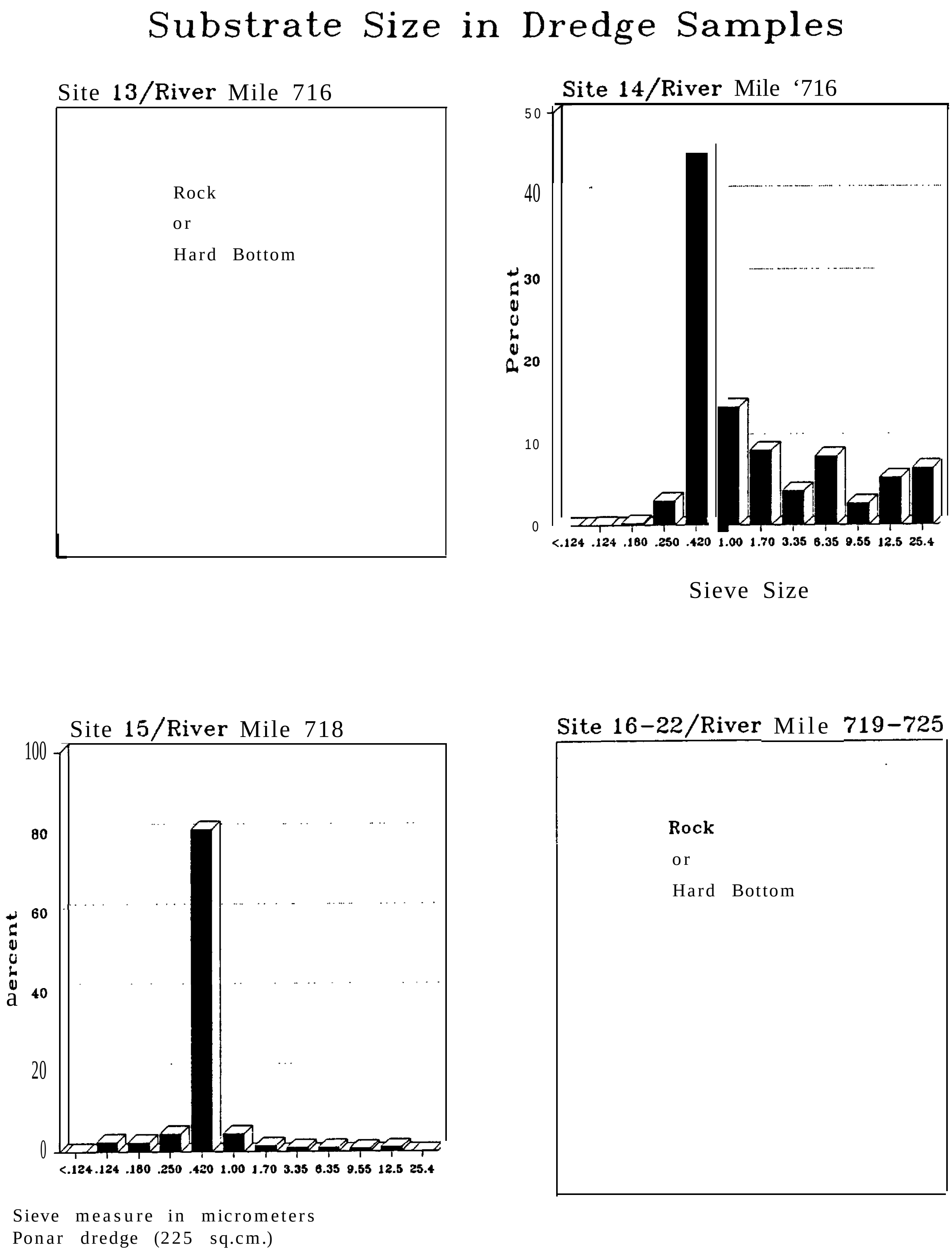


Figure 6. Substrate sizes in dredge samples taken from sample sites 13, 14, 15, 16 within Lake Roosevelt.

Discussion:

The Null Hypothesis investigated that movement patterns of white sturgeon in reservoir/river systems are random and not related to any characteristic of the environment. Within Lake Roosevelt, the null hypothesis was rejected due to the heavy use of reservoir in the Marcus area. This finding demonstrated that certain environmental factors play a role in influencing habitat preference. The specific factors, likely related to food availability and readiness for spawning may be common to the confluence of rivers into reservoir environments. However, in the case of Lake Roosevelt, the lower end of the interface between the river and reservoir happens to be located in a wide expanse of the reservoir forming a very large low velocity basin that is particularly suited for bottom substrate and flow patterns that sturgeon appear to prefer. Also, the Kettle River enters the Columbia at Marcus flats, which created very deep holes in which sturgeon can retreat. With the Kettle River bringing in nutrient, and the reservoir creating the first significant velocity reduction to settle silts and nutrients within the reservoir, it appears the right combination of factors are provided to attract sturgeon to that area.

For reasons that can only be hypothesized about at this point, the Marcus area is very important for the sturgeon population in Lake Roosevelt. Catch data from the study is supported by the sportsmen success in fishing for sturgeon at that location. Although access has played a role in making this a heavily fished area, the major reason is sturgeon appear to concentrate in that region of the reservoir/river system, and most likely have from the time Lake Roosevelt was impounded. Prior to flooding, Kettle Falls would have been a barrier except at certain flow conditions. It is possible that even then the Marcus area was a prime location for sturgeon.

Regarding the use of reservoir habitat, it was concluded from this study that such areas are readily used by sturgeon in Lake Roosevelt, and even preferred by some individuals at various times of the year. This appears contrary to observations made by Coon et al (1977) in the Snake River. However, the nature of the location at the interface of the reservoir and river system probably has a considerable influence on the residence behavior of the species. Also, the area of interception, ie. impoundment or river, may bias measures of subsequent preference behavior since the fish may only represent the behavior mode it is presently in at the time of capture. In general, habitat preferences are probably area specific depending on local geography. A seasonal movement pattern was noted, with a tendency to move downstream in the summer and fall months, and upstream in the winter and spring months. All the sturgeon showed a general tendency to stay in shallower water (80 feet and less) during the spring and summer months, and move to deeper water during the winter.

Observations from the present study were similar to that found on the Kootenai River with regard to some tagged fish not moving very much over the study period. However, in Lake Roosevelt that was only true for fish that had their sonic tag placed on while in the Marcus area. Other fish moved extensively. The fish from China Bend moved downstream to Marcus, and Gifford fish moved rapidly to and took up residence in the Marcus area, suggesting that Marcus may be both a feeding and spawning staging area. Fish captured at Gifford could have been moving to Marcus for reproductive activity the following year. Marcus may also have sufficient food resources for fish to drop downstream and recover after spawning. If this is the case, there may be general movement of fish throughout the system towards Marcus. At one time three fish tagged from well separated locations had traveled to Marcus and were so close to one another the tag signals appeared to be coming from the same spot over two days of monitoring.

Evidence was also apparent from setline data that residence behavior may be quite lengthy in some preferred habitat. Fish caught off the Colville River at RM 699, an area rich in very sediments, showed evidence of lengthy residence by the red abdominal stains acquired from the red silts. Dark red stains over the entire ventral surface and mouth parts from the bottom composition indicated they were not transient, but probably had resided in that area for an extended length of time. Red stains weren't detected on fish caught at other locations such as Gifford and Marcus. Preferred areas may have resident populations that don't leave the area except for spawning activity.

The substrate composition data was useful in demonstrating the general nature of the habitat preference, at least during the more sedentary period of their movement pattern. The presence of fish in areas with high levels of very fine bottom -sediments indicates that areas with reduced bottom currents or the substrate itself was generally favored. Substrate size associated with where fish most often resided would pass through the 0.42 micron sieve. This supports experimental findings of white sturgeon feeding behavior observed from laboratory studies (Miller, 1987). Similarly, shovelnose sturgeon were found by Hurley et al.(1987) more often over sand substrates than rock. White sturgeon appear to prefer substrates where food resources are most probably found.

Johnson et al. (199 1) noted that the upper stretch of Lake Roosevelt mimics an erosional rather than depositional sedimentation situation based on measures of toxic material accumulated within the sediments. Their data presents Marcus as the most downstream region prior to settling of suspensions introduced from the Celgar mill waste. Marcus is located just above a velocity reduction interface, which was apparent from the sediment samples collected there.

Observations from setline data in the sturgeon stock identification study gave some interesting but limited insight about the population not readily detected from the tag data. Apparent lower success rate by sturgeon sportsmen in Lake Roosevelt has caused some concern about the production potential of sturgeon in the system. Potential prey fish populations (squawfish, peamouth, suckers) has dropped in recent years based on their low rate of interception by the sport fishery. It is likely that the additional cropping by walleye on some of these overlapping forage species may limit prey availability to sturgeon. Certainly, sturgeon ability to predate on fish species has been demonstrated, and reduced numbers of prey fish species could affect sturgeon population size and growth. With regard to production, only one sturgeon sampled in the genetics sampling program was subsequently recaptured, which suggests the population size in the study area is not too depressed. One fish less than 50 cm was caught, but several were less than 100 cm which suggests that reproduction has been occurring in the reservoir/river system during the nearly 50 years of impoundment.

However, on the negative side, the length frequency distribution of sturgeon captured over the three year study (Fig. 7) indicates that the dominant size class among captured fish was around 150 cm. Fish that size in the lower part of the Columbia River would be around 20 years of age (Nigro, 1988), but in the upper portion of the river, 150 cm sturgeon is 25 to 30 years old (unpub. data, J. Hammond, BC). While that age class would have originated from spawn since Grand Coulee was built, the length distribution is similar to that of Kootenai River (Apperson 1990). The large fish size of the Kootenai River population is believed indicative of very little recruitment. In contrast, sturgeon caught in tagging operations below Bonneville Dam (Nigro, 1988) where good recruitment occurs, have a dominant length distribution represented by much smaller fish.

