BIOLOGICAL MONITORING PROGRAM

of the

SONOMA COUNTY AGGREGATE RESOURCES MANAGEMENT PLAN

NINE YEAR SUMMARY: 1982-1990

A TECHNICAL REPORT PREPARED FOR
THE SONOMA COUNTY PLANNING DEPARTMENT

by

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January 31, 1991

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MANAGEMENT PLAN-NINE YEAR SUMMARY: 1982-1990

OVERVIEW

In the establishment of the Aggregate Resources Management Plan it was determined that the instream removal of gravel could have an adverse impact on fisheries, aquatic life, and plant life of communities in and surrounding the Russian River. In conjunction with Greg Carr of the Planning Department, I developed a Procedures Manual (Northen, 1983) to guide the collection of long term data that might (1) elucidate some of these biological issues and (2) provide baseline information that would be useful in tracking changes in the ecosystem over time. Each year, I have submitted a report of data pertinent to these tasks. Using these reports, I have summarized and evaluated the information, indicating what it has to say about the issues in question. The work is presented in four parts: gravel analysis, insect analysis, vegetation analysis, and a discussion of some work done on terrace pits.

GRAVEL ANALYSIS

INTRODUCTION AND METHODS

A McNeil Sampler was used for collecting samples. This is a stainless steel cylinder that is placed in the river bed to remove (by hand) a all sediments from a volume 15 cm in diameter and 14 cm deep. Though samples are small, none of the finer sediments wash away in the current. In addition, it is primarily these surface materials that are used by living organism, so carefully taken data on such materials is valuable in assessing biological correlates of the sediments. The device took approximately 5,000 g dry weight of material from the river bed with each sample. The sampler can be used in depths up to about 12 inches. Because sampling was done in conjunction with collecting insects using a device that requires current to sweep dislodged insects into a net, all of the samples were taken from areas approximately 4-12 inches deep in runs, flats, and riffles. As a consequence, the data do not represent deep runs with strong currents or slow pools. They do enable one to compare different kinds of areas and different years on a common scale, however.

In 1982-84, Gravel samples were analyzed entirely in the field. Wet samples were passed through a series of progressively smaller sieves (sizes of which appear with results). After allowing gravitational water to drain away, the different fractions were then placed in a large graduate cylinder filled part way with water and the displacement was measured for the fraction of the sample represented by each particle size. For the "fines" however, which were particles that passed though the smallest sieve (one mm), volumes were measured by allowing materials to settle in a cylinder and then reading it from the side. After settlement, "sand" and "silt" were estimated visually by the appearance of the sediments. Some water was included in the sample, however. To correct this problem, a new method was adopted, and a correction factor was developed to make the 1982-84 data conform to the new method. In 1986, I compared field data taken by the 1982-84 method with weights and actual water displacement of the "silt" (which may have contained some organic material) and the sand of the less than one mm fraction. To correct earlier silt readings, I multiplied the volumes in the original data by .12, and for sand I multiplied the original volumes by .55 to put data from all years on the same scale. Note that the earlier method overestimated both of these values considerably.

In the 1985-89 analysis of gravel, samples were collected in the field, dried in the lab, and analyzed for percentages of particle size by sifting them and weighing the contents of the sieves. Prior to bagging the samples in the field, the water in the McNeil Sampler above the heavier aggregates was poured into one or more large graduate cylinders, which were left undisturbed for at least twenty minutes. This water contained all of the floccular, "silt" of the samples, as well as a small amount of sand that was swept into the cylinders by the decanting process. (Most sand remained with larger aggregates in the material that was bagged.) I then collected these sediments on filter paper, and their dry weights were added to those from the sieve analysis.

RESULTS

Table 1 gives basic information on the sites where both insects and gravel were collected.

TABLE 1. Data on sites where gravel and insects were collected. "SITE" indicates lower, lower middle, upper middle, or upper portions of the study area. All bank vegetation consisted of forbs (f), small cottonwoods of a few feet maximum height (c), small willows of the same size (w), or Coyote Brush (coy br). "F,AIR" and "F,H2O" are air and water temperatures in F. Current is in ft/sec, while algal cover is based on a visual estimate of the fraction of the underwater substratum covered.

