Maps! for cedar & each tributary with sample locations marked.

TITLE: **Lower Cedar River Section 205 Longfin Smelt Study**
DRAFT FINAL REPORT - Contract DACW67-95-M-0412

Prepared by: Richard Brocksmith and Thomas Sibley
Fisheries Research Institute
Box 357980
University of Washington
Seattle, WA 98195

Submitted to: US Army, Corps of Engineers
Seattle District
P.O. Box 3755
Seattle, WA 98124-2255

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SUMMARY

These results were collected during the first year of a two year study investigating the life history and ecology of longfin smelt in Lake Washington and the Cedar River. The project was designed to obtain information that will be used to evaluate potential impacts of a flood control project in the lower Cedar River on the longfin smelt population in Lake Washington.

Specific work items for FY 1995 included:

1) *Conduct literature review of available information on ecology of longfin smelt and their sigificance in Lake Washington.*

An annotated bibliography is included with this report that identified 19 references from the scientific literature that specifically address longfin smelt in Lake Washington. Additional information on the nearshore distribution of smelt will be available in the reports being prepared by Seattle District, as a component of ongoing Lake Washington studies.

List of references & literature review

2) *Collect fry trap data on capture of longfin smelt adults from the Washington Department of Fish and Wildlife (WDFW).*

The WDFW fry trap located in the lower Cedar River collects adult smelt after they spawn and are returning to Lake Washington. Data from 1992, 1993 and 1994 were obtained from WDFW and graphed as number of fish for individual sampling dates. These data confirm the significant differences in population abundances reported previously between even and odd year classes of longfin smelt in Lake Washington. Even year classes are at least an order of magnitude larger than odd year classes. Peak spawning occurs a month to 6 weeks later in even years than odd years.

3) *Monthly samples, February through May 1995, on spatial distribution of eggs, including spawning habitat measurements of depth, velocity and substrate size. Identify preferred spawning areas.*

Initial samples were collected on 7 March 1995 along cross channel transects at 300, 400, 600 and 1200 meters upstream from Lake Washington. Subsequent sampling was conducted on 30 March 1995, 28-29 April 1995, and 23-24 May 1995. The largest number of eggs were collected on 30 March. For each sampling period the maximum number of eggs was collected at 300 or 400 m. No strong correlations were established between egg numbers and depth or substrate size but egg numbers were inversely correlated with velocity.

4) *Determine appropriate methods to sample drifting eggs and larvae.*

Most samples were collected with a Surber sampler placed on the river bottom. This method is limited by high velocities or deep water. Other samples were collected by diving or with drift nets placed along shore. Drift nets were quite successful for collecting eggs and larvae in the Cedar River and should be used more extensively in the Cedar and other Lake Washington tributaries during 1996.

5) *Sample substrates of Lake Washington tributaries for eggs and migrating larvae.*

In addition to the Cedar River, considerable effort was extended sampling Lake Washington tributaries. May, Coal, Juanita, Denny, Swamp, Lyon, McAleer, and Thornton Creeks were sampled in March and April and the Sammamish Slough was sampled in March. Eggs were collected from May Creek in March and April and from Coal Creek in April. Spawning in smaller tributaries may be more significant during the abundant 1996 year class.

6) *Observe reproductive behavior of adults in artificial streams. Compare field microhabitat measurements with lab results to determine preferences for substrate size, depth and velocity.*

Preliminary laboratory observations were conducted in artificial streams at the Fisheries Research Institute and the Seward Park hatchery. These studies indicated the feasibility of obtaining useful information from laboratory observations and provide valuable experience for designing laboratory studies during the 1996 field year.

7) *Determine larval development time (temperature requirements) and larval behavior upon emergence.*

Smelt eggs were successfully spawned and raised to hatching under ambient conditions in the laboratory. Because the odd year class spawns earlier than we anticipated, there were no adults available for additional studies by the time the experimental procedures were established. Attempts to feed the newly emerged larvae were unsuccessful and all fry died within 6 days. Increased availability of adults during 1996 will allow us to more precisely define temperature requirements and expand our observations on emerging fry behavior.

8) *Report of 1995 results submitted to the Corps by 31 December 1995.*

This draft report will be revised in response to Corps comments and resubmitted in final form by 31 December.

All of the 1995 work items have been successfully completed and provide valuable information for planning and effectively conducting the 1996 studies. Special emphasis in 1996 should include additional sampling in deep water areas of the lower Cedar River and along the Lake Washington shorelines, use of drift nets to sample tributaries and longitudinal distribution of eggs and fry in the Cedar River, and increased laboratory observations of egg development and fry behavior. A comparison of spawning locations and egg densities between years will be essential to quantifying differences between odd and even year classes.

LOWER CEDAR RIVER SECTION 205 STUDY
FEASIBILITY PHASE - FY 1995

LONGFIN SMELT
DRAFT FINAL REPORT
1 December 1995

INTRODUCTION:

Longfin smelt (*Spirinchus thaleicthyes*) is the most abundant planktivorous fish species in Lake Washington and holds a crucial position in the overall trophic interactions in the lake. Smelt is the principal consumer of zooplankton, a potential competitor with juvenile sockeye salmon and an important prey species for higher trophic levels of piscivorous fish.

The Lower Cedar River Section 205 Study is a Corps of Engineers flood control project with the City of Renton as a local sponsor. One alternative for flood control is moderate dredging of the lower mile of the river. This may significantly impact the known spawning area of longfin smelt. Smelt spawn in the lower Cedar River between January and May and emerging fry enter Lake Washington between March and June. Although we are beginning to understand the important role of smelt in the Lake Washington ecosystem, relatively little is known about the spawning preferences of smelt or the behavior of newly hatched and emerging fry. It is important to obtain additional information on spawning preferences in order to predict the long term impacts of dredging on population abundance of smelt. These studies were designed to obtain some of that information.

OBJECTIVES:

Specific objectives of this study were identified in the Scope of Work.

1) A literature review conducted to retrieve all available references pertaining to the life history of the longfin smelt in the Lake Washington watershed and Cedar River basin is attached to this report as an annotated bibliography.

2) Smelt catch data from the sockeye frytrap on the Cedar River was obtained from Washington Department of Fish and Widlife(WDFW) for the years 1992-1994. are these the only years with data available?

3) The distribution of longfin smelt eggs in the lower Cedar River was monitored monthly between February and May. Water depth, velocity and substrate size were recorded at each sampling site to determine physical characteristics of preferred spawning sites.

4) We surveyed nine tributaries (May Creek, Coal Creek, Juanita Creek, Denny Creek, Sammamish Slough, Swamp Creek, Lyon Creek, McAleer Creek and Thornton Creek) of Lake Washington to locate spawning areas outside of the Cedar River basin.

5) Laboratory studies were conducted on incubating and hatching to provide information on developmental times of the longfin smelt.

6) Pilot studies were run to assess the feasibility of laboratory techniques in determining spawning site preferences with respect to substrate size.

would rather see substrate effects on egg survival

METHODS:

Egg samples were collected monthly on the lower Cedar River along transects established by the Army Corps of Engineers at 100m intervals upstream from Lake Washington. Two to four samples were collected at each of the selected transects. Sample sites were chosen to represent typical streambed morphology and substrate type and were less than 2.5 feet in depth. Beyond this depth, the sampling technique was inconsistent. need to measure deeper this year (van veen grab?) from boat or bridge

Samples were collected with a 0.1 m^2 Surber sampler. Gravel in each sample was scrubbed and then stirred to remove eggs during a five minute sampling effort. The eggs were collected in the Surber net placed immediately downstream from the sample plot. Eggs were preserved and transferred to 70% ethyl alcohol for later analysis. Sample depth was recorded in feet and the water velocity (m/s) was measured at a standard 4/10 of the water column above the bottom.

Correlations between egg abundance and water depth and velocity were calculated using Spearman's measure of correlation, rho (Conover 1971). This nonparametric test was chosen since we cannot assume that the egg abundance is normally distributed. Fisher's transformation was used to set 95% confidence intervals around rho.

Initial studies to determine appropriate methods to sample drifting eggs and larvae were conducted during the sampling period on both the Cedar River and other tributaries of Lake Washington. Drift nets facing upstream were attached to ribar for selected time periods and samples were stored in alcohol for later analysis in the laboratory.

Substrate sampling was performed along four transects from the Interstate 405 bridge to the 800 meter transect using a McNeil corer. Transect and sample plot placement were limited by the depth of the water since the McNeil corer proved to be ineffective at depths greater than 1.5 feet. Therefore, samples below the 400 meter transect were not taken. Samples were separated in the laboratory using a geometric series of United States Geological Survey sieves. The d_{50} or median value of each sample was derived from graphs of cumulative percents versus the log of each size class using the method presented by Gordon et al.(1992).

what about 400-800 meters? Why wasn't substrate sampling done at same location as egg sampling?

Tributaries were sampled for eggs one to three times during February, March and April. Between one and five samples were taken with corresponding depth and velocity measurements. Transects were selected to represent the lower portions of the tributaries in terms of velocity and substrate size. Substrate samples collected with the McNeil corer were taken in tributaries found to contain smelt eggs.

To determine development time and behavior upon emergence, ripe male and female adults were artificially spawned at the University of Washington hatchery and incubated in Lake Washington water.

A pilot study was conducted to evaluate substrate preference of spawning smelt. Ripe smelt were exposed to a matrix of substrate sizes in a raceway at the Seward Park hatchery. The substrate was ordered into three sections running the length of the raceway. They include sand (<0.85mm), medium-sized gravel (between 0.85mm and 4.0cm) and large gravel (>4.0cm). Depth and flow remained constant. Each section of substrate was sampled three times, at the top, middle and bottom of the section for a total of nine samples.

RESULTS:

Data on the number of longfin smelt caught by the WDFW frytrap on the Cedar River is presented in Figures 1-3 for 1992, 1993 and 1994, respectively. Figure 4 compares the catch for these three years. Two significant differences between years are apparent in these data. First the population abundance during even years is much higher than during odd years. In 1993 there was only one night when more than 50 adult smelt were collected in the fry trap. In contrast, during 1992 and 1994 there were several nights when more than 1000 smelt were collected. Spawning also occurs much earlier in odd years. In 1993 peak migration was finished by early in February. If a similar run curve occurred in 1995, peak spawning would have occurred before we started our sampling. Although we expected low numbers of eggs in our samples because it was an odd year class, we had not anticipated that the number of eggs would also be reduced by an earlier spawning period.

Number of smelt eggs at selected sampling sites in the lower Cedar River for early March, late-March, April and May is given in Tables 1-4. Date, transect location, distance from shore, depth, velocity, number of eggs, number of larvae and total number of eggs and larvae per transect are given also. Missing depth and velocity measurements were not recorded because of equipment failure in the field. Figures 5 and 6 show the relationship between egg abundance and depth for February and March data, respectively. Figures 7 and 8 show the relationship between egg abundance and velocity for February and March and Figures 9 and 10 relationship between egg abundance and the distance upstream.