Reaching conclusions about poor recruitment occurring in Lake Roosevelt based just on the lack of small fish in setline catches, however, isn't warranted without considering other information. Young and older sturgeon are known to segregate in

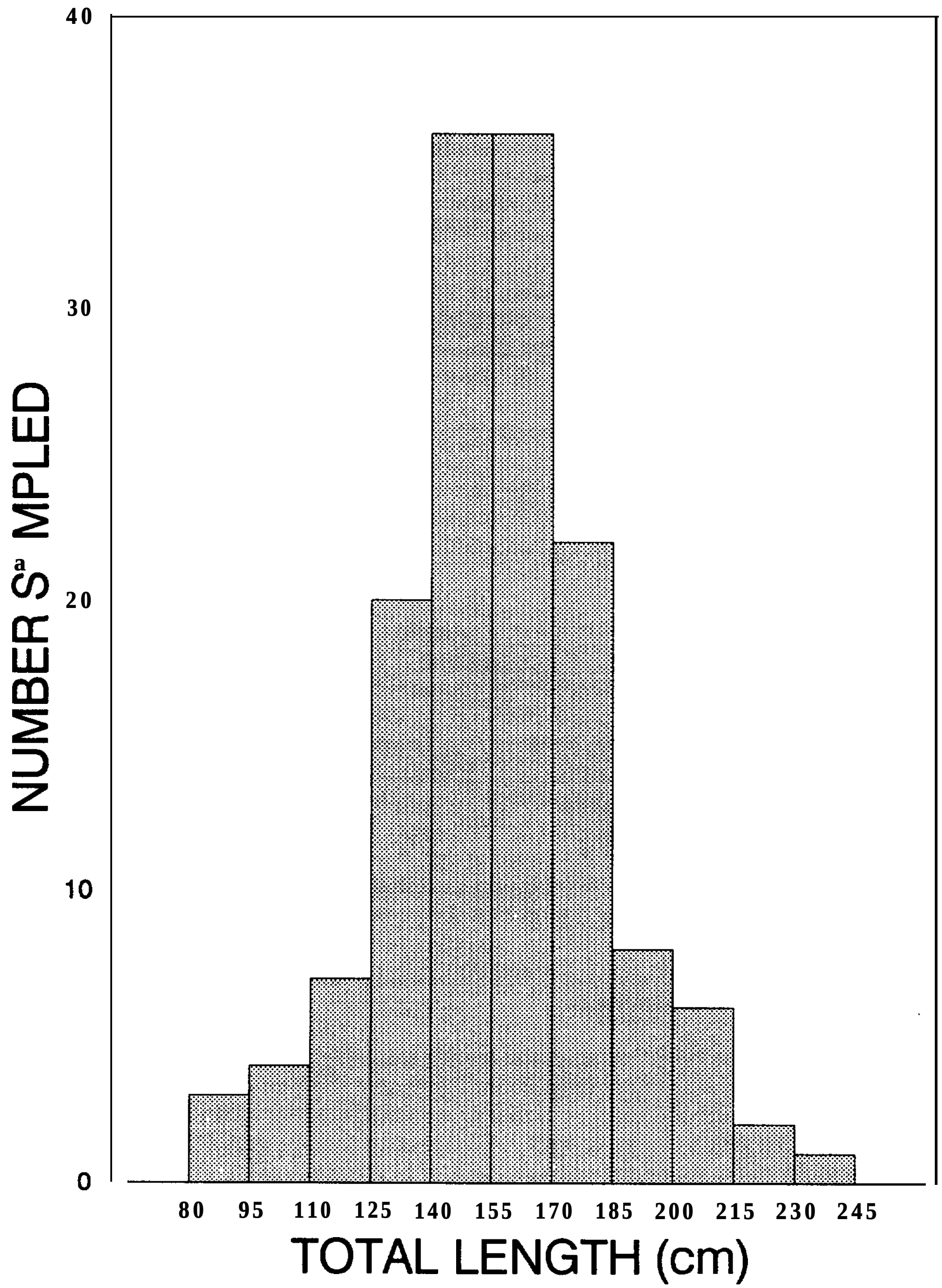


Figure 7. Graph of sturgeon captured during sampling (1988-1990; n=145) in Lake Roosevelt by their total length.

different areas in other systems, and fishing effort in this study didn't attempt to monitor distribution by catch. Effort was expended primarily in areas where success was experienced, and that could seriously bias the catch toward larger fish. Also, sport fishing at Boundary Dam on the Pend O'reille River as it enters the Columbia was a favorite sturgeon fishing site of British Columbia sportsmen. The size of fish caught varied, but there was a preponderance of young sturgeon around the 100 cm. size range, which suggests that young fish reside in the river well above the reservoir for some time before joining the larger fish downstream.

Although the tagging study did not encompass the river area north of the US/Canada border, we feel this area may be very important in the life history of Lake Roosevelt white sturgeon. Canadian Ministry of Environment creel records show a somewhat steady annual fishery for sturgeon at the confluence of the Pend O'reille and the Columbia, and the area upstream where the Kootenai enters the Columbia. This region needs further investigation particularly with respect to spawning activity and the subsequent early life history.

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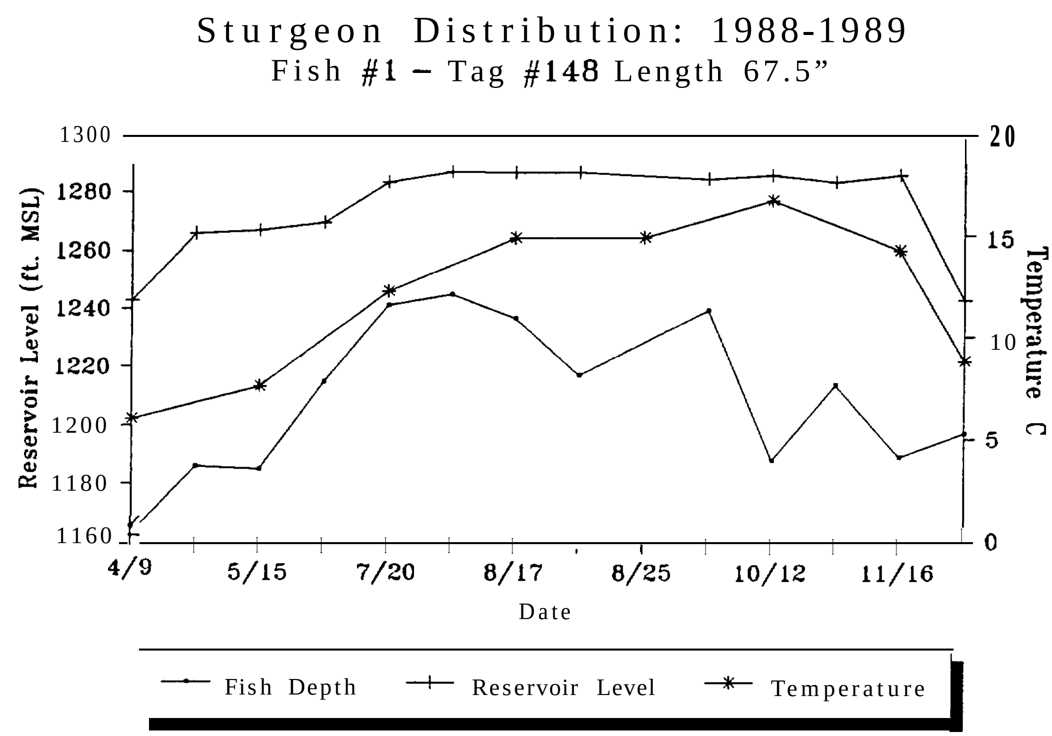
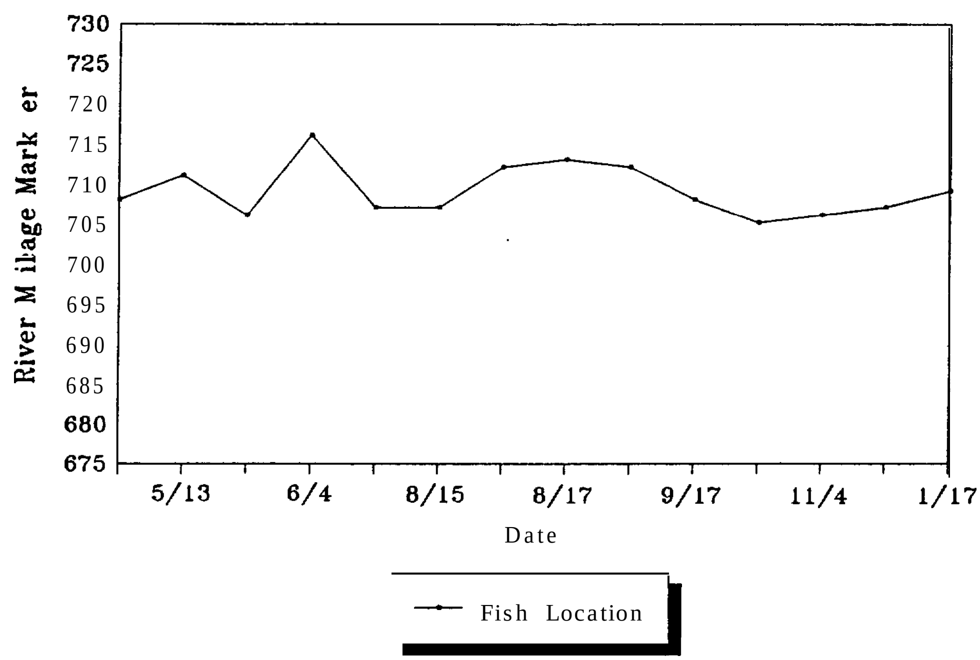
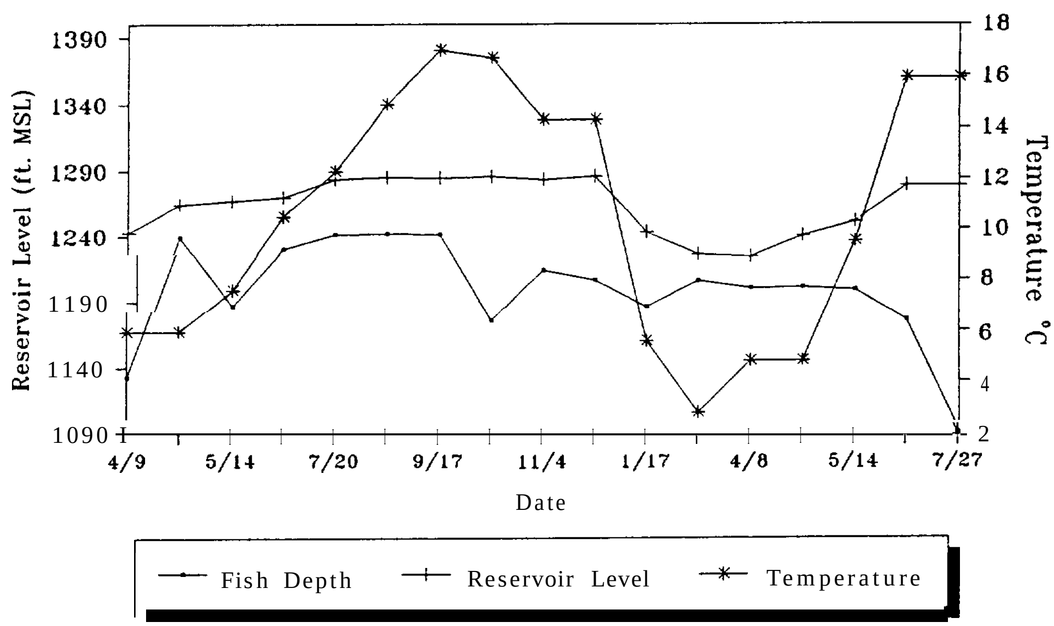
APPENDIX