AREA	NUM	YEAR	DATE	SITE	HABITAT	BANK VEG.	F,AIR	F,H20	CURR	ALG.COV.
Piombo	1	1989	3-Nov	lwr.	riffle	none	71	59	3.6	0.6
Piombo	1	1989	3-Nov	1-md.	riffle	f,w	58	57	2.4	0.5
Piombo	1	1989	3-Nov	u-md.	run	f,c,w	58	56	2.1	0.3
Piombo	1	1989	3-Nov	uppr.	flat	f	73	61	1.7	1
McCut.	3	1989	4-Nov	lwr.	riffle	c,w	71	62	2.3	0.6
McCut.	3	1989	4-Nov	1-md.	riffle	f,c,w	71	62	1.9	0.8
AREA	NUM	YEAR	DATE	SITE	HABITAT	BANK VEG.	F.AIR	F.H20	CURR	ALG.COV.
McCut.	3	1989	4-Nov	u-md.	riffle	f,c,w	72	64	1.9	0.8
McCut.	3	1989	4-Nov	uppr.	run	f,c,w	75	64	3.7	0.05
MidRch	5	1989	3-Nov	lower	run	f,c	72	57	2.7	0.4
MidRch	5	1989	3-Nov	upper	riffle	f,c,w	71	58	2.4	0.25
Contrl	6	1989	5-Nov	lower	riffle	W	73.4	59.9	2.9	0.25
Contrl	6	1989	5-Nov	upper	flat	c,w	66.2	58.1	2.7	0.75
Dewitt	2	1988	19-Nov	lwr.	riffle	f,w	56	57	3.1	1
Dewitt	2	1988	19-Nov	1-md.	flat	f,w	59	61	1.7	1
Dewitt	2	1988	19-Nov	u-md.	riffle	f,w	66	60	2.8	0.5
Dewitt	2	1988	19-Nov	uppr.	riffle	r,w	68	60	3	0.6
H.G.I.	4	1988	20-Nov	lwr.	run	none	66	59	1.9	1
H.G.I.	4	1988	30-Nov	1-md.	run	none	56	55	2.8	0
H.G.I.	4	1988	30-Nov	u-md.	run	none	56	55	2.4	0
H.G.I.	4	1988	30-Nov	uppr.	run	none	56	55	3.6	0
MidRch	5	1988	30-Nov	lower	run	f,c,w	67	57	3	0
MidRch	5	1988	2-Dec	upper	riffle	W	57	57	3.2	0.5
Contrl	6	1988	2-Dec	lower	riffle	c	66	57	3.3	0.7
Contrl	6	1988	2-Dec	upper	riffle	c	67	57	3.3	0.7
Piombo	1	1987	1 5-Nov	lwr.	run	f	58	56	3.6	0.05
Piombo	1	1987	1 5-Nov	l-md.	riffle	c	62	57	2.6	0.1
Piombo	1	1987	15-Nov	u-md.	run	W	65	56	2.2	0.8
Piombo	1	1987	1 5-Nov	uppr.	flat	none	62	55	2.8	0.3
McCut.	3	1987	18-Nov	lwr.	flat	f,c,w	64	57	2.5	0.4
McCut.	3	1987	18-Nov	1-md.	flat	c,w	56	57	1.9	0.6
McCut.	3	1987	18-Nov	u-md.	riffle	c,w	66	57	3.6	0.75
McCut.	3	1987	18-Nov	uppr.	run	none	63	55	4	0.15
MidRch	5	1987	8-Nov	lower	run	f,c,w	65	61	2.5	0.7
MidRch	5	1987	8-Nov	upper	riffle	f,w	64	60	1.9	0.2
Contrl	6	1987	19-Nov	lower	run	f,w	65	59	2.4	0.7
Contrl	6	1987	19-Nov	upper	riffle	f,c	65	59	3.1	0.5
Dewitt	2	1986	3-Oct	lwr.	run	f,c,w	75	67	2.9	0.2
Dewitt	2	1986	3-Oct	1-md.	flat	c,w	75	65	2	0.5
Dewitt	2	1986	3-Oct	u-md.	riffle	c,w	75	66	2	0.3