Spawning surveys in Lake Washington tributaries (Tables 5-13) collected eggs in May Creek and Coal Creek.

sampled at what distances from mouth?

Results of the substrate sampling for the Cedar River, May Creek and Coal Creek are given in Tables 14 as weight per size-class and in Table 15 as percent of the total sample. Cumulative percents versus size-class of each sample are graphed in Figures 11-14.

Initial studies to determine appropriate methods to sample drifting eggs and larvae were conducted during the sampling period on both the Cedar River and other tributaries of Lake Washington. Results of the drift net studies are recorded in Tables 1-4.

To evaluate fry behavior upon emergence 20 eggs were put in aquaria containing sand, gravel, or no substrate as a control to test for behavior after emergence. Upon hatching, the larvae were observed swimming strongly near the surface of the incubation container. No detectable differences in behavior were seen among the three aquaria. All larvae died within six days of hatching, despite attempts to feed them.rotifers, *Daphnia* spp., *Artemia* spp. and algae.

A pilot study to evaluate the preference of spawning smelt for substrate size was conducted at the Seward Park hatchery. Egg density measurements (Table 16) arranged according to substrate size and spatial arrangement in the trough show considerably higher numbers of eggs and larvae associated with the sand particles.

DISCUSSION:

The WDFW numbers on the longfin smelt run in the Cedar River are arguably the most complete set of data we have on the timing of the run and their relative sizes. First, Moulton (1970) sampling of egg distribution and of the appearance of ripe smelt showed the major portion of the even-year run to spawn in early to late March while the odd-year run of 1969 peaked in late February to early March. Our 1995 data for the odd-year class suggests that the spawning numbers were very low by March. However, frytrap catch data only provides an index of smelt abundance rather than a quantitative estimate. The trap was not designed to capture smelt and the capture efficiency is unknown. In addition it provides no information on the spatial distribution of spawners within the river.

The distribution of eggs was not closely correlated with water depth or velocity. Due to small sample sizes, the confidence intervals of the February data could not be calculated. Correlation coefficient values range between the +1 and -1 with values above 0.8 having a strong positive correlation and values below -0.8 having a strong negative correlation. The null hypothesis of mutual independence of egg abundance was tested against water depth and water velocity independently for the February and March data.. The null hypothesis of mutual independence of velocity and egg abundance for March was rejected ($p< 0.10$) suggesting an inverse relationship exists between water velocity and egg abundance.

Moulton (1970) sampled May Creek, Coal Creek, Juanita Creek, Denny Creek, Swamp Creek, Lyon Creek, McAleer Creek and Thornton Creek and found evidence of smelt spawning in May, Coal and Juanita Creeks. We found eggs in May and Coal Creeks, but not Juanita Creek. Moulton's study was conducted during an abundant, even-year run. Proximity of May and Coal Creek to the main spawning ground of the Cedar River suggests that of spawning in these streams may represent straying adults from the Cedar River population. The numbers of eggs for 1995 in these streams is low and suggests very few numbers of smelt utilizing them for spawning grounds. However, we might expect more spawning to occur in these tributaries during even years.

Due to the depth limitations of the McNeil corer, samples could not be taken within the area used by the smelt for spawning. Therefore, no correlations can be made from our data. This data is included for use in future investigations. Since the area of focus is the lower portion and the deepest part of the river, we believe that a more applicable method should be used in the future. Possible techniques include manual or air-driven dredges capable of sampling defined areas or surficial surveys by visual estimation. These methods may reveal more pertinent information since they would focus more closely on the surface layer which is the most important for the smelt due to sedimentation and scour.

In 1965, Dryfoos found that the development of smelt eggs took 40 days at 7.0^{0}C. That represents 280 Centigrade temperature units (CTU). Moulton found that development took 25 days in a temperature range of 9.6^{0}C to 10.6^{0}C, for a CTU of 253. Our artificial spawning produced larvae in an average of 29 days in a temperature range of 8.0^{0}C to 9.5^{0}C for a CTU of 254. Attempts to keep the larvae alive more than six days after emerging never proved successful, so behavior studies past this time were not possible. However, recently hatched juveniles swam very strongly towards the top of the water column indicating that larvae are swept out of the river system as soon as they emerge. This theory is supported by the fact that we do not see large numbers of larvae in sediment samples.

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SPAWNING DISTRIBUTION - ~~FEBRUARY~~ March

Date	Transect (m)	Distance (m)	Depth (ft)	Velocity (m/s)	Eggs	Larvae
3/7/95	300	10 m from E	0.4	0	0	0
	300	24 m from E	0.4	0.02	6	0
	300	25 m from E	0.7	0.02	15	0
	300	27 m from E	1.7	0.05	30	0
					51	0
3/7/95	400	7 m from E	1	0.42	34	0
	400	12 m from E	0.9	0.45	21	0
	400	17 m from E	1	0.59	13	0
	400	20 m from E	1.1	0.43	9	0
	400	27 m from E	1.7	0.58	16	0
					93	0
3/7/95	600	5 m from E	1.2	0.98	0	0
	600	10 m from E	1.6	1.08	0	0
	600	20 m from E	1.3	0.87	0	0
	600	30 m from E	0.9	0.9	0	0
					0	0
3/7/95	1200	5 m from W	0.3	0.21	0	0
	1200	10 m from W	0.5	0.42	0	0
	1200	15 m from W	1	0.62	2	0
	1200	20 m from W	1.5	0.88	0	0
					2	0

Table 1

April

SPAWNING DISTRIBUTION - MARCH

Date	Transect (m)	Distance (m)	Depth (ft)	Velocity (m/s)	Eggs	Larvae
4/6/95	0	5 m from E	3.2	0.15	2	2
	0	10 m from E	3.3	0.13	3	0
					5	2
4/6/95	200	5 m from W	2.9	0.19	7	0
	200	15 m from W	3.1	0.27	20	3
					27	3
3/30/95	300	10 m from E	1.2	0	33	0
	300	25 m from E	1.1	0	14	0
	300	27 m from E	1.6	0	82	0
					129	0
3/30/95	400	7 m from E	1.5	0.29	22	0
	400	12 m from E	1.6	0.36	4	0
	400	20 m from E	1.7	0.44	2	0
	400	27 m from E	2	0.43	0	0
	400	33 m from E	2.7	0.43	5	0
					33	0
4/6/95	Drift Net @ 500	5 m from W			76	7
	10 a.m. to 1 p.m.					
3/30/95	1200	7 m from W	0.3	0.19	0	0
	1200	15 m from W	0.9	0.63	0	0
	1200	20 m from W	1.5	0.84	0	0
					0	0

drifting eggs?

Table 2

SPAWNING DISTRIBUTION - APRIL

Date	Transect (m)	Distance (m)	Depth (ft)	Velocity (m/s)	Eggs	Larvae
4/28/95	300	8 m from E	2	0.05	0	0
	300	20 m from E	0.5	0.02	0	0
					0	0
4/29/95	400	5 m from E	1.8	0.19	2	0
	400	15 m from E	1.9	0.29	2	1
	400	25 m from E	2.2	0.32	2	0
					6	1
4/29/95	800	5 m from W	1.7	0.85	0	0
	800	15 m from W	1.3	0.71	0	0
	800	30 m from W	0.9	0.44	0	0
					0	0
4/28/95	1200	10 m from W	0.2	0.12	0	0
	1200	20 m from W	1.2	0.76	0	0
	1200	25 m from W	1.8	0.87	0	0
					0	0
4/28/95	1600	5 m from E	0.9	0.55	0	0
	1600	10 m from E	1.3	0.66	0	0
	1600	15 m from E	1.4	0.75	0	0
					0	0
4/28/95	I-405	10 m from E	1.1	0.89	0	3
	I-405	20 m from E	1.7	0.84	1	1
	I-405	35 m from E	0.7	0.43	0	0
					1	4

larvae? must indicate eggs further upstream since such poor swimmers.

Table 3

SPAWNING DISTRIBUTION - MAY

Date	Transect (m)	Distance (m)	Depth (ft)	Velocity (m/s)	Eggs	Larvae
5/24/95	300	5 m from E	N/A	N/A	0	0
	300	20 m from E	N/A	N/A	0	0
	300	25 m from E	N/A	N/A	0	0
					0	0
5/24/95	400	7.5 m from E	N/A	N/A	0	0
	400	15 m from E	N/A	N/A	0	0
	400	25 m from E	N/A	N/A	0	0
					0	0
5/24/95	800	5 m from W	N/A	N/A	0	0
	800	15 m from W	N/A	N/A	0	0
	800	25 m from W	N/A	N/A	0	0
					0	0
5/23/95	1200	10 m from W	N/A	N/A	0	0
	1200	17.5 m from W	N/A	N/A	0	0
	1200	22.5 m from W	N/A	N/A	0	0
					0	0
5/23/95	1600	7.5 m from E	N/A	N/A	0	0
	1600	12.5 m from E	N/A	N/A	0	0
	1600	17.5 m from E	N/A	N/A	0	0
					0	0
5/23/95	I-405	10 m from E	N/A	N/A	0	0
	I-405	20 m from E	N/A	N/A	0	0
	I-405	30 m from E	N/A	N/A	0	0
					0	0

Table 4

need reference points

SPAWNING DISTRIBUTION - MAY CREEK

Date	Transect	Distance (ft)	Depth (ft)	Velocity (m/s)	Eggs
3/14/95	25 yds below first driving bridge	10 ft from W	0.8	0.61	3
	25 yds below first driving bridge	10 ft from E	1.2	0.48	2
	2 yds above first driving bridge	5 ft from W	0.8	0.55	4
	10 yds below ped bridge	2 ft from W	1.1	0.99	2
	Upstream edge of secong driving bridge	2 ft from E	1	0.85	0
4/27/95	25 yds below first driving bridge	10 ft from W	1.3	0.03	1
	25 yds below first driving bridge	10 ft from E	1.4	0.02	0
	2 yds above first driving bridge	5 ft from W	1.1	0.05	0
	10 yds below ped bridge	2 ft from W	1	0.17	0
	Upstream edge of second driving bridge	2 ft from E	0.4	0.34	0
Drift	2 yds above first driving bridge	10 ft from W			0

Table 5

SPAWNING DISTRIBUTION - COAL CREEK

Date	Transect	Distance (ft)	Depth (ft)	Velocity (m/s)	Eggs
2/25/95-2/26/95	50 ft below 1st culvert	3 ft from S	8 inches	Hi	0
Drift 4 p.m.-9 a.m.	Upstream edge of 1st culvert	3 ft from S	10 inches	Medium	0
	20 ft below RR bridge	3 ft from N	8 inches	Hi	0
3/14/95 2 p.m.	50 ft below S property marker	10 ft from S	0.7 ft	0.93	0
	S property marker(rebar)	18 ft from S	0.8 ft	0.58	0
	End of picket fence and iris patch	7 ft from S	0.8 ft	0.85	0
	20 ft below first culvert	4 ft from S	1.1 ft	0.76	0
4/27/95 12 p.m.	S property marker (rebar)	18 ft from S	0.9 ft	0.25	1 immature
	End of picket fence	7 ft from S	0.8 ft	0.29	4 immature and 2 eyed