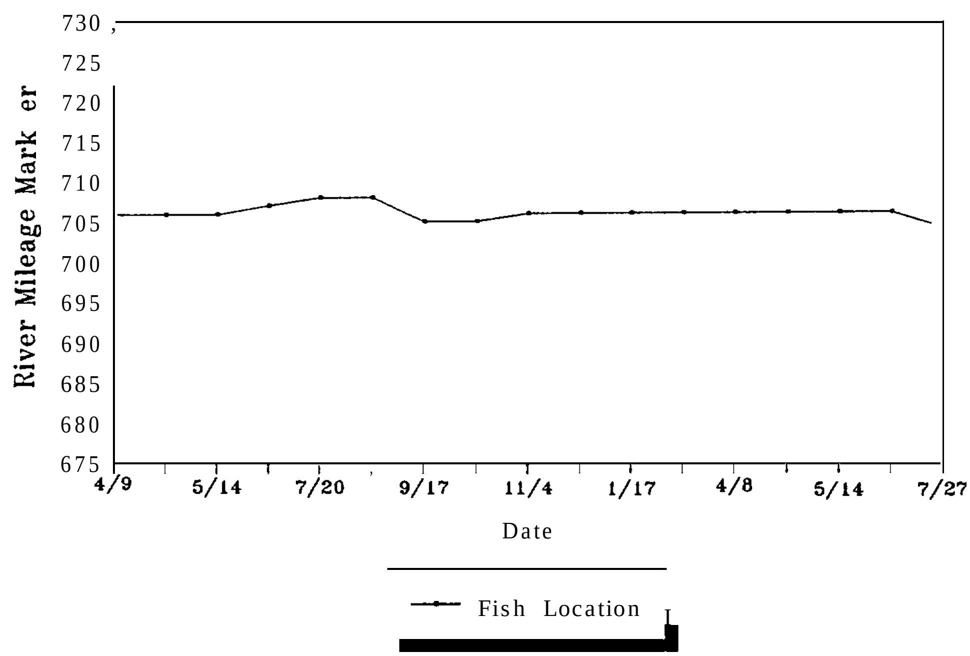




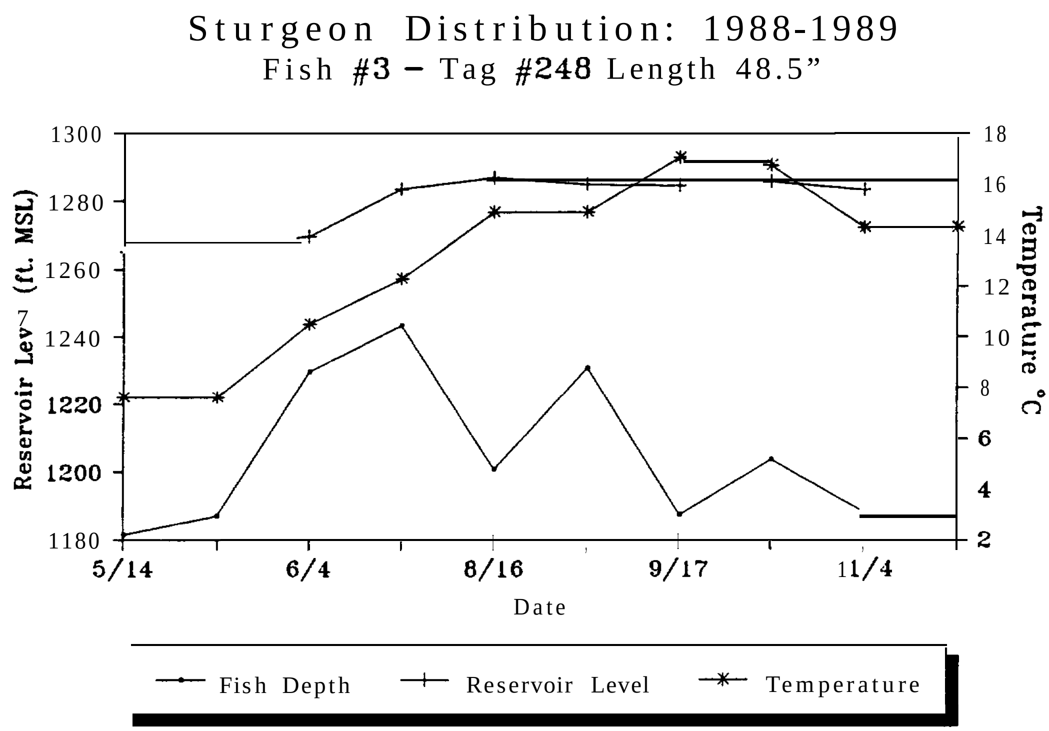
Appendix Figure 1. Movements and distribution of tagged sturgeon #1 in Lake Roosevelt in relation to time of year, temperature and reservoir level.

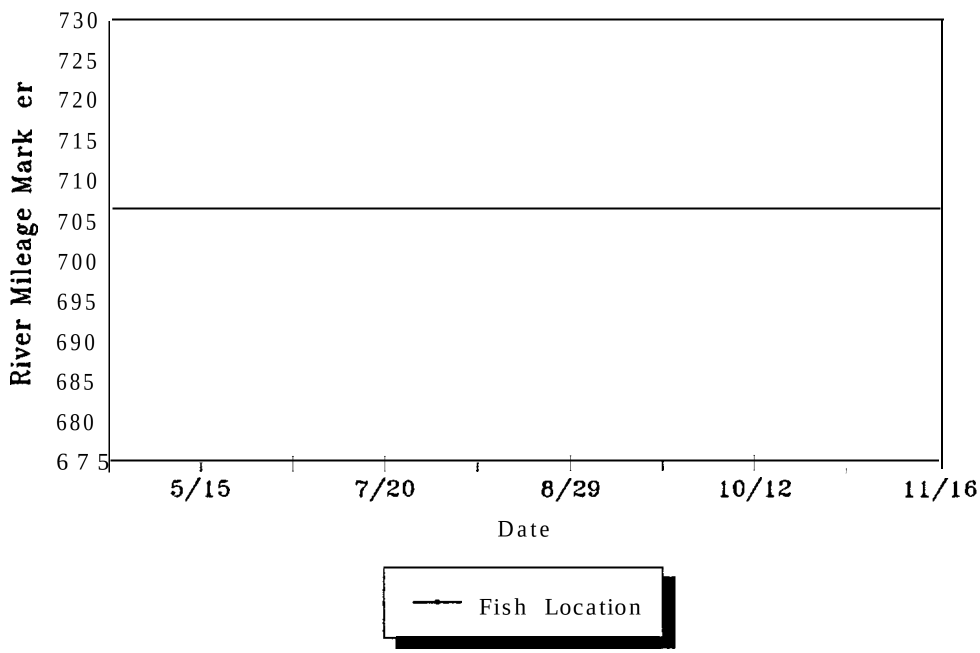
Sturgeon Distribution: 1988-1989
Fish #2 – Tag #2728 Length 60.0”



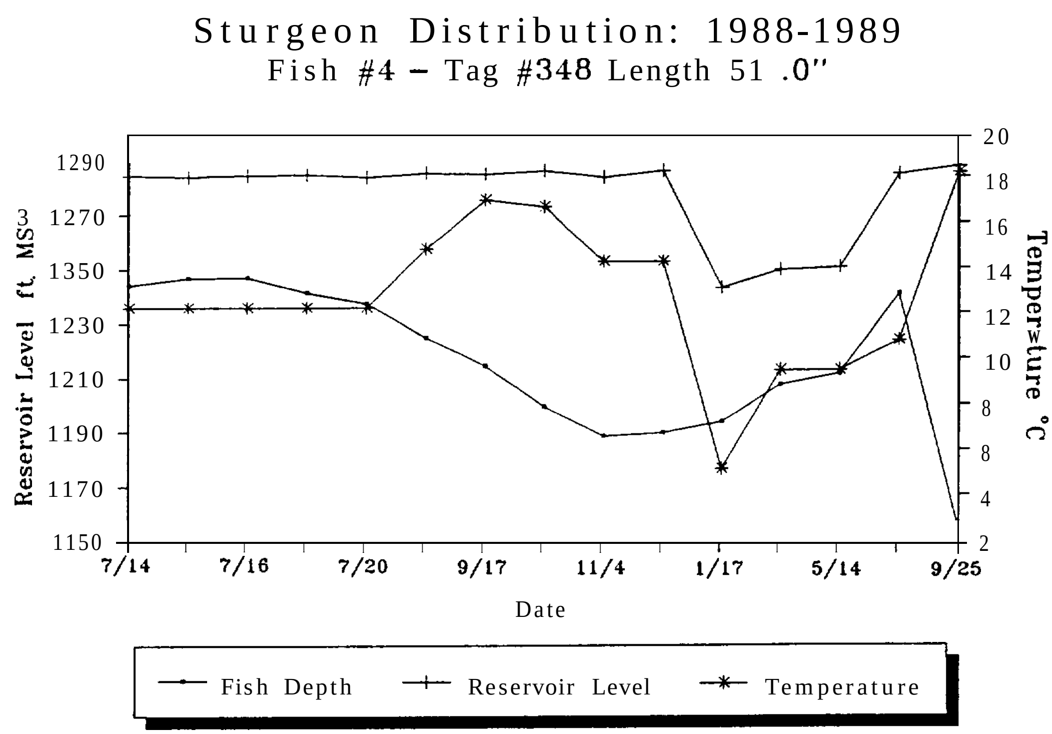


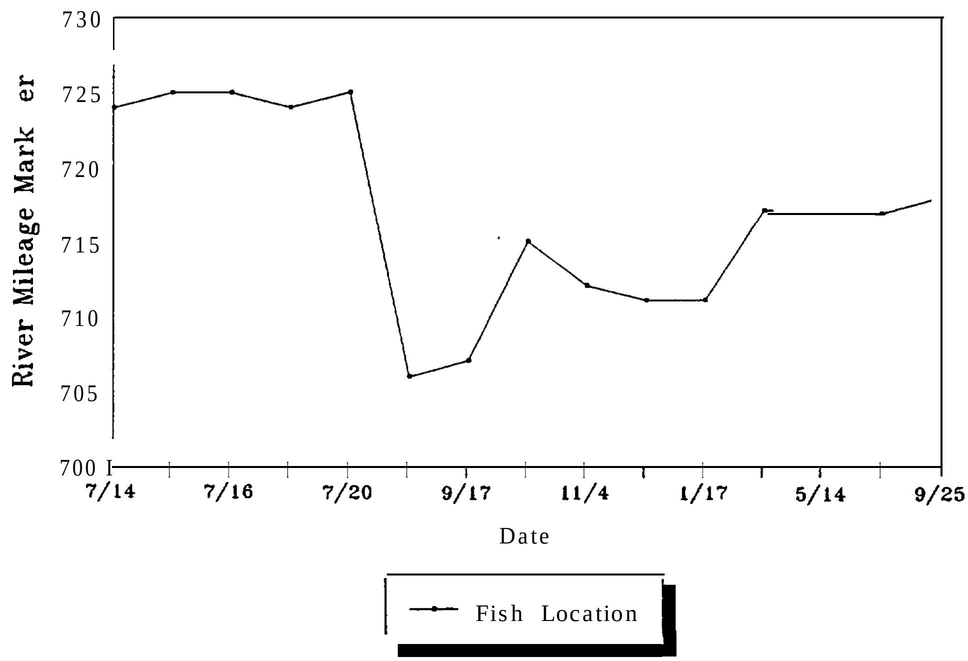
Appendix Figure 2. Movements and distribution of tagged sturgeon **#2** in Lake Roosevelt in relation to time of year, temperature and reservoir level.