TABLE 1. continued

AREA	NUM	YEAR	DATE	SITE	HABITAT	BANK VEG.	F.AIR	F.H20	CURR	ALG.COV.
Dewitt	2	1986	3-Oct	uppr.	riffle	c,w	75	63	1.6	0.1
H.G.I.	4	1986	24-Oct	lwr.	flat	f,w	70	65	2.6	0.3
H.G.I.	4	1986	31-Oct	l-md.	run	f,w	70	62	2.4	0.3
H.G.I.	4	1986	24-Oct	u-md.	run	f,w	70	65	3.3	0.3
H.G.I.	4	1986	31-Oct	uppr.	run	f,w	70	62	2.6	0.2
MidRch	5	1986	4-Oct	lower	riffle	f,w	86	70	3	0.1
MidRch	5	1986	4-Oct	upper	flat	f,w	86	69	1.4	1
Contrl	6	1986	2-Nov	lower	riffle	W	85	62	1.7	0.6
Contrl	6	1986	2-Nov	upper	riffle	f,w	85	62	2.5	0.5
Piombo	1	1985	15-Nov	lwr.	run	none	60	54	3.3	0.1
Piombo	1	1985	15-Nov	1-md.	run	none	60	57	5	0.5
Piombo	1	1985	15-Nov	u-md.	run	coy br	60	57	3.3	0.2
Piombo	1	1985	15-Nov	uppr.	run	none	61	56	2.9	0.6
McCut.	3	1985	3-Nov	lwr.	run	f,w	68	65	2	0.5
McCut.	3	1985	3-Nov	1-md.	flat	f,w	68	64	1.1	1
McCut.	3	1985	4-Nov	u-md.	riffle	f,w	75	62	2	1
McCut.	3	1985	4-Nov	uppr.	flat	f,w	75	65	1.7	1
MidRch	5	1985	20-Oct	lower	run	f,w	75	66	2.2	1
MidRch	5	1985	26-Oct	upper	run	f,w	71	63	2.5	0.3
Contrl	6	1985	27-Oct	lower	riffle	W	78	63	2	1
Contrl	6	1985	2-Nov	upper	riffle	W	69	60	1.3	1
Dewitt	2	1984	29-Oct	lwr.	No Data	No Data	65.3	63.5	0.7	No Data
Dewitt	2	1984	29-Oct	1-md.	No Data	No Data	65.3	63.5	1.7	No Data
Dewitt	2	1984	30-Oct	u-md.	No Data	No Data	65.3	63.5	2	No Data
Dewitt	2	1984	30-Oct	uppr.	No Data	No Data	65.3	63.5	0.8	No Data
H.G.I.	4	1984	7-Nov	lwr.	No Data	No Data	68	64.4	1.2	No Data
H.G.I.	4	1984	7-Nov	1-md.	No Data	No Data	68	64.4	0.6	No Data
H.G.I.	4	1984	8-Nov	u-md.	No Data	No Data	68	64.4	1.8	No Data
H.G.I.	4	1984	8-Nov	uppr.	No Data	No Data	68	64.4	2	No Data
MidRch	5	1984	24-Oct	lower	No-Data	No Data	80.6	64.4	1.7	No Data
MidRch	5	1984	25-Oct	upper	No Data	No Data	80.6	64.4	5	No Data
Contrl	6	1984	6-Nov	lower	No Data	No Data	68	64.4	1	No Data
Contrl	6	1984	6-Nov	upper	No Data	No Data	68	64.4	No Data	No Data
Piombo	1	1982	29-Oct	lower	run	none	No Data		56.3	2.5 0
Piombo	1	1982	3-Nov	upper	run	f,c,w	No Data		57.2	1.7 1
Dewitt	2	1982	23-Oct	lower	run	none	No Data		64.4	3.6 0
Dewitt	2	1982	23-Oct	upper	run	c,w	No Data		53.6	1.4 0
H.G.I.	4	1982	5-Nov	lower	riffle	No Data	No Data		57.2	1.1 0.5
H.G.I.	4	1982	5-Nov	upper	riffle	c,w	No Data		59	1.1 0.5
MidRch	5	1982	8-Oct	lower	run	f,w	No Data		66.2	1.7 0.4
MidRch	5	1982	3-Nov	upper	run	f,w	No Data		59	1.7 0.4
Contrl	6	1982	15-Oct	lower	riffle	f,w	No Data		66.2	0.4 0.8
Contrl	6	1982	16-Oct	upper	run	f,w	No Data		64.4	1.7 1

SUMMARY OF DATA ON SEDIMENTS

Table 2 gives a summary of all years' data. It should be noted that some sites have fluctuated considerably from year to year in a given particle size category. The category that varied most from year to year in a given area was "above 45.2 mm." This was because a few larger rocks (up to a diameter of 15 cm, the diameter of the sample itself) could greatly influence the percentage in this category. Some fluctuation in the numbers would be expected due to random variation from sample to sample.

TABLE 2. Summary of data on all samples. Each value in the first tabulation for "ALL AREAS" represents the average of 36 McNeil samples taken from 12 sites, except for 1982, where 30 samples from ten sites are represented. Summary values on the far right may be significant in terms of eventual recovery of the river to the point were salmon may breed (see text).

ALL AREAS	Silt/ Clay	Sand (<1mm)	1.0- 2.7	2.8- 5.5	5.6- 11.1	11.2- 22.3	22.4- 45.2	>45.2	"Fines" (<1mm)	"Mid-sized"	>1 inch (>22.4mm)
1982	0.6	13.0	13.3	10.7	15.3	20.0	17.6	9.5	13.7	59.3	27.1
1984	1.4	10.8	12.1	11.7	17.4	21.4	17.4	7.7	12.3	62.6	25.1
1985	0.2	12.8	11.0	10.9	16.4	21.8	19.6	7.4	12.9	60.1	27.0
1986	0.6	13.2	7.5	10.4	16.9	21.3	20.4	9.7	13.8	56.1	30.1
1987	0.5	13.2	10.0	9.6	13.8	18.5	21.6	12.9	13.7	51.8	34.5
1988	0.9	9.9	9.4	12.1	17.9	19.3	18.5	12.0	10.8	58.7	30.5
1989	0.8	10.1	10.9	10.8	15.2	18.7	19.9	13.7	10.9	55.5	33.6

AREA 1 PIOMBO	Silt/ Clay	Sand (<1mm)	1.0- 2.7	2.8- 5.5	5.6- 11.1	11.2- 22.3	22.4- 45.2	>45.2	"Fines" (<1mm)	"Mid-sized"	>1 inch (>22.4mm)
1989	0.9	6.7	9.1	8.3	12.2	16.9	20.2	25.8	7.6	46.5	46.0
1987	0.5	13.4	11.4	11.3	15.7	20.4	18.8	8.6	13.9	58.8	27.4
1985	0.2	15.7	11.0	10.6	16.0	22.4	20.5	3.7	15.9	60.0	24.2
1982	1.3	15.9	8.7	8.5	13.5	17.7	15.8	18.6	17.2	48.4	34.4
AvgAllYrs	0.7	12.9	10.1	9.7	14.3	19.3	18.8	14.2	13.6	53.4	33.0