Table 6

SPAWNING DISTRIBUTION - JUANITA CREEK

Date	Transect	Distance (ft)	Depth (ft)	Velocity (m/s)	Eggs
3/14/95 4 p.m.	50 ft above ped bridge	10 ft from W	0.8	0.61	0
	60 ft above ped bridge	8 ft from W	0.7	0.63	0
	75 ft above ped bridge	10 ft from W	0.5	0.84	0
4/27/95 1 p.m.	50 ft above ped bridge	10 ft from W	1.3	0.07	0
	75 ft above ped bridge	10 ft from W	0.7	0.08	0

Table 7

SPAWNING DISTRIBUTION - DENNY CREEK

Date	Transect	Distance	Depth	Velocity	Eggs
		(ft)	(ft)	(m/s)	
3/24/95 4:30 p.m.	10 ft below mouth	1 ft from S	0.5	Medium	0
	50 ft above 1st ped bridge	1 ft from S	0.5	Medium	0
4/27/95 2 p.m.	10 ft below mouth	1 ft from S	0.7	0.05	0
	50 ft above first ped bridge	1 ft from S	0.4	0.19	0

Table 8

SPAWNING DISTRIBUTION - SAMMAMISH SLOUGH

Date	Transect	Distance	Depth	Velocity	Eggs
		(ft)	(ft)	(m/s)	
3/24/95 4 p.m.	30 ft below 68th St bridge	2 ft from E	0.7	0	0

Table 9

SPAWNING DISTRIBUTION - SWAMP CREEK

Date	Transect	Distance (ft)	Depth (ft)	Velocity (m/s)	Eggs
3/24/95 3 p.m.	60 ft below 1st bridge below 175th St bridge	4 ft from E	1.2	Low	0
	150 ft below 175th St bridge	10 ft from E	0.7	Medium	0
	Downstream edge of 175th St bridge	Center of bridge	1	Low	0
4/27/95 3 p.m.	60 ft below 1st bridge below 175th St bridge	4 ft from E	1.2	0.08	0
	150 ft below 175th St bridge	10 ft from E	0.5	0.18	0

Table 10

SPAWNING DISTRIBUTION - LYON CREEK

Date	Transect	Distance	Depth	Velocity	Eggs
		(ft)	(ft)	(m/s)	
3/24/95 1 p.m.	15 ft below BG Trail	2 ft from N	0.8	N/A	0
	40 ft above Beach Dr bridge	5 ft from N	0.8	N/A	0
	10 ft below Civic Club bridge	6 ft from S	0.7	N/A	0
	5 ft below ped bridge of 17337 Beach Dr	6 ft from N	0.4	N/A	0
4/27/95 4 p.m.	40 ft above Beach Dr Bridge	5 ft from N	0.4	0.39	0
	10 ft below Civic Club bridge	6 ft from S	0.4	0.49	0

Table 11

SPAWNING DISTRIBUTION - McALEER CREEK

Date	Transect	Distance (ft)	Depth (ft)	Velocity (m/s)	Eggs
3/24/95 12:30 p.m.	100 ft above Halmon Rd bridge	7 ft from S	0.4	N/A	0
	5 ft below Beach Dr bridge	5 ft from S	0.7	N/A	0
	20 ft above Shore Dr bridge	2 ft from S	0.8	N/A	0
	20 ft above Shore Dr bridge	6 ft from S	1.1	N/A	0
4/27/95 4:30 p.m.	5 ft below Beach Dr bridge	5 ft from S	0.5	0.62	0
	20 ft above Shore Dr bridge	6 ft from S	0.8	0.29	0

Table 12

SPAWNING DISTRIBUTION - THORNTON CREEK

Date	Transect	Distance (ft)	Depth (ft)	Velocity (m/s)	Eggs
3/24/95 11 a.m.	Corner of 9220 49th Ave NE	2 ft from N	1	0.78	0
	End of 49th Ave NE	2 ft from N	0.8	0.48	0
	40 ft above Pumping Station ped bridge	5 ft from N	1.1	0.59	0
	80 ft above Pumping Station ped bridge	5 ft from N	0.8	N/A	0
4/27/95 5 p.m.	End of 49th Ave NE	2 ft from N	0.4	0.26	0
	40 ft above Pumping Station ped bridge	5 ft from N	0.6	0.44	0

Table 13

SUBSTRATE SIZES FOR CEDAR RIVER AND TRIBUTARIES - WEIGHT PER SIZE CLASS

Area	Date	Transect	Distance	63mm	31.5mm	16mm	8mm	4mm	2mm	1mm	0.5mm	0.25mm	0.125mm	0.063mm	Total
				(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
Cedar River	9/5/95	I-405	10m	1880	1401.5	1192.1	812.7	546.4	344	258.7	304.2	183.3	33.8212	8.0603	7015.8815
Cedar River	9/5/95	I-405	20m	1122.6	1745.3	1166.3	966.7	548.8	399	417.6	289.4	117.1	23.224	10.1669	6897.2909
Cedar River	9/5/95	I-405	30m	1056.7	1437.3	1580.7	914.7	537.3	356.4	218.1	151.9	221.4	31.1915	11.094	6565.2855
Cedar River	9/5/95	1600	10m	0	1526.8	1669.3	1060.3	699.1	525.5	389.1	263	129.3	17.1454	5.1018	6367.4472
Cedar River	9/5/95	1600	15m	1599.8	1027.5	1207.3	1302.6	744.2	463.8	522.9	381.1	140.1	24.0339	7.3461	7524.48
Cedar River	9/5/95	1200	15m	0	2459.4	2064.1	976.1	457.2	274.5	102.1	65.6	171.3	69.3957	26.2982	6678.4939
Cedar River	9/5/95	1200	20m	0	1390.9	2080.9	1007.1	607.5	453.9	301.7	188.6	229.1	46.7688	21.2914	6375.9602
Cedar River	9/5/95	1200	25m	401.9	3351.8	951.1	853	575.3	466.6	680.5	293	150.9	33.7598	7.6145	7921.9743
Cedar River	9/5/95	800	5m	0	2530.7	2040.7	945.5	486.4	296.9	103.2	41	208.1	241.3691	86.839	6988.7081
Cedar River	9/5/95	800	15m	559.3	1596.5	1866.5	1246.6	745.8	540	393.7	259.8	253.2	68.1643	21.9585	7621.0228
Cedar River	9/5/95	800	30m	0	1541.5	2046.8	1178.6	813.5	564.2	634.4	406.1	296	61.4928	12.5472	7627.24
May Creek	9/13/95	Upstream edge of 2nd driving	2 ft from East	0	2182.6	1375	1116.5	759	569.8	410.1	383.7	333.7	62	8.2	7261.6
May Creek	9/13/95	25 yds below 1st driving bridge	10 ft from West	3360.5	331	840.3	750.7	300.1	165.4	161.2	309.5	404.2	119.6	29.8	6812.5
Coal Creek	9/13/95	South property marker	18 ft from South	522.4	1671	1428	1228.7	819.9	569.7	384.8	303.4	275.2	63.7	18.4	7330
Coal Creek	9/13/95	20 ft below 1st culvert	4 ft from South	486.6	2612	1202.7	824	539.6	335.6	214.6	229.7	225.5	69	25.5	6804.2

Table 14

SUBSTRATE SIZES FOR CEDAR RIVER AND TRIBUTARIES - CUMULATIVE PERCENT OF WEIGHT

Area	Date	Transect	Distance	0.063mm	0.125mm	0.25mm	0.5mm	0.85mm	1.0mm	2.0mm	4.0mm	8.0mm	16.0mm	31.5mm	63.0mm
				cum %	cum %	cum %	cum %	cum %	cum %	cum %	cum %	cum %	cum %	cum %	cum %
Cedar River	9/5/95	I-405	10m	0.0011	0.0060	0.0321	0.0755	0.0827	0.1196	0.1686	0.2465	0.3624	0.5323	0.7320	1.0000
Cedar River	9/5/95	I-405	20m	0.0015	0.0048	0.0218	0.0638	0.0770	0.1375	0.1954	0.2749	0.4151	0.5842	0.8372	1.0000
Cedar River	9/5/95	I-405	30m	0.0017	0.0064	0.0402	0.0633	0.0707	0.1039	0.1582	0.2400	0.3794	0.6201	0.8390	1.0000
Cedar River	9/5/95	1600	10m	0.0008	0.0035	0.0238	0.0651	0.0781	0.1392	0.2217	0.3315	0.4981	0.7602	1.0000	1.0000
Cedar River	9/5/95	1600	15m	0.0010	0.0042	0.0228	0.0734	0.0872	0.1567	0.2184	0.3173	0.4904	0.6508	0.7874	1.0000
Cedar River	9/5/95	1200	15m	0.0039	0.0143	0.0400	0.0498	0.0517	0.0670	0.1081	0.1765	0.3227	0.6317	1.0000	1.0000
Cedar River	9/5/95	1200	20m	0.0033	0.0107	0.0466	0.0762	0.0837	0.1311	0.2023	0.2975	0.4555	0.7819	1.0000	1.0000
Cedar River	9/5/95	1200	25m	0.0010	0.0052	0.0243	0.0613	0.0810	0.1669	0.2258	0.2984	0.4061	0.5262	0.9493	1.0000
Cedar River	9/5/95	800	5m	0.0124	0.0470	0.0767	0.0826	0.0838	0.0985	0.1410	0.2106	0.3459	0.6379	1.0000	1.0000
Cedar River	9/5/95	800	15m	0.0029	0.0118	0.0450	0.0791	0.0883	0.1399	0.2108	0.3086	0.4722	0.7171	0.9266	1.0000
Cedar River	9/5/95	800	30m	0.0016	0.0097	0.0485	0.1018	0.1112	0.1944	0.2684	0.3750	0.5295	0.7979	1.0000	1.0000
May Creek	9/13/95	Upstream edge of 2nd driving	2 ft from East	0.0011	0.0097	0.0556	0.1085	0.1169	0.1733	0.2518	0.3563	0.5101	0.6994	1.0000	1.0000
May Creek	9/13/95	25 yds below 1st driving bridge	10 ft from West	0.0044	0.0219	0.0813	0.1267	0.1326	0.1563	0.1805	0.2246	0.3348	0.4581	0.5067	1.0000
Coal Creek	9/13/95	South property marker	18 ft from South	0.0025	0.0112	0.0487	0.0901	0.0962	0.1487	0.2265	0.3383	0.5059	0.7008	0.9287	1.0000
Coal Creek	9/13/95	20 ft below 1st culvert	4 ft from South	0.0037	0.0139	0.0470	0.0808	0.0866	0.1181	0.1674	0.2467	0.3678	0.5446	0.9285	1.0000

Table 15

SUBSTRATE PREFERENCE STUDY

Substrate Size

	Sand	Small Gravel	Large Gravel
Eggs	57	37	16
Larvae	12	3	8
Eggs	102	3	4
Larvae	18	2	0
Eggs	0	0	3
Larvae	0	0	0

Direction of Flow

increasing flows? to what?