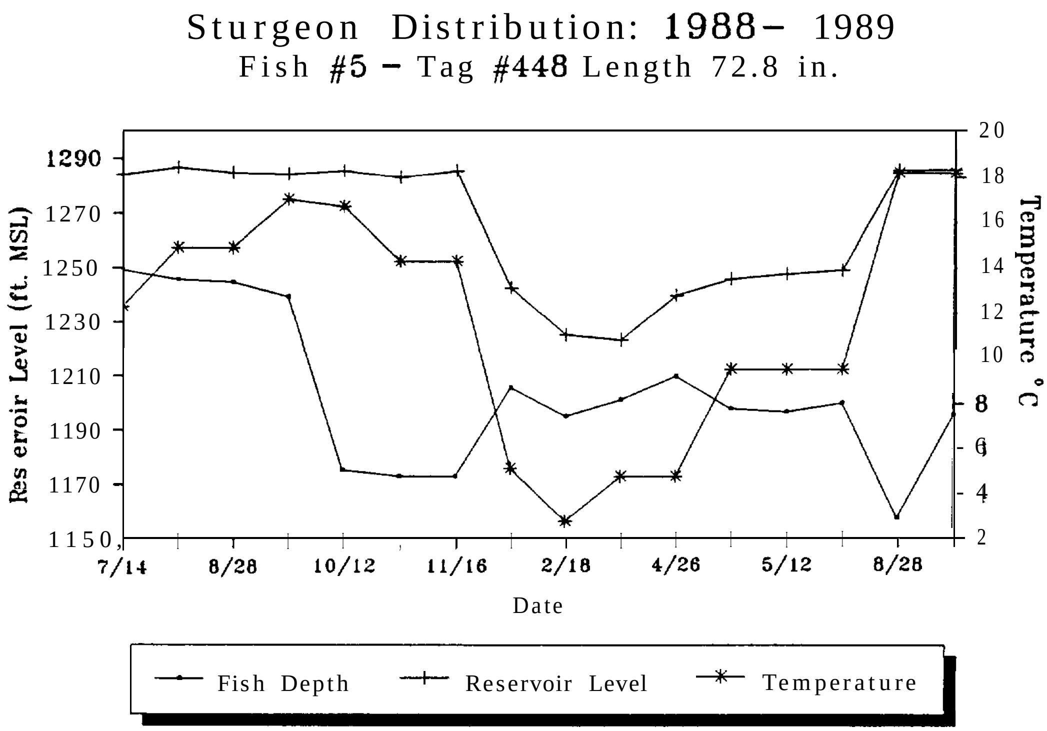


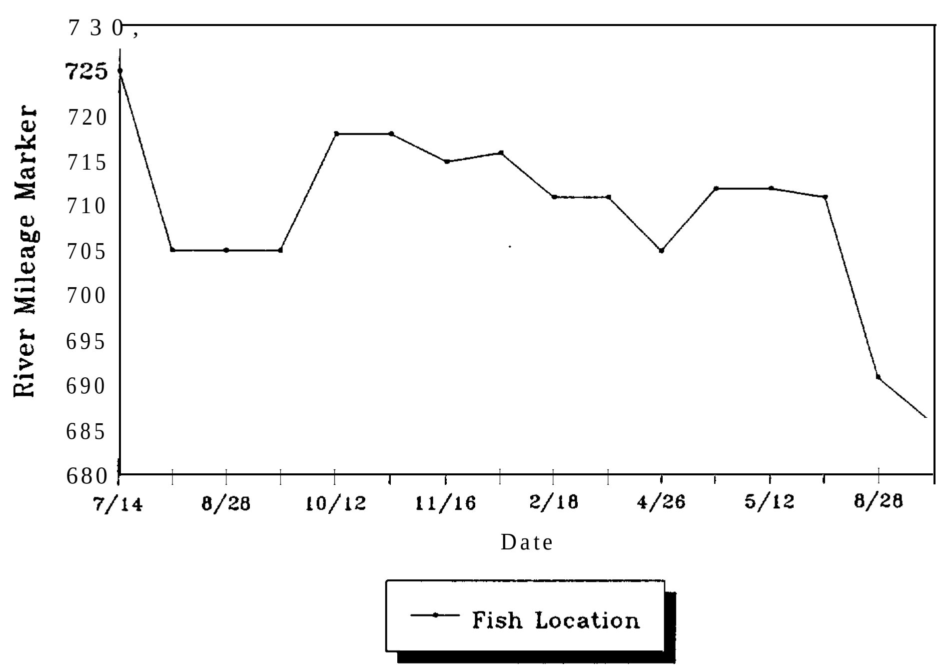
Appendix Figure 3. Movements and distribution of tagged sturgeon #3 in Lake Roosevelt in relation to time of year, temperature and reservoir level.





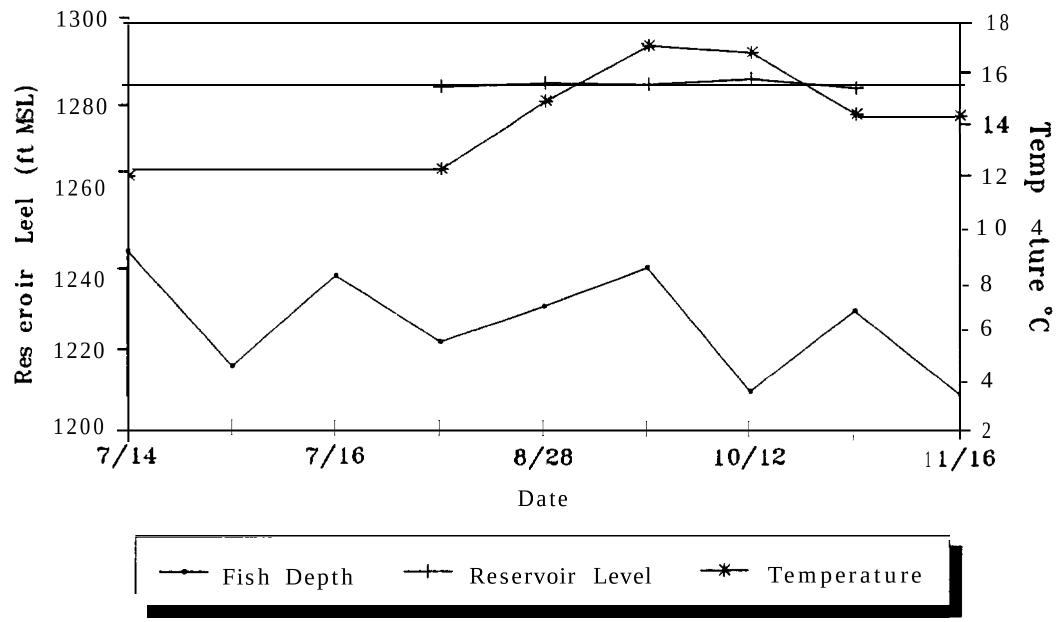
Appendix Figure 4. Movements and distribution of tagged sturgeon #4 in Lake Roosevelt in relation to time of year, temperature and reservoir level.

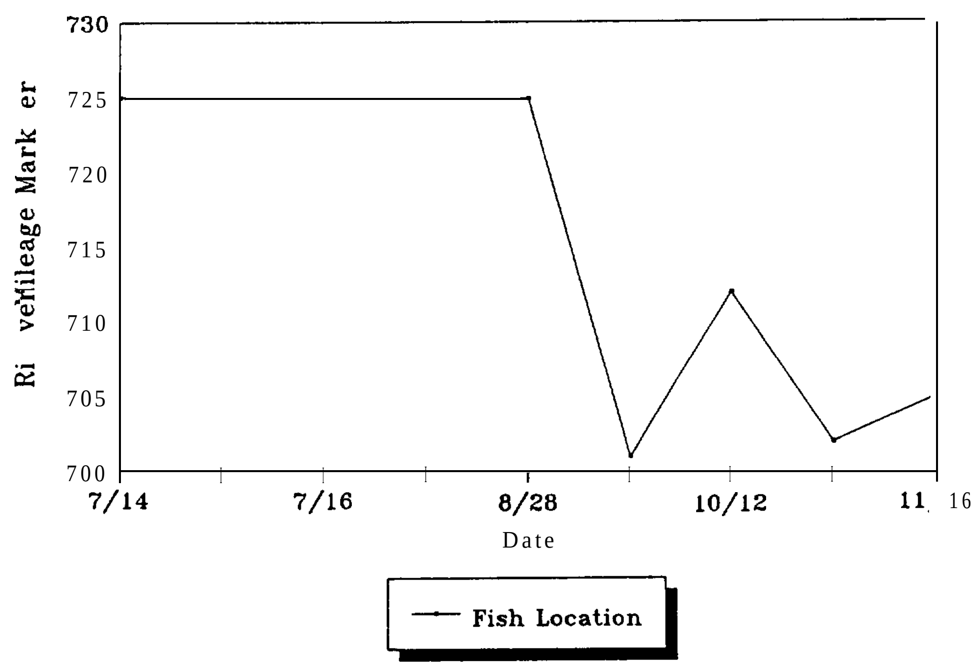




Appendix Figure 5. Movements and distribution of tagged sturgeon #5 in Lake Roosevelt in relation to time of year, temperature and reservoir level.

Sturgeon Distribution: 1988-1989
Fish #6 – Tag #548 Length 52.5"