AREA 2 DEWITT	Silt/ Clay	Sand (<1mm)	1.0- 2.7	2.8- 5.5	5.6- 11.1	11.2- 22.3	22.4- 45.2	>45.2	"Fines" (<1mm)	"Mid-sized"	>1 inch (>22.4mm)
1988	0.7	7.2	9.0	10.3	14.5	17.5	21.9	19.1	7.9	51.3	41.0
1986	0.5	11.8	8.7	9.0	12.2	19.9	21.0	16.9	12.3	49.8	37.9
1984	2.2	11.9	11.9	10.2	14.6	21.1	19.0	9.1	14.1	57.7	28.1
1982	0.6	15.0	17.4	12.6	15.6	18.4	14.7	5.8	15.5	64.0	20.5
AvgAllYrs	1.0	11.5	11.8	10.5	14.2	19.2	19.2	12.7	12.5	55.7	31.9

AREA 3 MCCUTCH	Silt/ Clay	Sand (<1mm)	1.0- 2.7	2.8- 5.5	5.6- 11.1	11.2- 22.3	22.4- 45.2	>45.2	"Fines" (<1mm)	"Mid-sized"	>1 inch (>22.4mm)
1989	1.0	9.2	11.7	12.3	17.3	20.1	22.1	6.4	10.2	61.4	28.5
1987	0.6	11.2	8.9	7.2	10.8	15.9	24.9	20.5	11.8	42.8	45.4
1985	0.1	11.0	11.4	9.5	13.9	18.2	21.6	14.4	11.1	53.0	36.0
AvgAllYrs	0.6	10.5	10.7	9.7	14.0	18.1	22.9	13.8	11.0	52.4	36.6

AREA 4 H.G.I.	Silt/ Clay	Sand (<1mm)	1.0- 2.7	2.8- 5.5	5.6- 11.1	11.2- 22.3	22.4- 45.2	>45.2	"Fines" (<1mm)	"Mid-sized"	>1 inch (>22.4mm)
1988	1.3	11.2	6.6	12.6	20.9	22.0	17.5	8.0	12.5	62.1	25.5
1986	0.9	13.0	3.5	8.6	18.1	23.7	25.2	7.0	13.9	53.9	32.2
1984	0.8	9.4	9.3	10.4	20.2	23.9	15.8	10.3	10.2	63.7	26.1
1982	0.3	7.1	9.8	9.0	13.9	21.8	27.3	10.8	7.4	54.5	38.1
AvgAllYrs	0.8	10.2	7.3	10.1	18.3	22.9	21.4	9.0	11.0	58.6	30.5

AREA 5 MID REACH	Silt/ Clay	Sand (<1mm)	1.0- 2.7	2.8- 5.5	5.6- 11.1	11.2- 22.3	22.4- 45.2	>45.2	"Fines" (<1mm)	"Mid-sized"	>1 inch (>22.4mm)
1989	0.2	18.4	13.3	14.2	17.3	17.6	13.8	5.4	18.6	62.4	19.2
1988	0.8	15.1	16.7	18.6	23.4	17.6	8.0	0.0	15.9	76.3	8.0
1987	0.2	18.1	13.5	14.5	18.0	17.4	14.7	3.8	18.3	63.4	18.5
1986	0.3	15.1	12.4	19.6	27.0	18.0	7.7	0.0	15.4	77.0	7.7
1985	0.3	15.0	10.3	11.4	18.5	23.5	14.1	7.2	15.3	63.7	21.3
1984	0.2	13.6	19.8	18.1	20.8	16.6	10.8	0.0	13.8	75.4	10.8
1982	0.6	15.9	12.4	10.8	16.2	20.8	15.7	7.7	16.4	60.1	23.4
AvgAllYrs	0.4	15.9	14.1	15.3	20.2	18.8	12.1	3.4	16.3	68.3	15.6

AREA 6 CONTROL	Silt/ Clay	Sand (<1mm)	1.0- 2.7	2.8- 5.5	5.6- 11.1	11.2- 22.3	22.4- 45.2	>45.2	"Fines" (<1mm)	"Mid-sized"	>1 inch (>22.4mm)
1989	0.9	10.6	10.3	9.6	14.8	20.6	21.1	12.3	11.5	55.3	33.4
1988	0.7	7.6	8.5	8.4	13.5	19.3	24.2	18.1	8.3	49.7	42.3
1987	0.8	12.2	5.6	6.1	11.7	20.9	27.6	15.3	13.0	44.3	42.9
1986	0.6	14.6	8.4	7.8	13.6	22.6	22 4	10.2	15.2	52.4	32.6
1985	0.1	8.5	10.7	13.9	20.5	26.1	19.7	0.7	8.6	71.2	20.4
1984	2.4	8.9	10.6	11.1	14.0	21.7	23.8	7.6	11.2	57.4	31.4
1982	0.3	11.4	18.1	12.8	17.1	21.2	14.4	4.6	11.7	69.3	19.0
AvgAllYrs	0.8	10.5	10.3	10.0	15.0	21.8	21.9	9.8	11.4	57.1	31.7