Table 16

WDFW Cedar River Frytrap Data - 1992

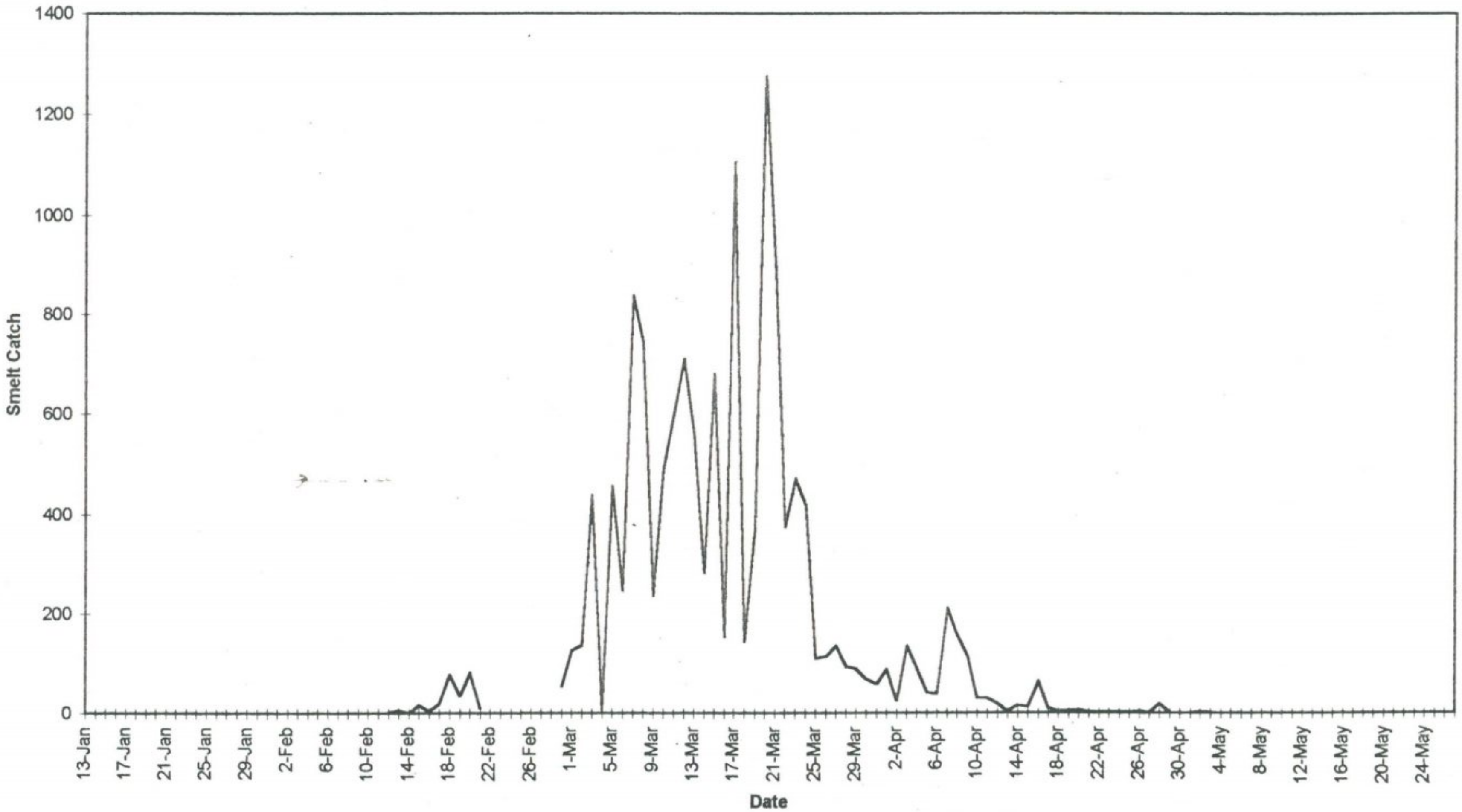


Figure 1

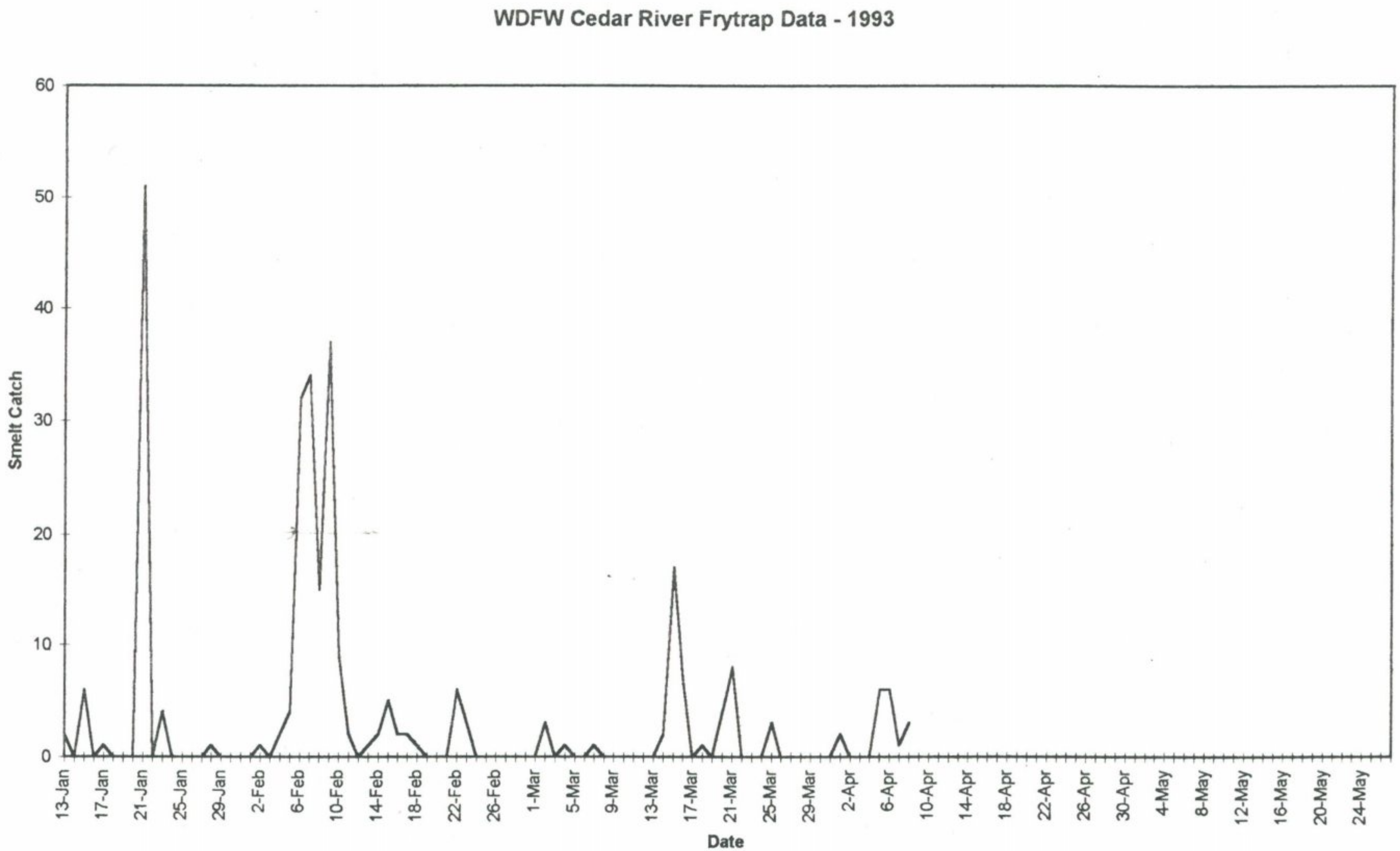

WDFW Cedar River Frytrap Data - 1993
60
50
40
30
20
10
0
Smelt Catch
13-Jan
17-Jan
21-Jan
25-Jan
29-Jan
2-Feb
6-Feb
10-Feb
14-Feb
18-Feb
22-Feb
26-Feb
1-Mar
5-Mar
9-Mar
13-Mar
17-Mar
21-Mar
25-Mar
29-Mar
2-Apr
6-Apr
10-Apr
14-Apr
18-Apr
22-Apr
26-Apr
30-Apr
4-May
8-May
12-May
16-May
20-May
24-May
Date