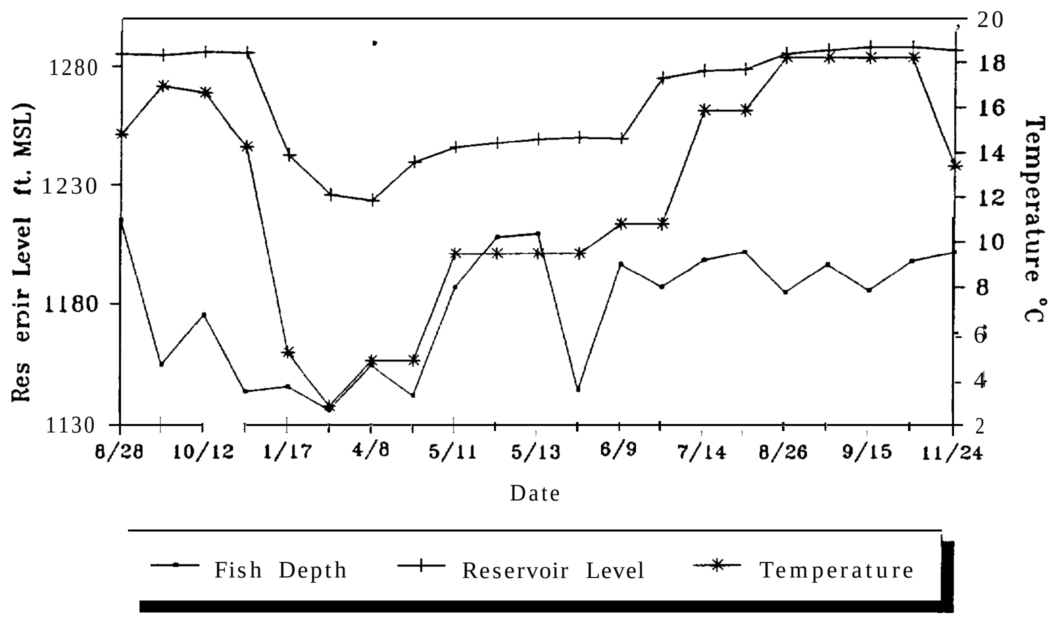


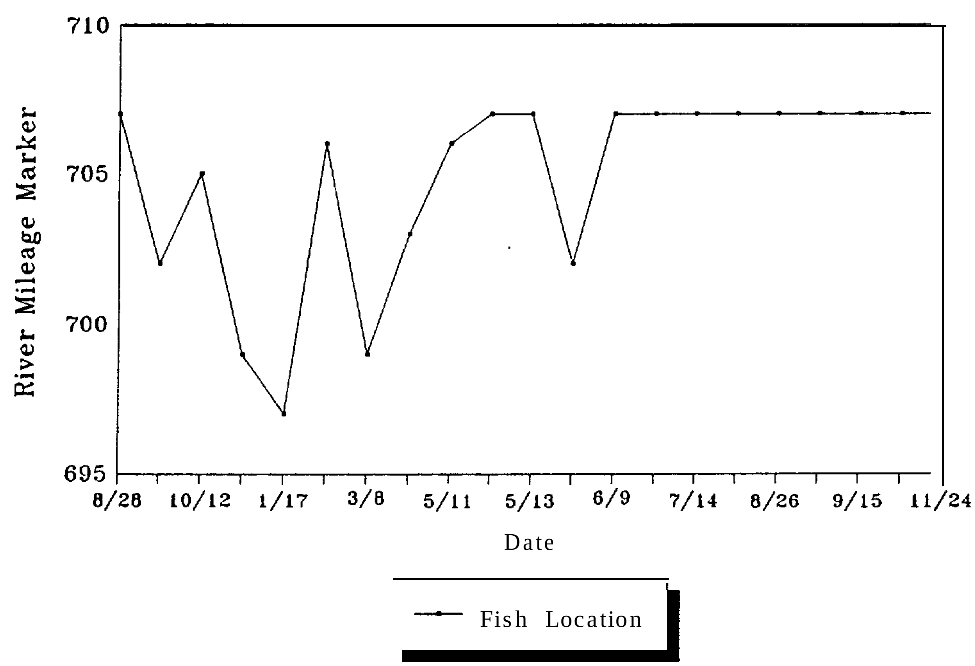


Appendix Figure 6. Movements and distribution of tagged sturgeon #6 in Lake Roosevelt in relation to time of year, temperature and reservoir level.

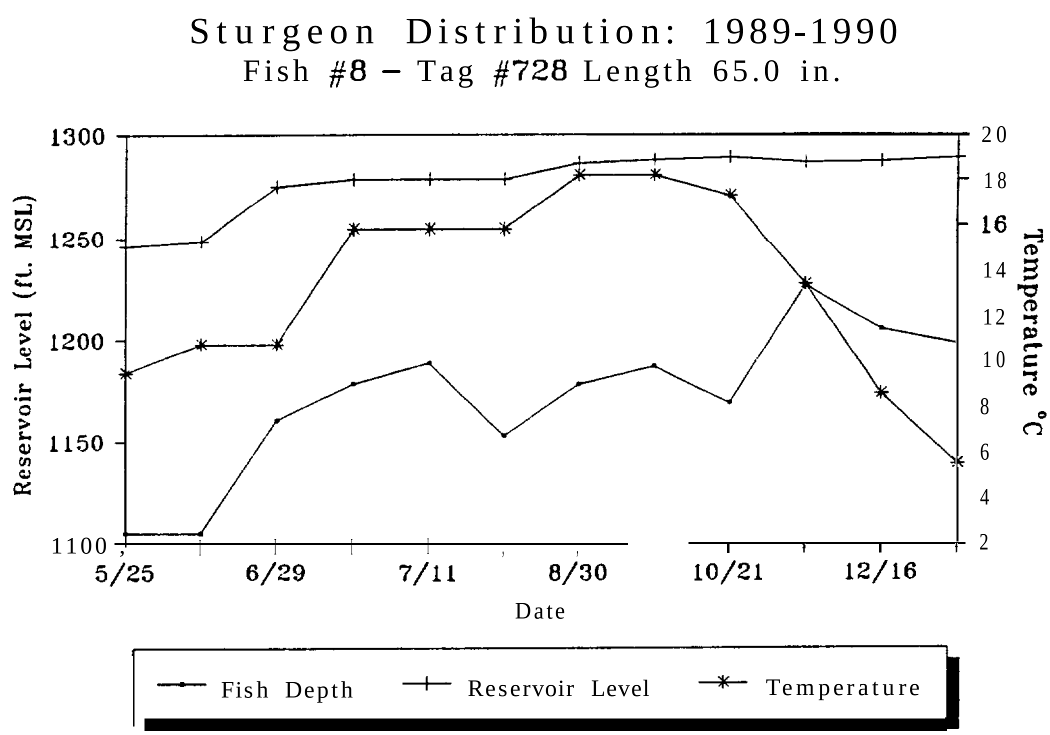
Sturgeon Distribution: 1988-1989

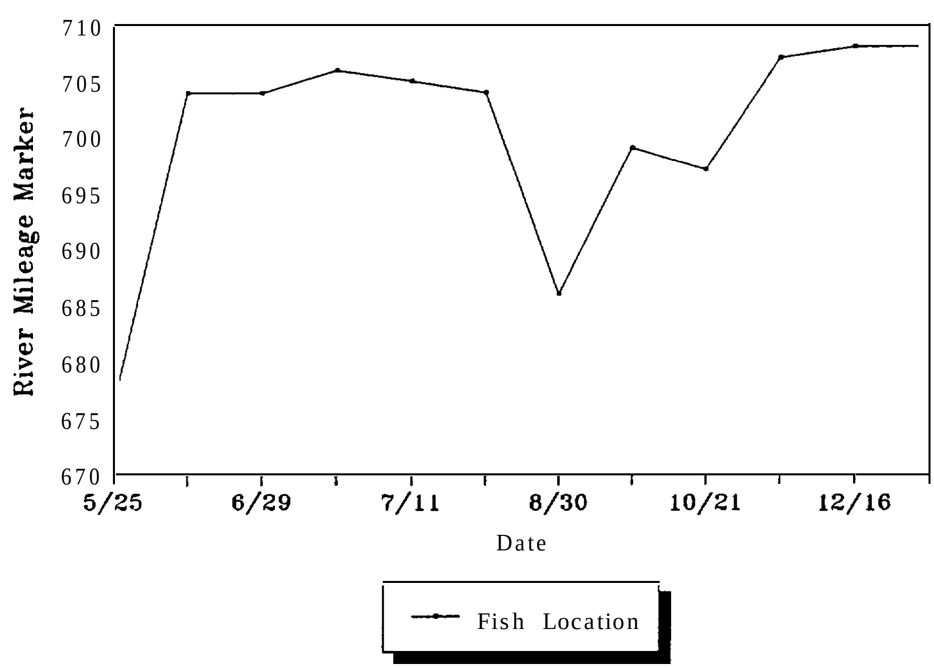
Fish #7 – Tag #948 Length 81.75 in.





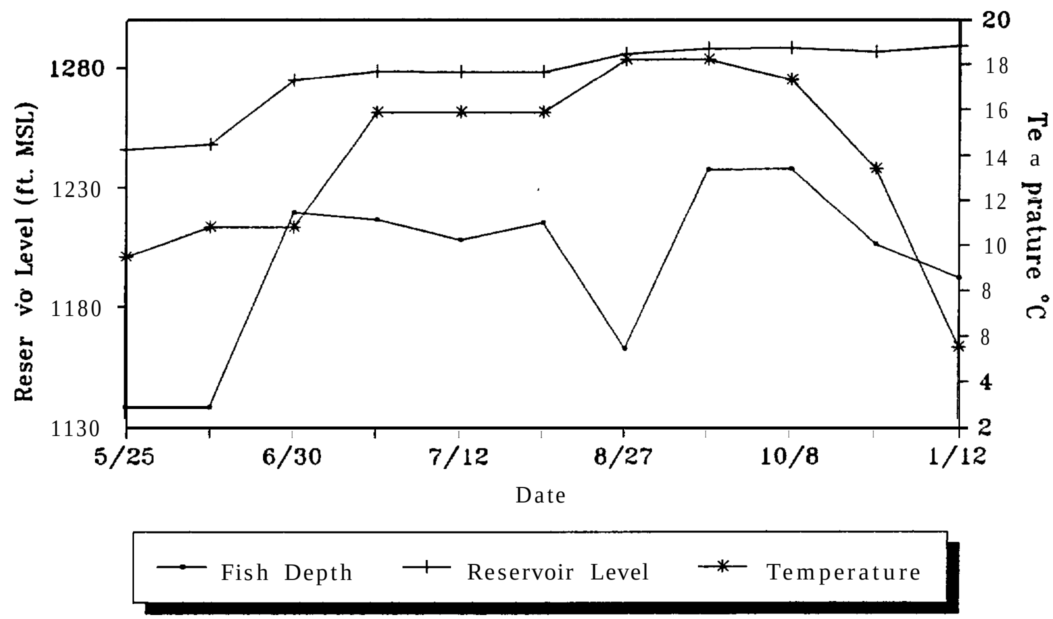
Appendix Figure 7. Movements and distribution of tagged sturgeon **#7** in Lake Roosevelt in relation to time of year, temperature and reservoir level.

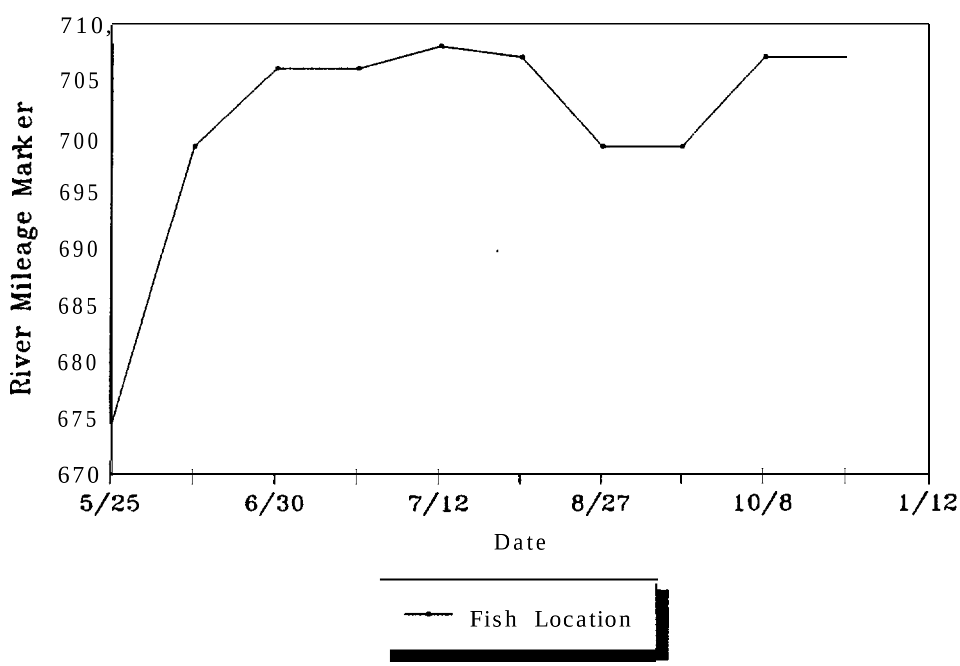




Appendix **Figure** 8. Movements and distribution of tagged sturgeon **#8** in Lake Roosevelt in relation to time of year, temperature and reservoir level.