MAIN TRENDS IN RIVER SEDIMENTS

A major question addressed by the project design is whether or not in-channel mining is having an adverse affect on the sediments of the river channel. All of the samples were taken each year before any major flooding and sediment transport. As a consequence, the sediment samples reflect any influence of the current year's mining integrated with past years' deposition at that point in the river channel. The best way to examine this question is to combine sediment categories into groups that may have meaning for anadromous salmon, based on other studies. As indicated in earlier reports, Van Woert and Smith (1962) as cited in Hopkirk and Northen (1980) concluded that gravel less than one inch in diameter may not be greater than 50% of the total if successful-spawning of one salmon species (King Salmon) is to occur. Hall and Lantz (1969) showed that 50% or better survival of salmon (Coho) occurred only when fine sediments of less than .9 mm were lower than 20% of the substrate sample. The biological values of the Russian River proper certainly go beyond management for salmon, but these are some of the most sensitive species. They do not now breed within the main channel, but evaluating data in terms of the suitability of the habitat for this activity provides a useful "yardstick" for measuring year to year changes. For this reason, I have combined sediment categories into "fines" of less than 1 mm, approximating Hall and Lantz's criterion (an examination of Table 2 will show that most of this sediment was sand), "mid-sized" particles from 1-22.4 mm, and "greater than 22.4 mm" which approximates the "greater than one inch" criterion of Van Woert and Smith. Figs. 1 through 6 show annual trends in all sites for these categories.

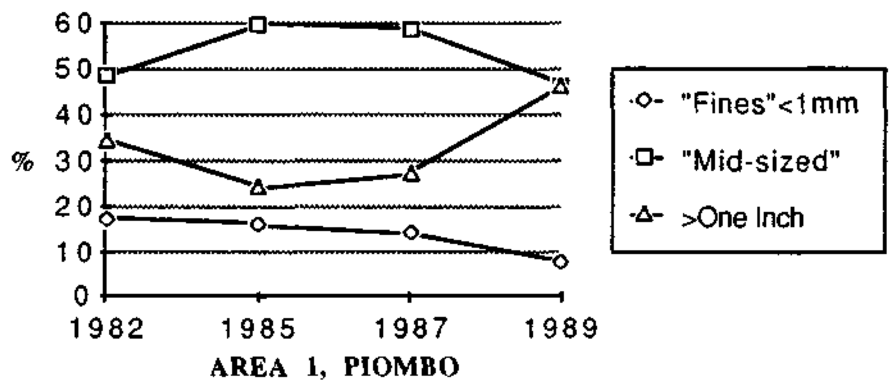


FIGURE 1. Trends in average annual values for Area 1, a mined area.

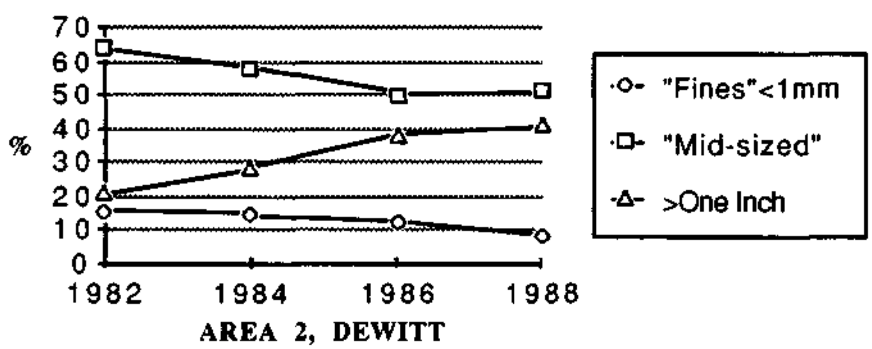


FIGURE 2. Trends in average annual values for Area 2, a mined area.

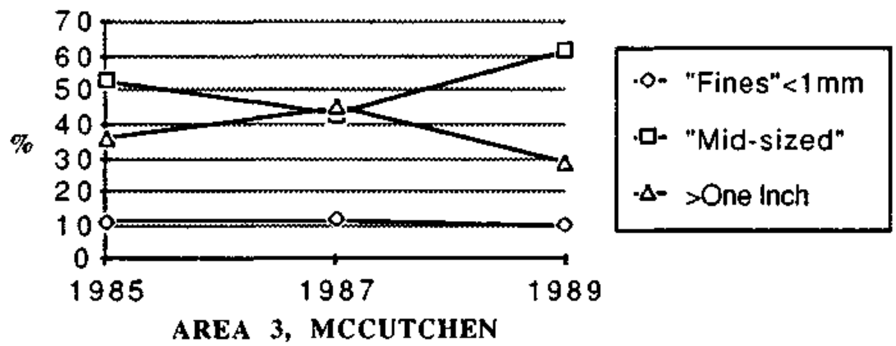


FIGURE 3. Trends in average annual values for Area 3, a mined area.

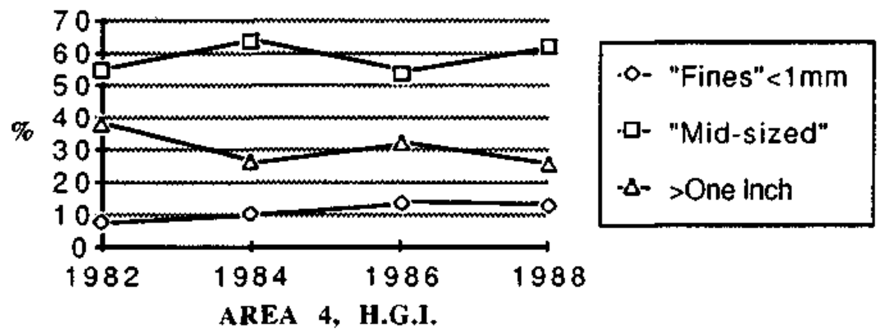


FIGURE 4. Trends in average annual values for Area 4, a mined area. Samples in this area were taken only at the far upstream section.