Figure 2

WDFW Cedar River Frytrap Data - 1994

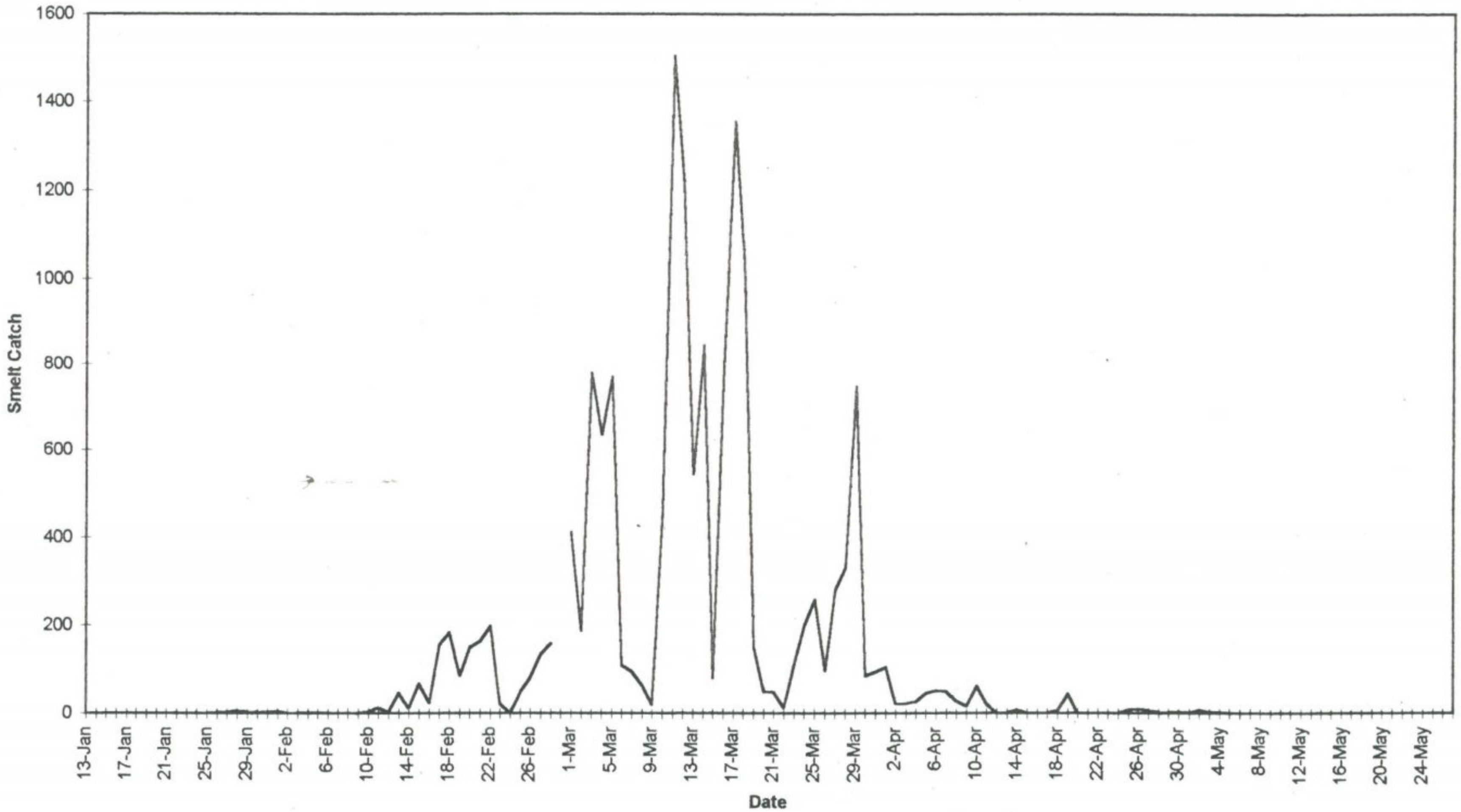


Figure 3

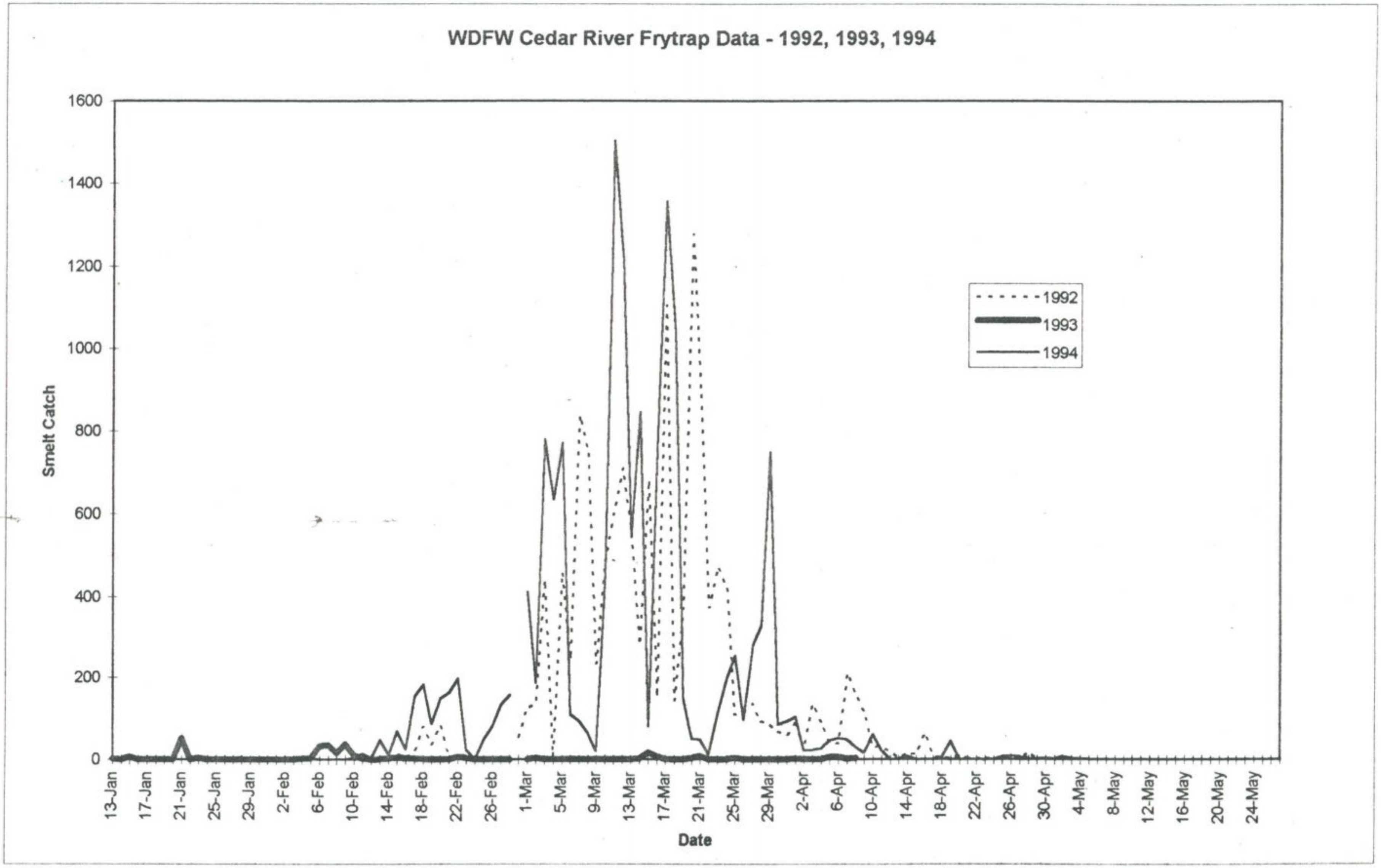

WDFW Cedar River Frytrap Data - 1992, 1993, 1994
Smelt Catch
1600
1400
1200
1000
800
600
400
200
0
1992
1993
1994
13-Jan
17-Jan
21-Jan
25-Jan
29-Jan
2-Feb
6-Feb
10-Feb
14-Feb
18-Feb
22-Feb
26-Feb
1-Mar
5-Mar
9-Mar
13-Mar
17-Mar
21-Mar
25-Mar
29-Mar
2-Apr
6-Apr
10-Apr
14-Apr
18-Apr
22-Apr
26-Apr
30-Apr
4-May
8-May
12-May
16-May
20-May
24-May
Date

Figure 4

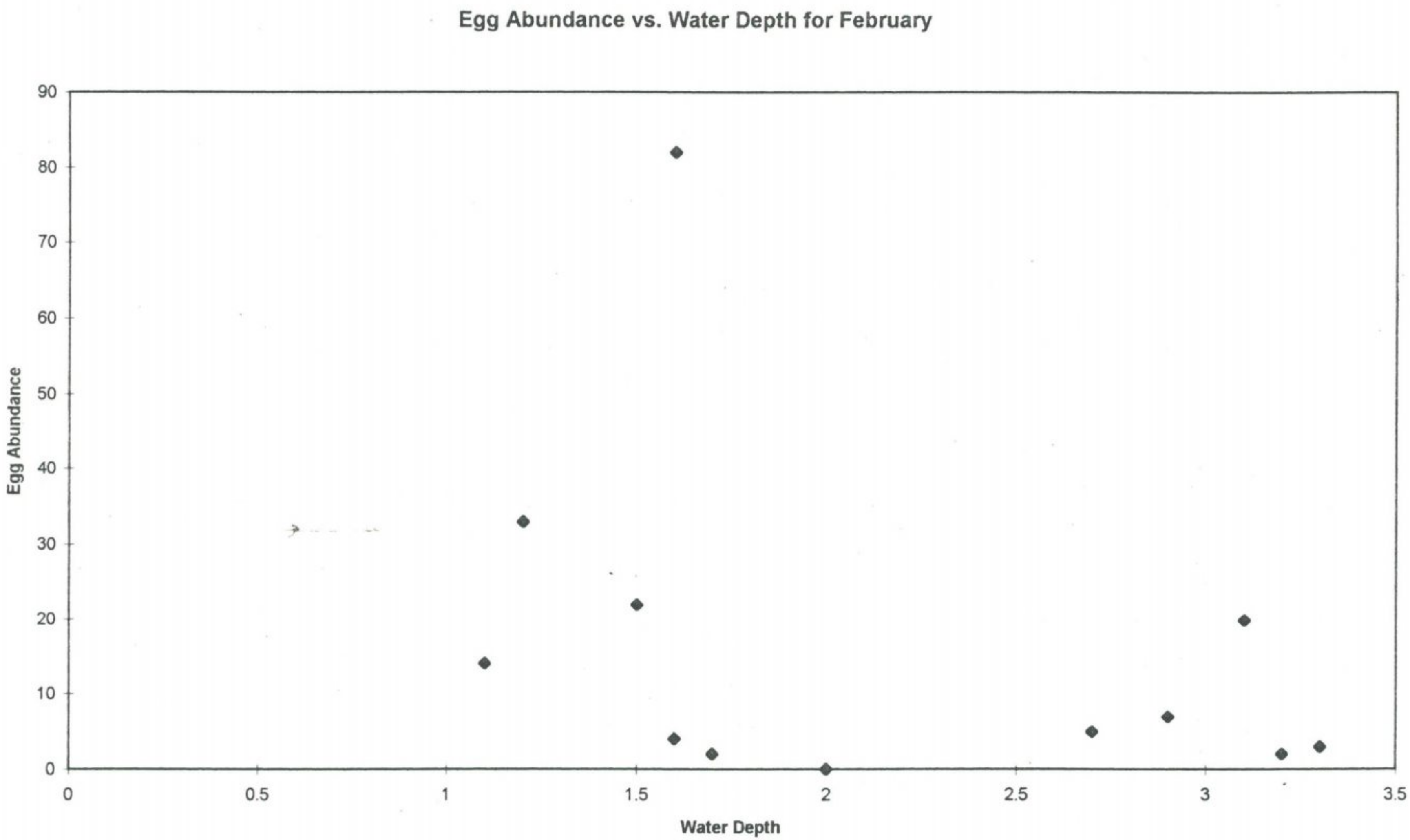

Egg Abundance vs. Water Depth for February
Egg Abundance
Water Depth
0
10
20
30
40
50
60
70
80
90
0
0.5
1
1.5
2
2.5
3
3.5