Sturgeon Distribution: 1989-1990
Fish #9 – Tag #8128 Length 60.0 in.

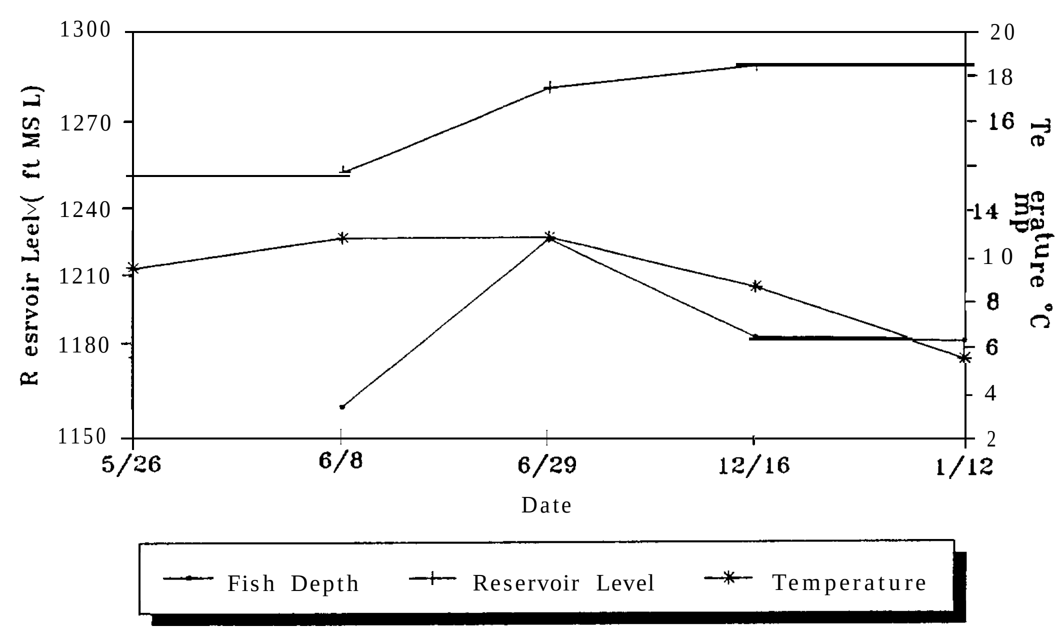


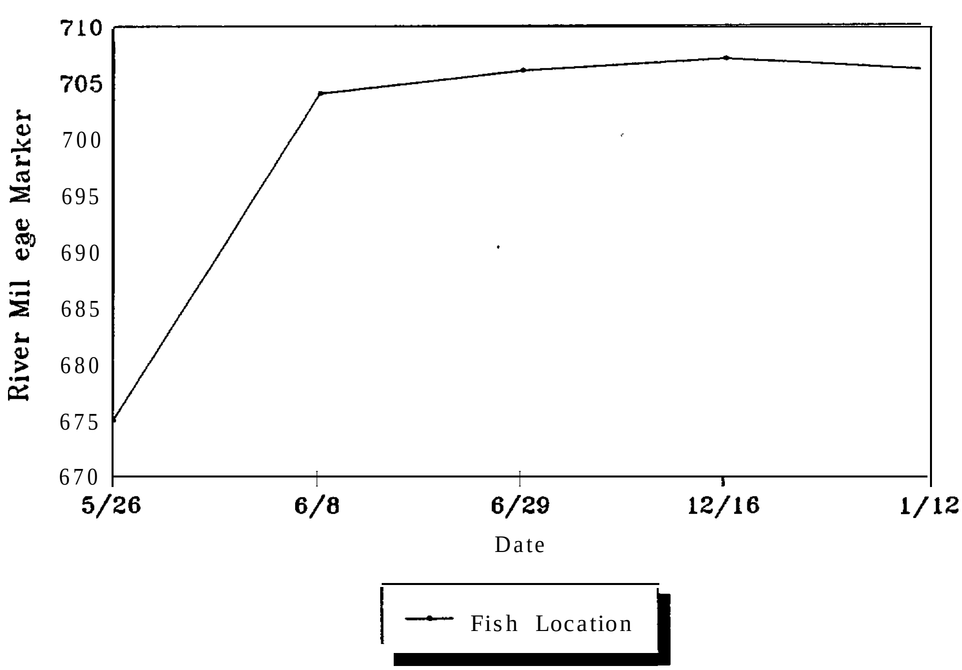


Appendix Figure 9. Movements and distribution of tagged sturgeon #9 in Lake Roosevelt in relation to time of year, temperature and reservoir level.

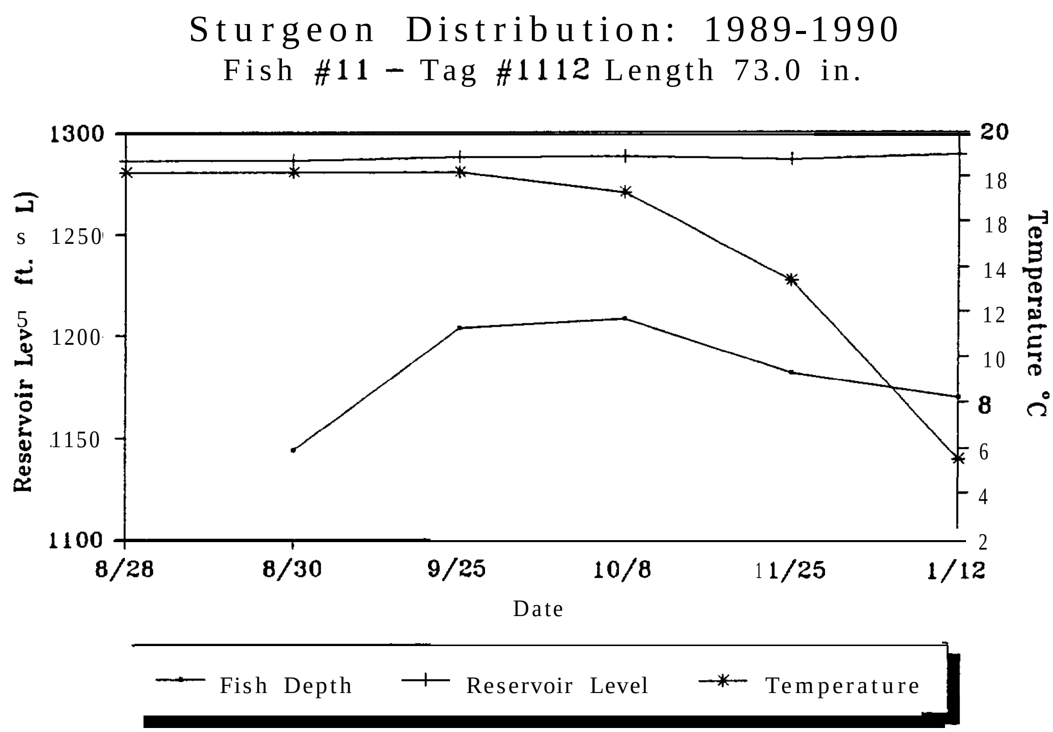
Sturgeon Distribution: 19894990

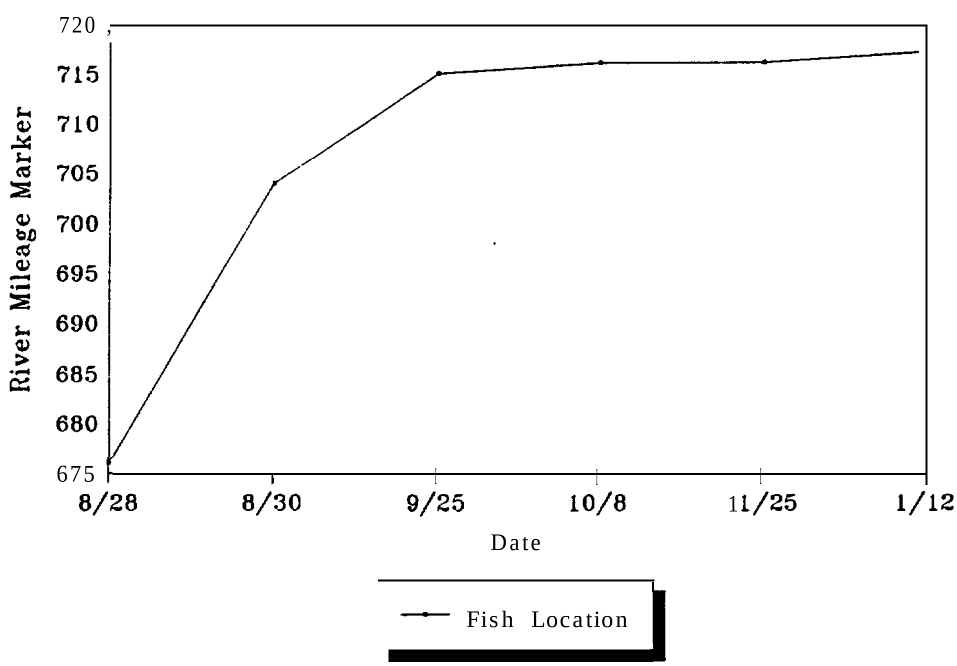
Fish #10 - Tag #913 Length 68.0 in.