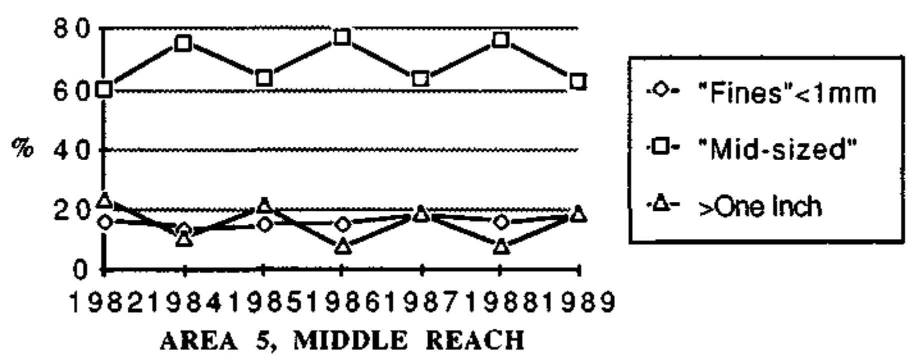


FIGURE 5. Trends in average annual values for Area 5, the indirect impact area just downstream from the Syar operation in the Middle Reach.

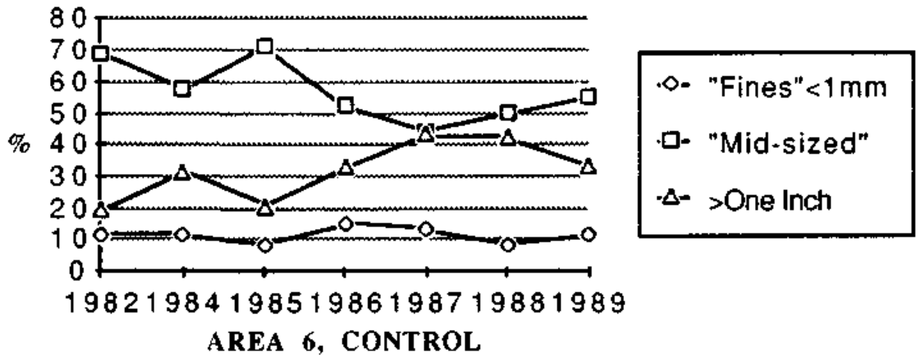


FIGURE 6. Trends in average annual values for Area 6, the Control Area on the Stuhlmuller property off West Soda Rock Lane

Examination of these figures shows that Area 5, the Indirect Impact Area, has had consistently higher levels for fines and lower levels for the greater-than-one-inch categories, compared with the other sites. It is conceivable that extraction results in a depletion of larger sediments and a downstream deposition of finer sediments. I would regard such a conclusion as tentative, however, since only one such site has been studied (see below for recommendations on modification of the monitoring plan). Sites where the samples have been taken within heavily disturbed channels (Areas 1-3) do not show clear differences from sites where the samples were little affected (Area 4) or away from (Area 6) extraction activities. Fig. 7 shows the fines and large aggregate categories summed over all years for all sites.

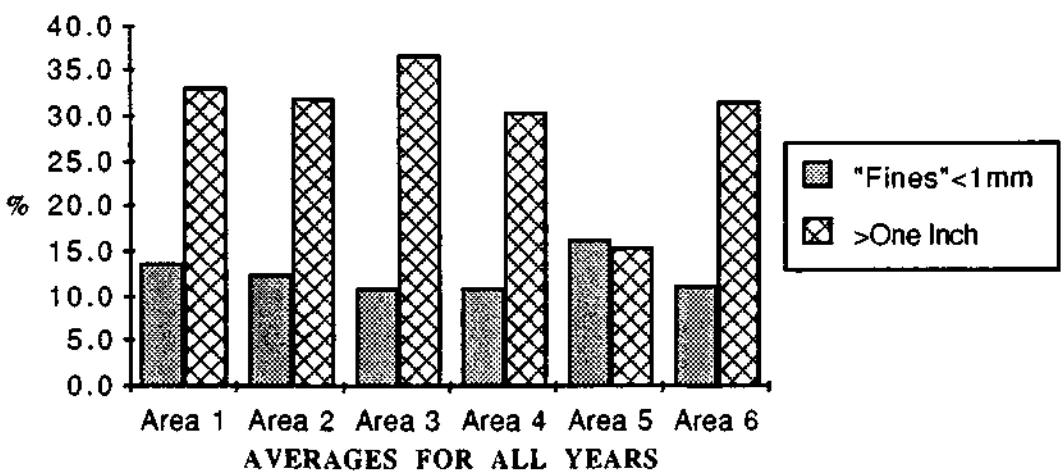


FIGURE 7. Averages over all years for fines and larger aggregates for the study areas.