Figure 5

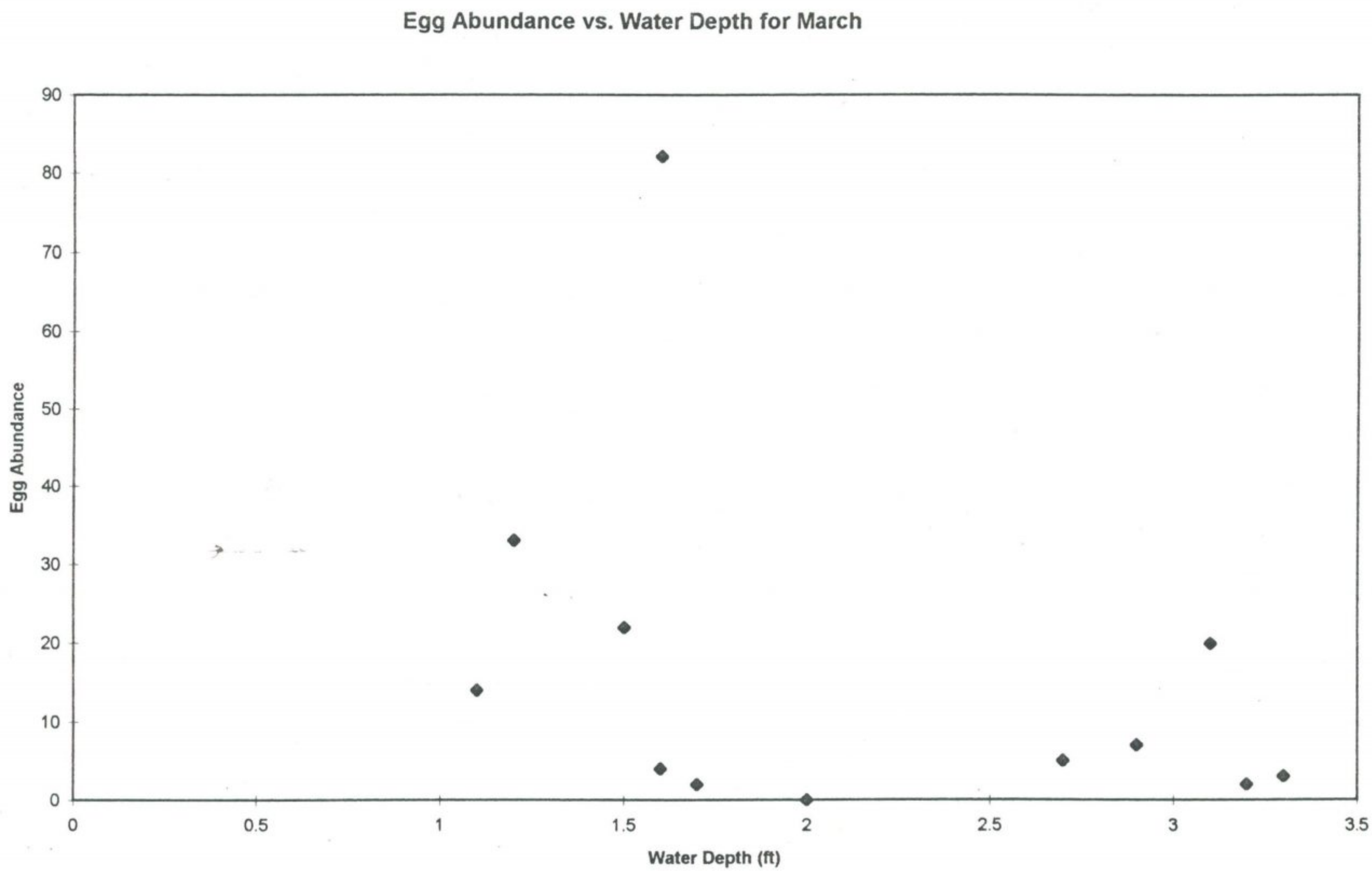

Egg Abundance vs. Water Depth for March
90
80
70
60
50
40
30
20
10
0
Egg Abundance
0
0.5
1
1.5
2
2.5
3
3.5
Water Depth (ft)

Figure 6

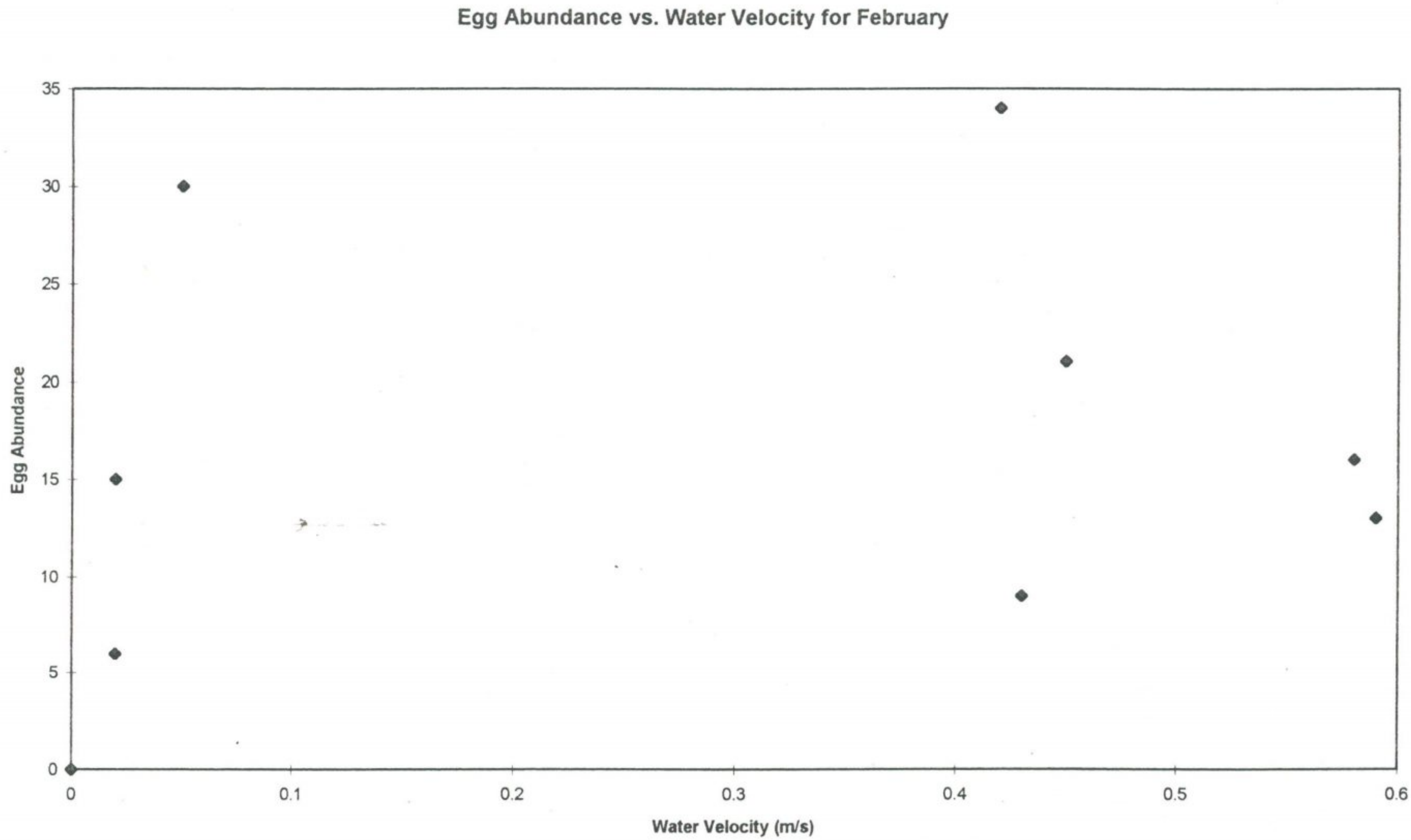

Egg Abundance vs. Water Velocity for February
Egg Abundance
35
30
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Water Velocity (m/s)

Figure 6

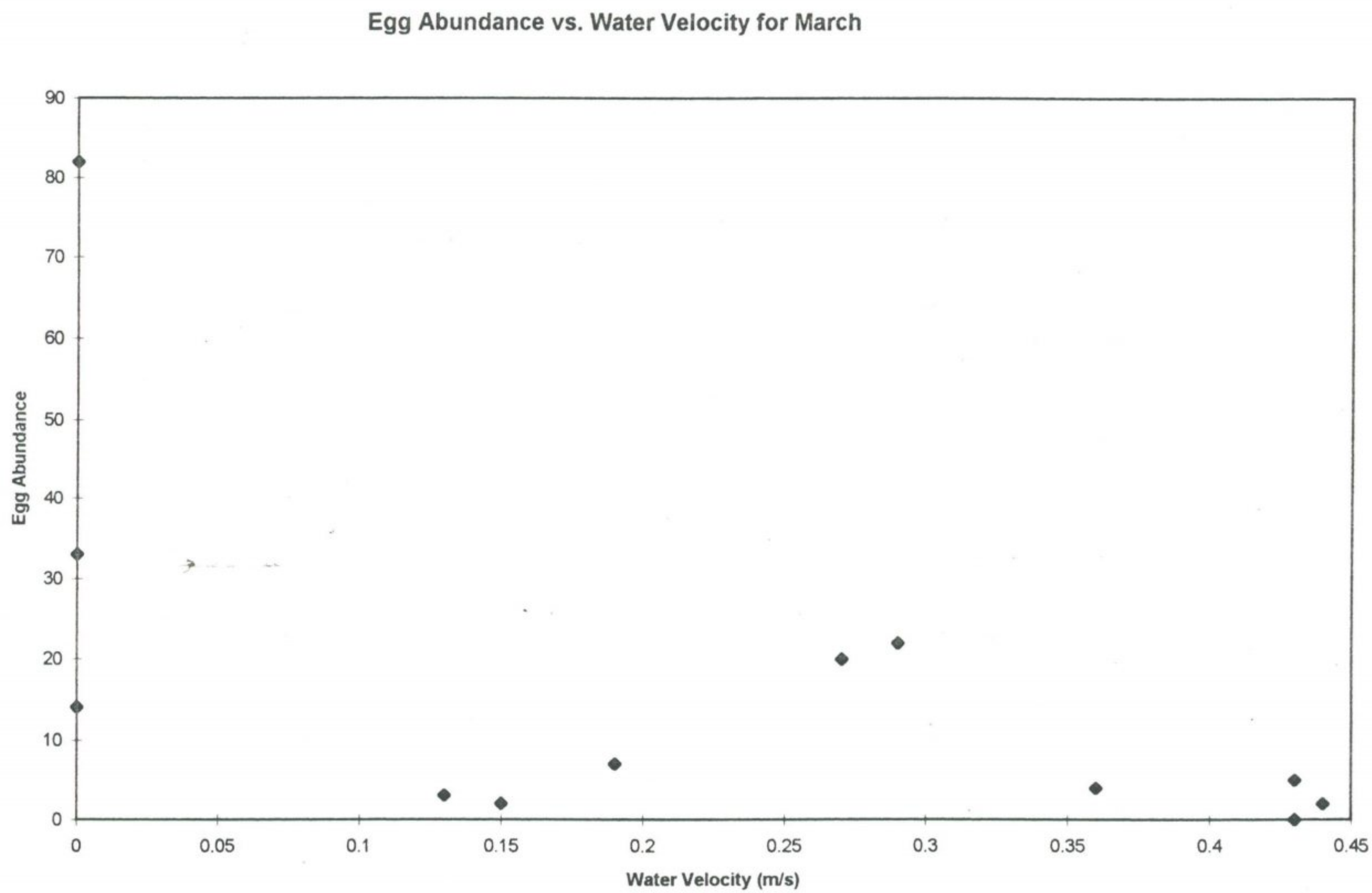

Egg Abundance vs. Water Velocity for March
Egg Abundance
90
80
70
60
50
40
30
20
10
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Water Velocity (m/s)