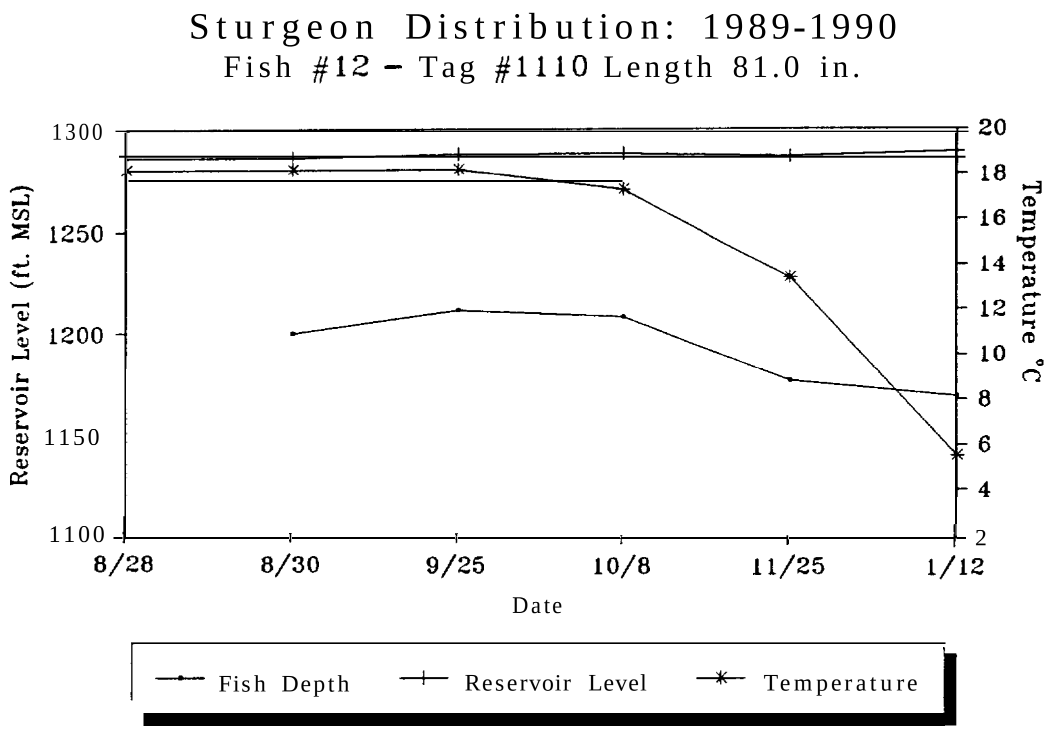


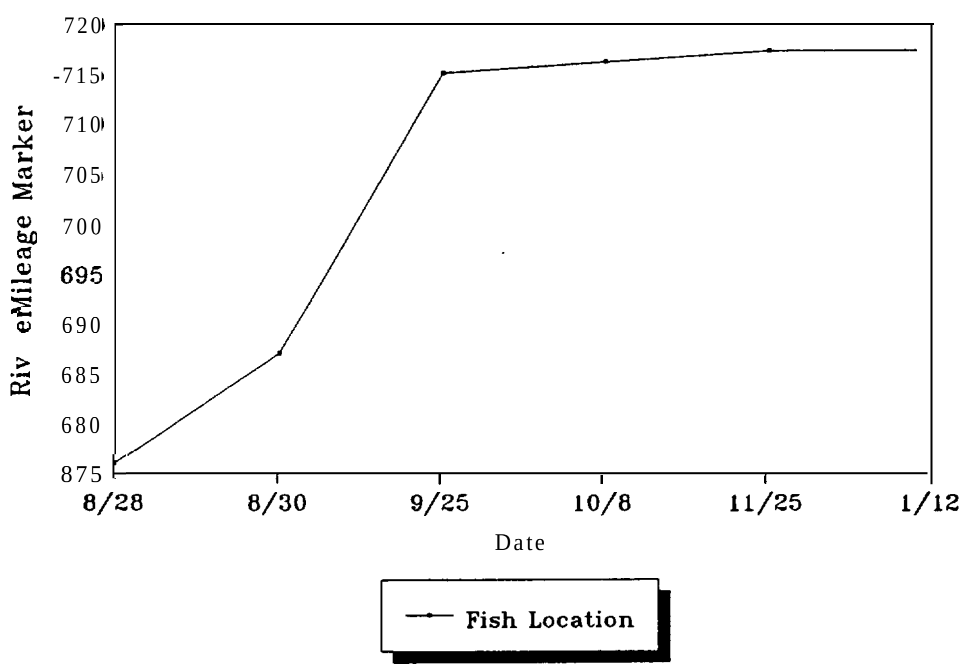
Appendix Figure 10. Movements and distribution of tagged sturgeon #10 in Lake Roosevelt in relation to time of year, temperature and reservoir level.



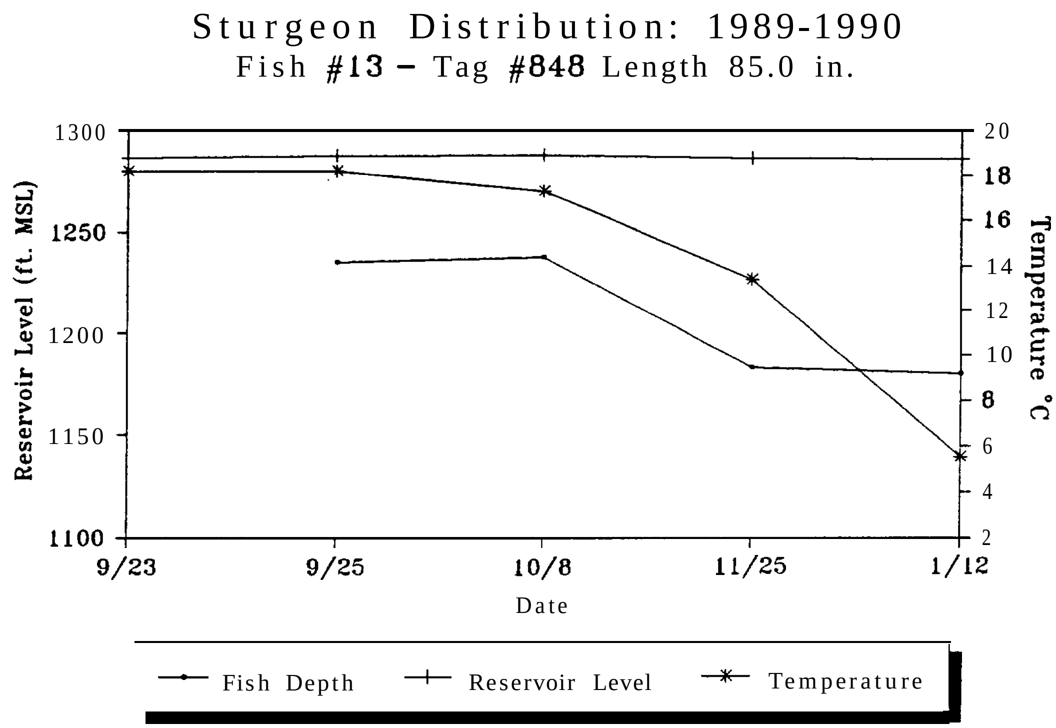


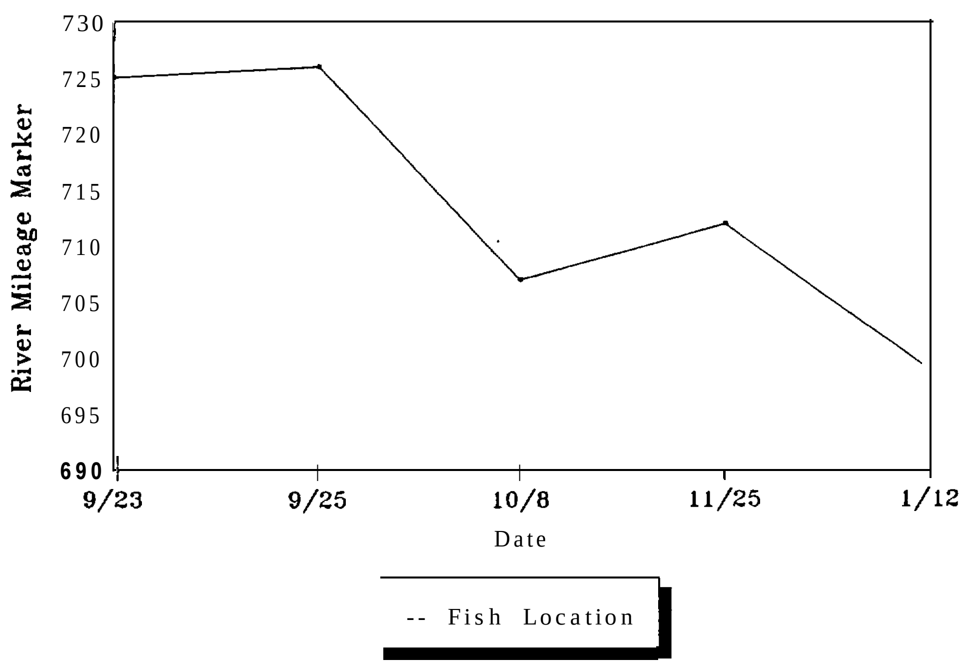
Appendix Figure 11. Movements and distribution of tagged sturgeon #1 1 in Lake Roosevelt in relation to time of year, temperature and reservoir level.





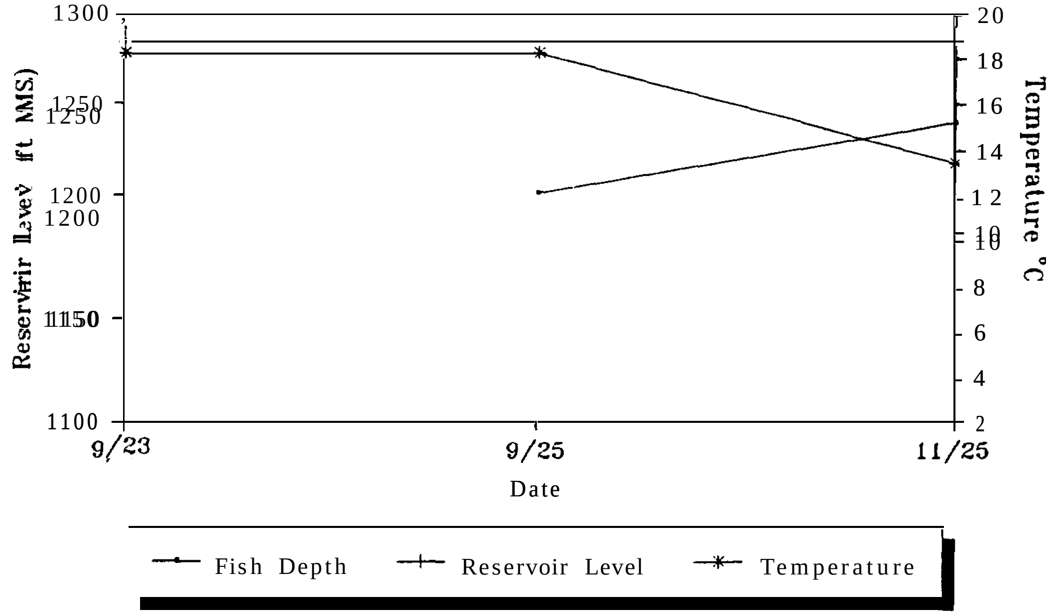
Appendix Figure 12. Movements and distribution of tagged sturgeon **#12** in Lake Roosevelt in relation to time of year, temperature and reservoir level.