A second question regarding aggregate materials is whether or not there is any trend in the particle size distribution for the channel as a whole over the duration of the study. Figure 8 shows that there has been a slight decrease in fines and increase in materials in the greater than one inch category over the eight years of the study. The apparent changes in fines may be due to several dry years, during which there was little extraction. An increase in particles greater than one inch diameter appears in 1986/1987, when there was no obvious association with rainfall. If real, the values in Fig. 8 (next page) shows a slight improvement in the sediments from the standpoint of requirements for salmon breeding. Fines have been consistently below 20%, and may be decreasing. Larger particles are increasing, but have not begun to exceed the 50% level. Clearly, it would be desirable to continue monitoring to have additional data to evaluate and track these trends.

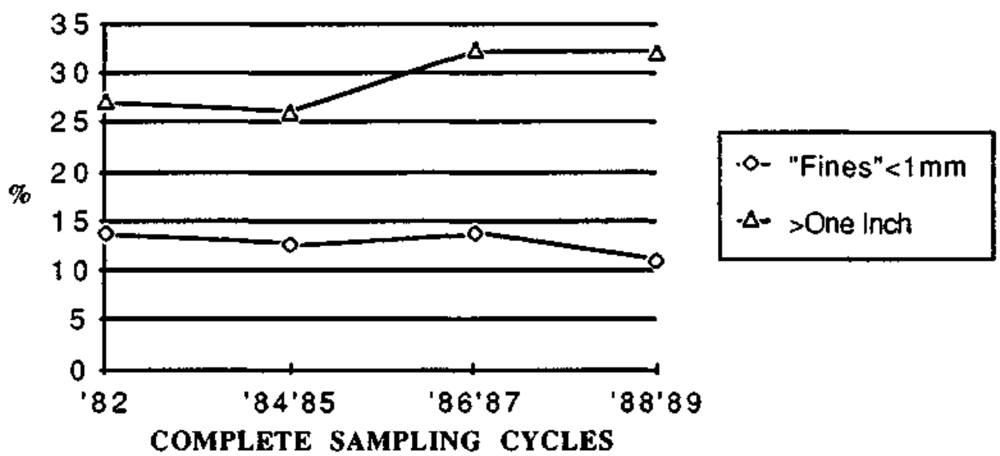


FIGURE 8. Trend in major size categories for all sites. (Note: 1983 data are missing because early heavy rains prevented sampling. 1982 data do not include Area 3 because access was not granted.) Data from 1984 on are lumped into sampling cycles in which data were taken from four sampling sites for each area.

AQUATIC INVERTEBRATES

METHODS

The method for collecting aquatic invertebrates involved using a Serber Sampler in the same location as each gravel sample. A metal frame was inserted into the bottom sediments upstream of a nylon net that attached to it. The person taking the samples then thoroughly scraped all of the rocks and turned the sediment (by hand) washing the insects into the net. The contents of the net were placed with a small amount of water in an enamel pan, and specimens were hand picked from there with tweesers or an eye dropper into a container of 20-30% Ethanol. Identification and counting of insects were done in the laboratory.

RESULTS

The complete set of data included 29 families of aquatic insects in eight orders, and non-insects from seven other groups, which were identified only by common name. The list below gives these groups. A number of them were represented by only a few individuals, and are not tabulated separately in this data summary. Others were very common and accounted for the preponderance of individuals.

Order Ephemeroptera-Mayflies
- Families Baetidae, Heptageniidae, Leptophlebiidae, Trichorythidae. and Ephemerellidae

Order Megaloptera - Alderflies and Relatives
- Family Sialidae

Order Odonata-Damselflies and Dragonflies
- Families Gomphidae, Libellulidae, Coenagrionidae, and Calopterygidae

Order Hemiptera-True Bugs
- Families Naucoridae, Corixidae, Saldidae, and Veliidae

Order Trichoptera - Caddisflies
- Families Hydropsychidae, Hydroptilidae, Leptoceridae, and Philopomatidae

Order Lepidoptera-Moths and Butterflies
- Family Pyralidae

Order Coleoptera-Beetles
- Families Dytiscidae, Elmidae, Hydraenidae, Psephenidae, Dryopidae, and Hydrophilidae

Order Diptera - Gnats and Flies
- Families Chironomidae, Simuliidae, Tipulidae, and Ceratopogonidae

Other Groups, by Common Name
- Water Mites, Planarians, Snails, Clams, Annelids, Crustaceans, and Ribbon Worms

Table 3 gives data by locality on the major groups, while Table 4 provides an overall comparison among sites. The area of river bottom sampled at each sampling site was .28 m, thus total densities in a given year ranged from 14/square m at Area 4 in 1982 to 998/square m at Area 2 in 1988. Most values tended toward the middle of this range.

TABLE 3. Summary of insect numbers for each study area, by year. In 1982, all areas were sampled with three Serber samples in each of two sampling sites, a procedure that was continued for Area 5 (Middle Reach) and Area 6 (Control). From 1984 on, the mining locations (Areas 1-4) were sampled with three Serber samples from each of four sampling sites. Each annual entry represents the average numbers per sampling site, while entrys at the bottom represent the averages over all years.