Figure 8

Egg Abundance vs. Distance Upstream for February

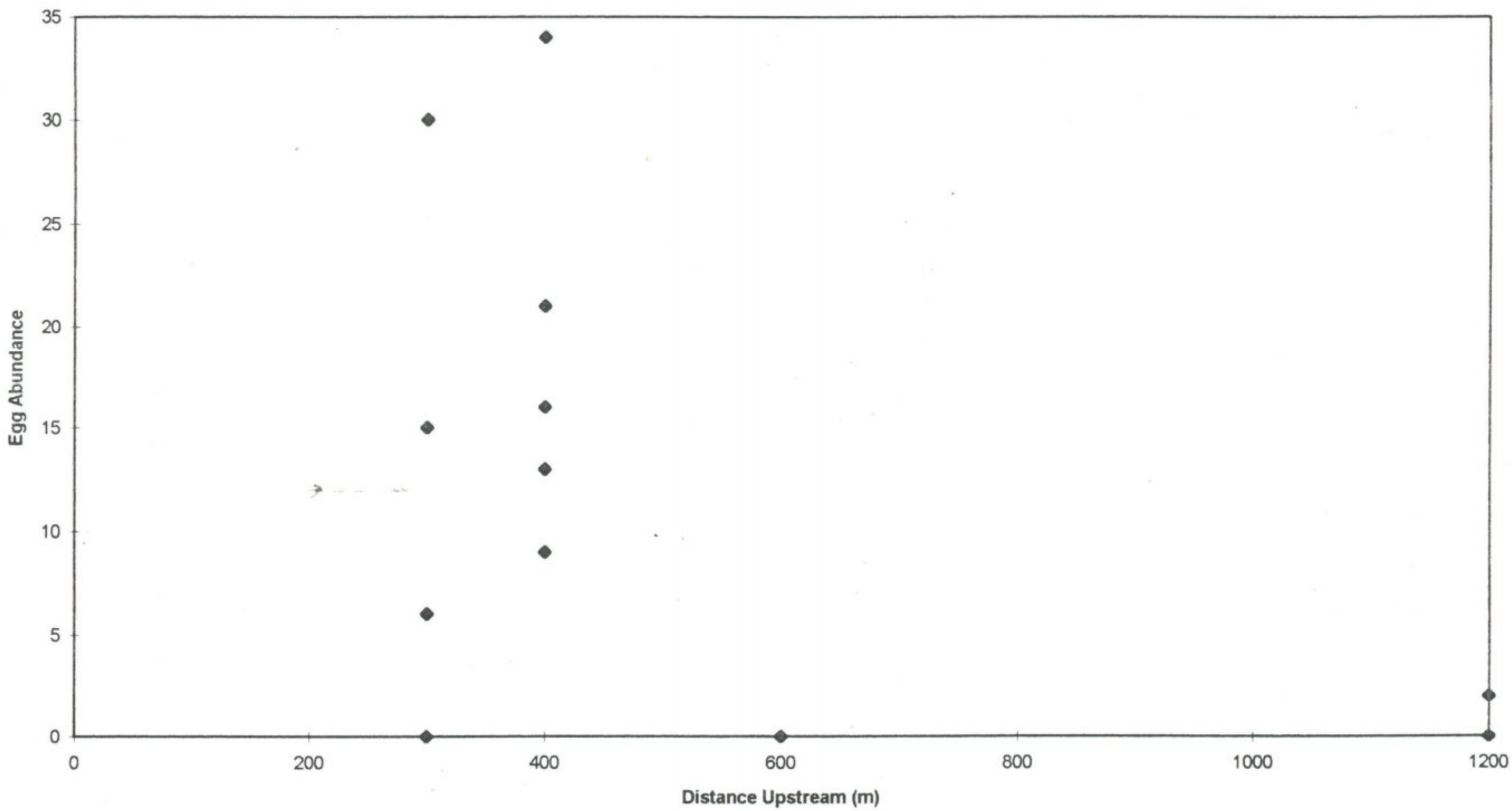
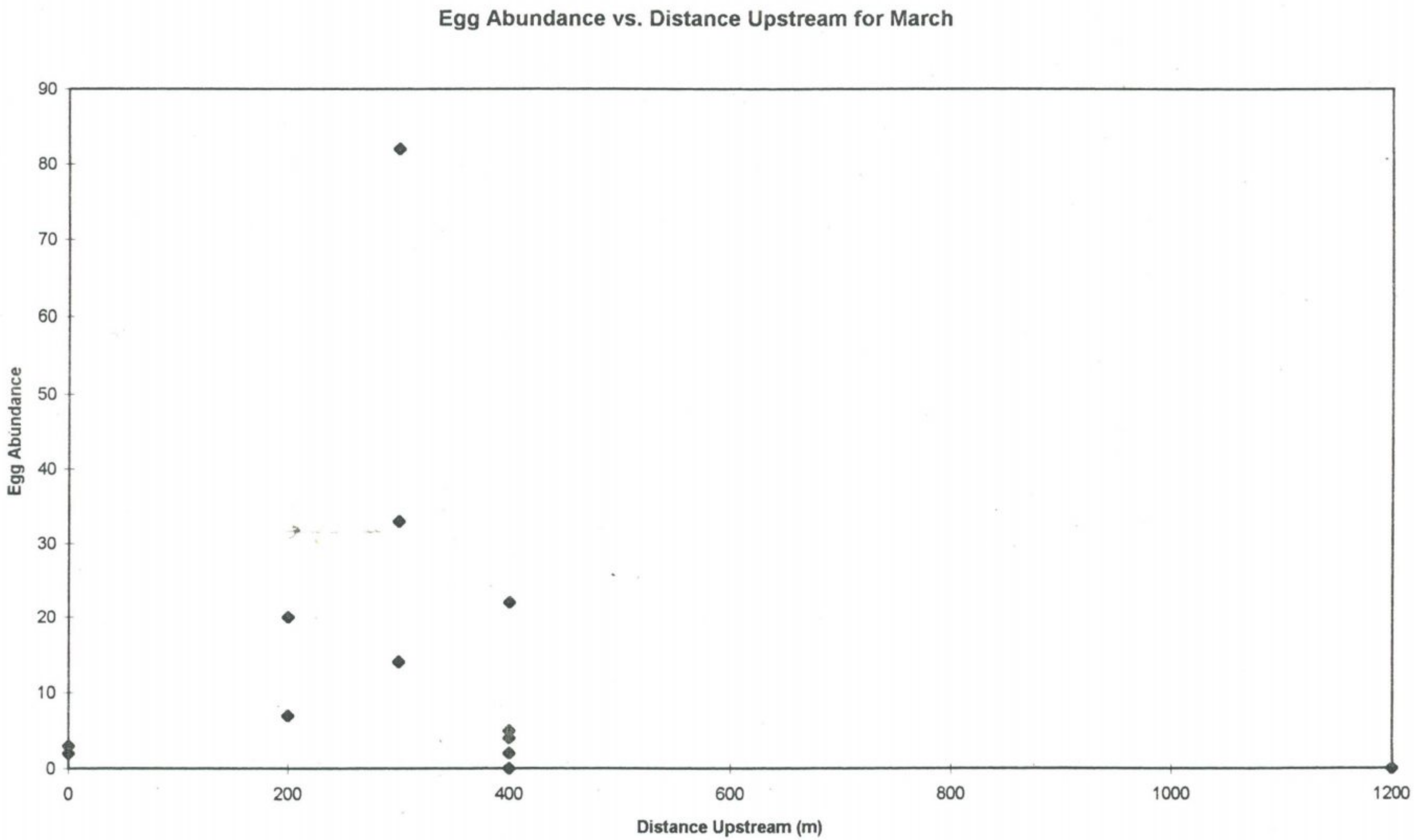


Figure 9



Egg Abundance vs. Distance Upstream for March
Egg Abundance
Distance Upstream (m)
0
10
20
30
40
50
60
70
80
90
0
200
400
600
800
1000
1200