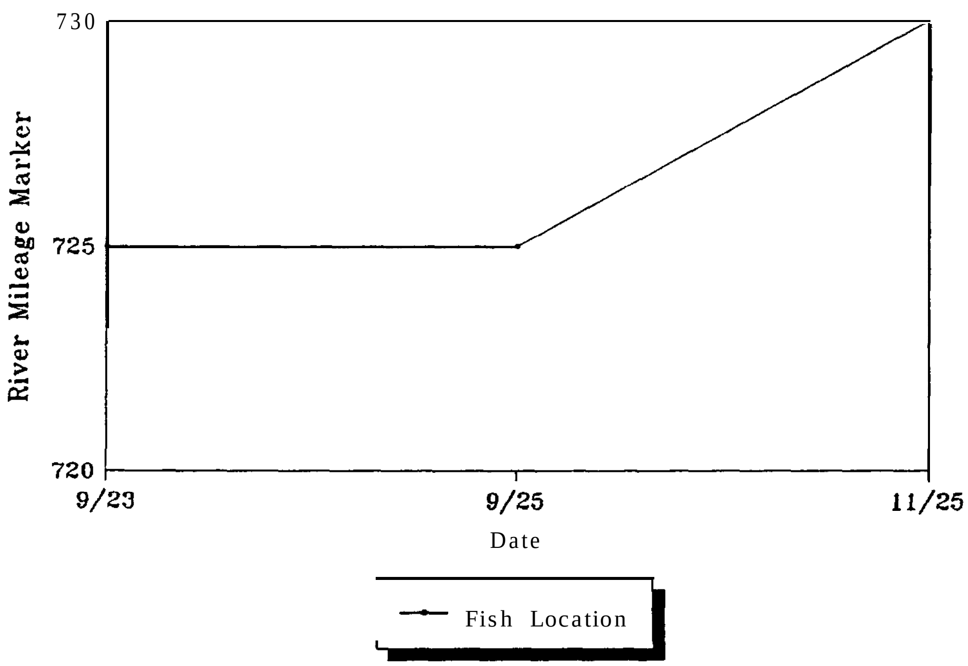




Appendix Figure 13. Movements and distribution of tagged sturgeon #13 in Lake Roosevelt in relation to time of year, temperature and reservoir level.

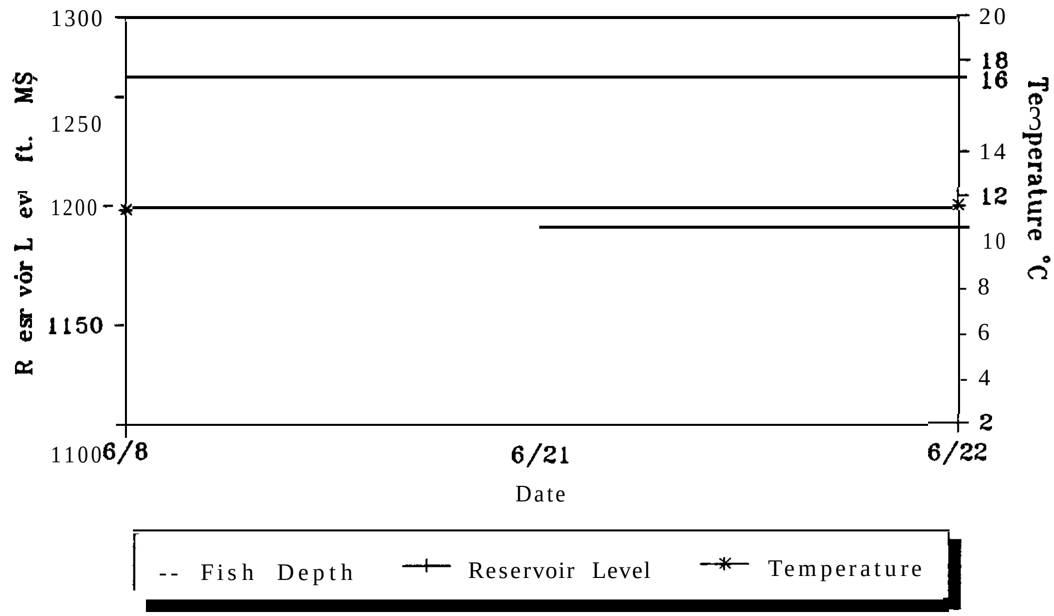
Sturgeon Distribution: 1989
Fish #14 – Tag #748 Length 104 in.

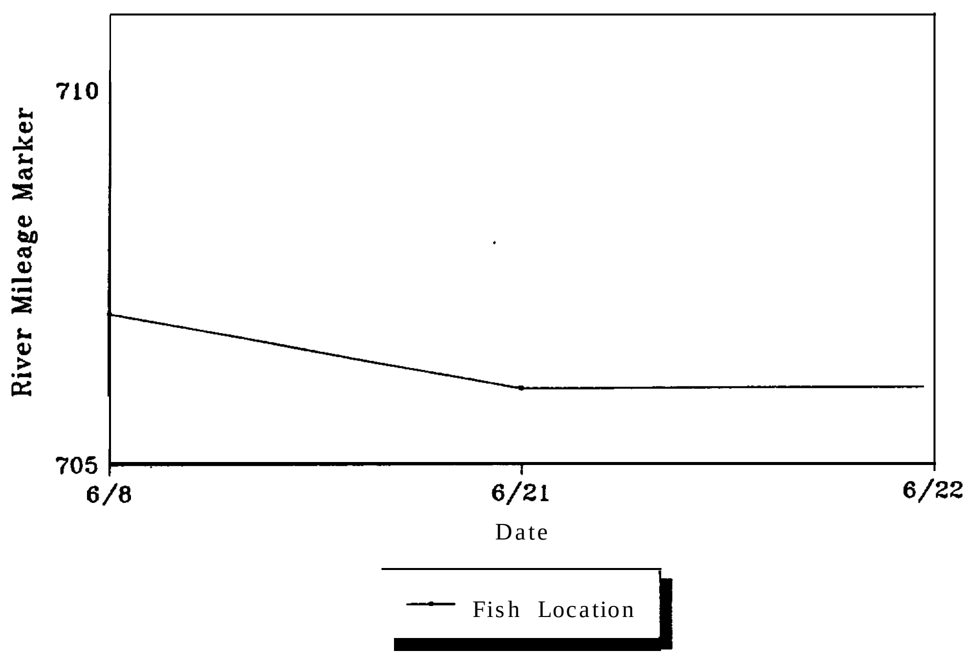




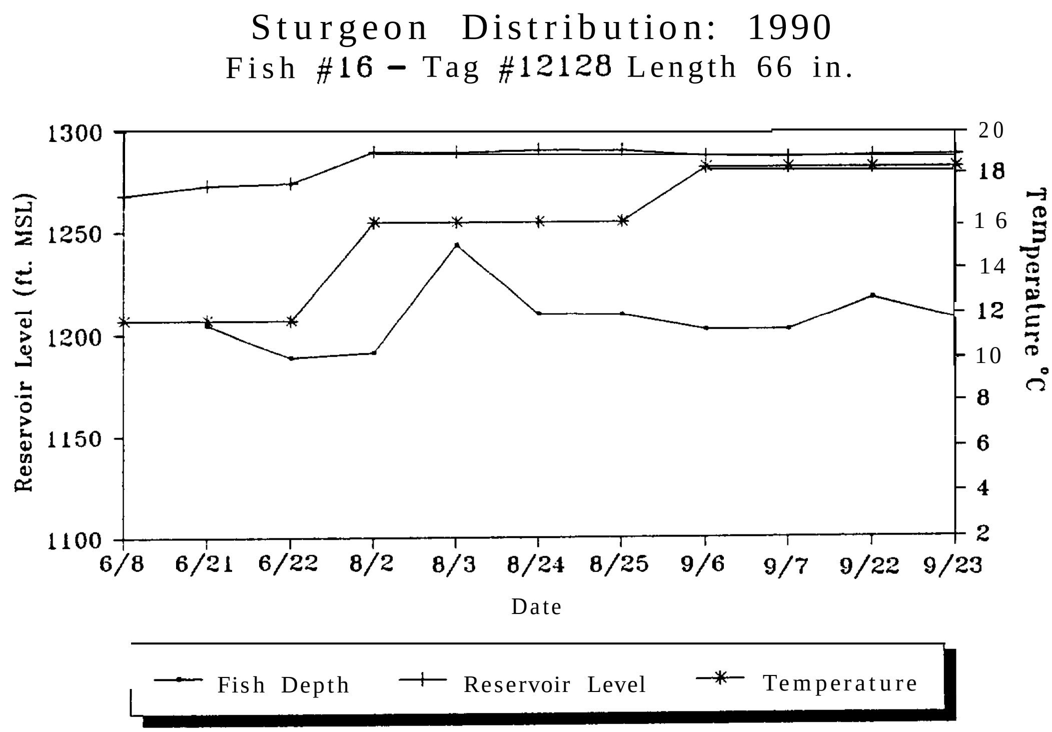
Appendix Figure 14. Movements and distribution of tagged sturgeon **#14** in Lake Roosevelt in relation to time of year, temperature and reservoir level.

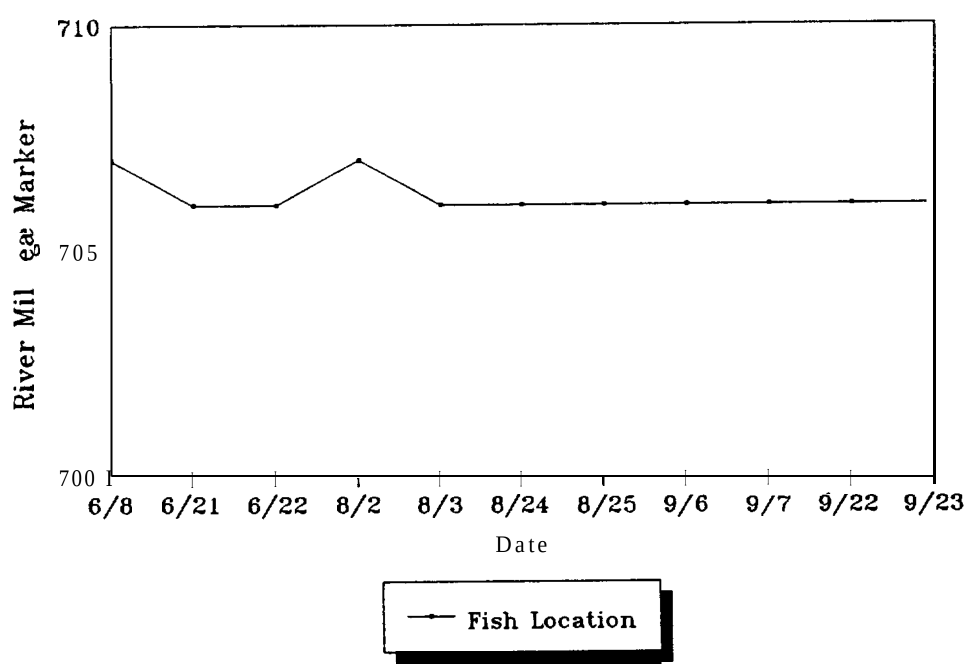
Sturgeon Distribution: 1990
Fish #15 - Tag #648 Length 63 in.





Appendix Figure 15. Movements and distribution of tagged sturgeon #15 in Lake Roosevelt in relation to time of year, temperature and reservoir level.





Appendix Figure 16. Movements and distribution of tagged sturgeon **#16** in Lake Roosevelt in relation to time of year, temperature and reservoir level.