Figure 10

CUMULATIVE DISTRIBUTION OF SUBSTRATE SIZE FOR I-405 TRANSECT

Median 10m = 14 20m = 12 30m = 12

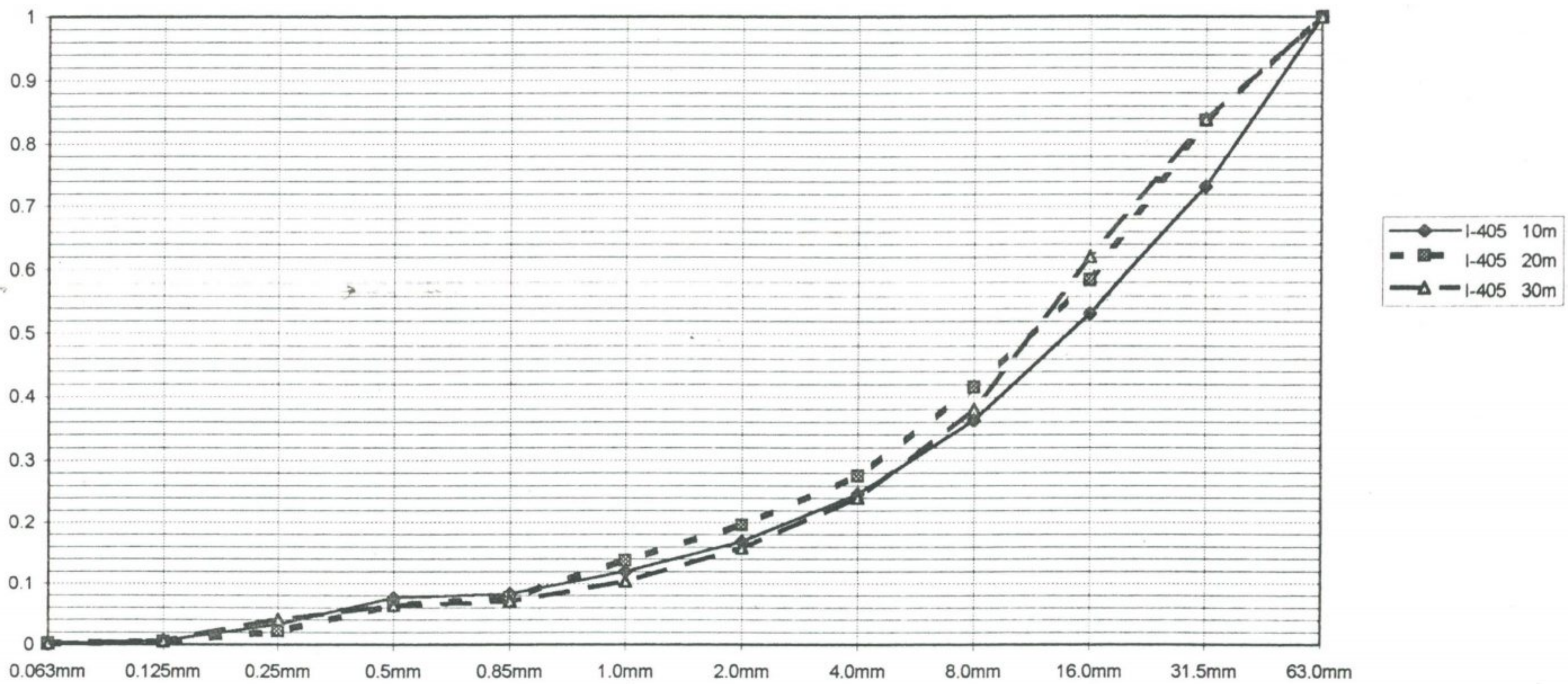


Figure 11

CUMULATIVE DISTRIBUTION OF SUBSTRATE SIZE FOR 1600m TRANSECT

Median 10m = 8 15m = 9

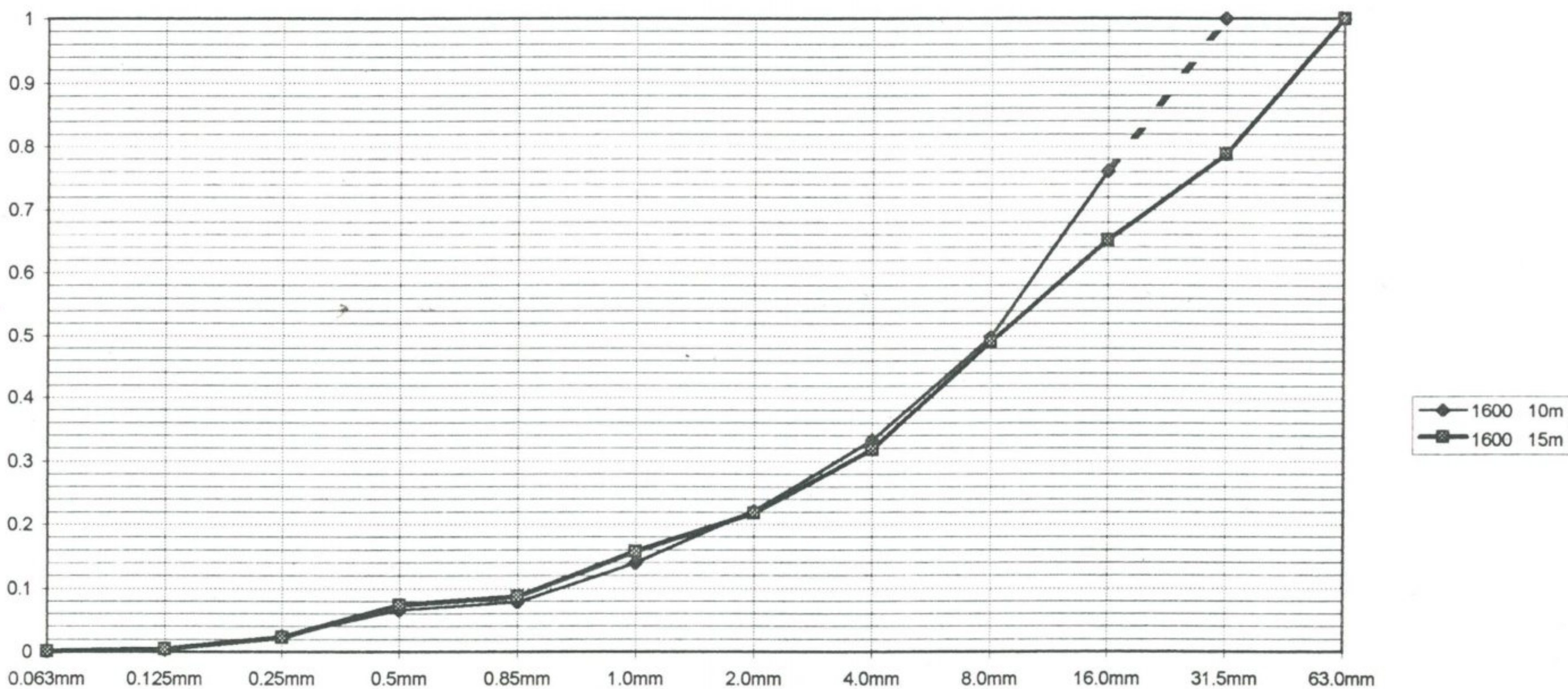


Figure 12

CUMULATIVE DISTRIBUTION OF SUBSTRATE SIZE FOR 1200m TRANSECT

Median 15m = 12 20m = 9 25m = 14

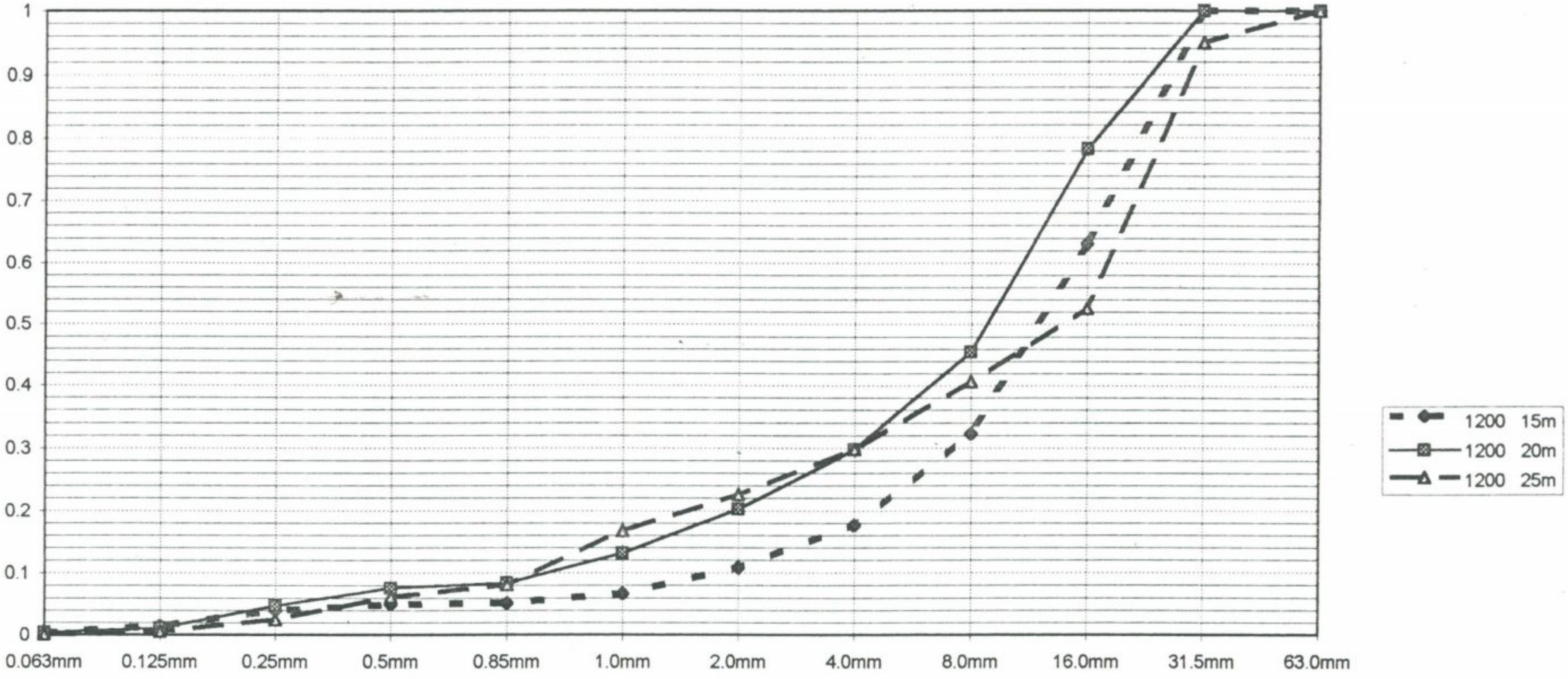


Figure 13

CUMULATIVE DISTRIBUTION OF SUBSTRATE SIZE FOR 800M TRANSECT

Median 5m = 12 15m = 9 30m = 7

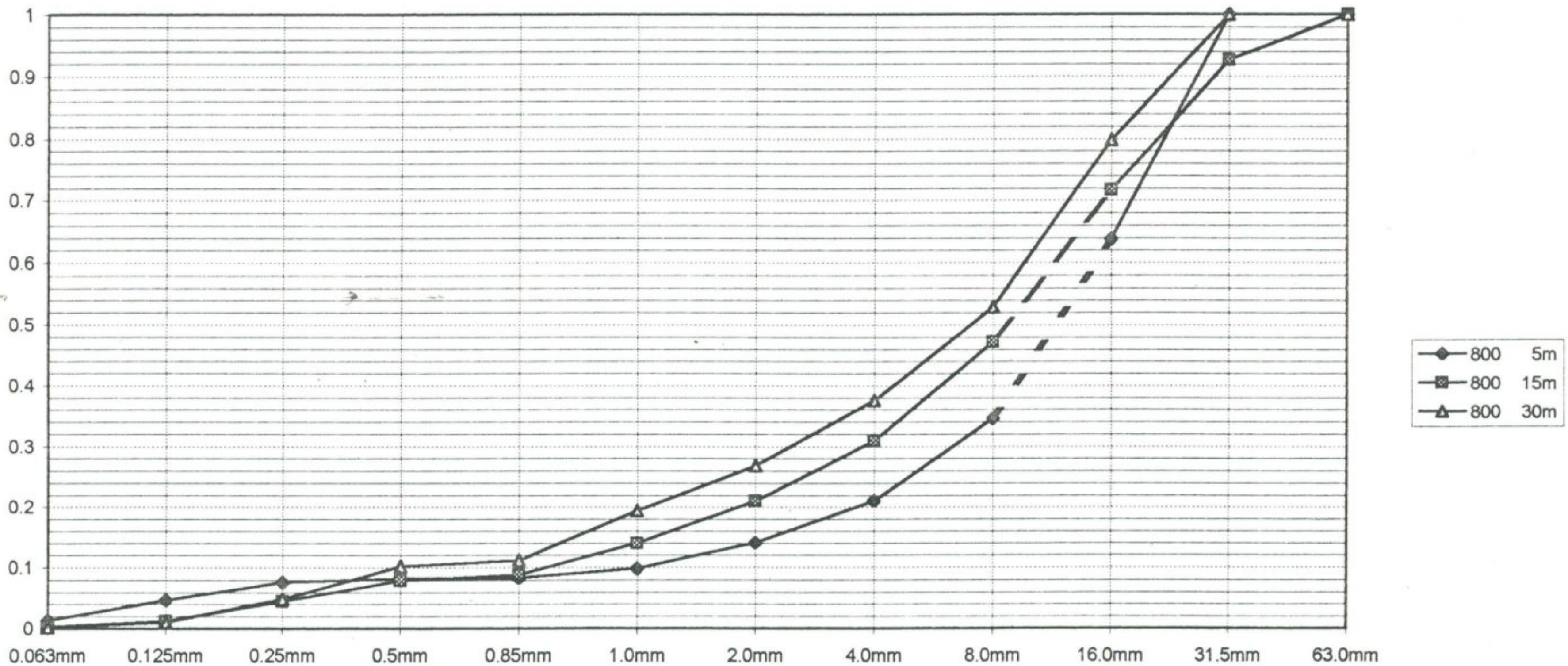


Figure 14