Area 1, Piombo	Year	Baetidae	Hydro-psychidae	Elmidae	Chiro-nomidae	Simu-liidae	Tipulidae	Planarians	Others	Number Fams.	Total Indivs.
	1982	13.0	54.0	0.0	0.0	0.0	0.0	0.0	4.0	3.0	64.5
	1985	41.5	48.5	1.0	13.3	8.0	0.0	1.0	3.0	6.3	115.3
	1987	28.5	35.3	8.0	2.3	16.3	1.0	16.0	8.8	6.3	104.8
	1989	7.5	26.8	4.0	0.0	0.0	0.0	14.3	4.8	6.0	53.5
	Avg.	22.6	41.1	3.3	3.9	6.1	0.3	7.8	5.1	5.4	84.5

Area 2, Dewitt	Year	Baetidae	Hydro-psychidae	Elmidae	Chiro-nomidae	Simu-liidae	Tipulidae	Planarians	Others	Number Fams.	Total Indivs.
	1982	12.0	0.0	0.0	0.0	0.0	1.0	0.0	5.5	2.5	12.0
	1984	6.0	27.8	2.0	3.5	0.0	0.0	7.3	20.0	9.8	64.0
	1986	21.7	15.0	3.5	0.0	16.7	4.5	3.0	29.8	6.8	76.3
	1988	36.0	203.0	21.3	16.0	1.0	1.0	12.3	6.0	7.3	279.3
	Avg.	18.9	61.4	6.7	4.9	4.4	1.6	5.6	15.3	6.6	107.9

Area 3, McCut.	Year	Baetidae	Hydro-psychidae	Elmidae	Chiro-nomidae	Simu-liidae	Tipulidae	Planarians	Others	Number Fams.	Total Indivs.
	1985	13.0	44.3	1.5	1.0	5.0	2.0	14.5	4.8	6.0	58.3
	1987	37.3	104.3	9.0	3.0	90.0	1.0	12.3	8.8	8.0	170.8
	1989	17.0	61.5	10.3	0.0	1.0	0.0	19.7	7.0	6.8	110.8
	Avg.	22.4	70.1	6.9	1.3	32.0	1.0	15.5	6.8	6.9	113.3

Area 4, H.G.I.	Year	Baetidae	Hydro-psychidae	Elmidae	Chiro-nomidae	Simu-liidae	Tipulidae	Planarians	Others	Number Fams.	Total Indivs.
	1982	0.0	1.0	0.0	0.0	0.0	0.0	0.0	3.5	1.0	4.0
	1984	16.3	0.0	0.0	1.0	0.0	0.0	4.5	9.5	5.3	24.3
	1986	16.5	14.0	5.3	0.0	4.3	3.0	5.5	9.5	9.8	58.0
	1988	4.3	7.5	3.0	12.0	0.0	1.5	9.0	12.0	8.5	37.3
	Avg.	9.3	5.6	2.1	3.3	1.1	1.1	4.8	8.6	6.1	30.9

Area 5 MidRch	Year	Baetidae	Hydro-psychidae	Elmidae	Chiro-nomidae	Simu-liidae	Tipulidae	Planarians	Others	Number Fams.	Total Indivs.
	1982	2.0	26.0	0.0	0.0	0.0	0.0	0.0	5.5	4.0	35.0
	1984	38.0	57.5	3.5	1.0	1.0	0.0	2.5	54.0	8.5	137.5
	1985	4.5	10.5	4.0	2.5	0.0	0.0	11.0	6.5	7.0	31.5
	1986	9.5	7.0	1.0	0.0	0.0	6.0	0.0	21.5	5.5	41.5
	1987	13.5	9.5	16.0	0.0	1.0	6.5	1.5	6.5	7.5	54.0
	1988	19.5	11.0	3.0	0.0	1.0	7.0	3.0	14.0	7.5	46.0
	1989	19.5	7.0	5.5	0.0	1.0	4.0	25.0	5.0	7.5	54.0
	Avg.	15.2	18.4	4.7	0.5	0.6	3.4	6.1	16.1	6.8	57.1

Area 6 Control	Year	Baetidae	Hydro-psychidae	Elmidae	Chiro-nomidae	Simu-liidae	Tipulidae	Planarians	Others	Number Fams.	Total Indivs.
	1982	57.0	89.0	0.0	0.0	0.0	2.0	0.0	12.5	4.0	115.0
	1984	13.0	0.0	0.0	7.0	0.0	0.0	2.0	39.0	5.0	50.0
	1985	6.0	6.5	2.0	1.0	0.0	0.0	3.0	51.0	5.5	68.0
	1986	4.0	32.0	6.0	0.0	2.5	1.5	6.5	4.5	9.0	57.0
	1987	25.0	35.0	6.0	5.0	2.0	0.0	4.5	20.5	8.0	84.5
	1988	2.0	4.0	1.0	0.0	0.0	0.0	2.5	4.0	5.0	10.0
	1989	29.5	19.5	13.5	4.0	1.0	3.0	1.0	13.5	8.0	80.5
	Avg.	19.5	26.6	4.1	2.4	0.8	0.9	2.8	20.7	6.4	66.4

TABLE 4. Average values of all sites over all years.

		Baetidae	Hydro-psychidae	Elmidae	Chiro-nomidae	Simu-liidae	Tipulidae	Planarians	Others	Number Fams.	Total Indivs.
Area 1	Avg.	22.6	41.1	3.3	3.9	6.1	0.3	7.8	5.1	5.4	84.5
Area 2	Avg.	18.9	61.4	6.7	4.9	4.4	1.6	5.6	15.3	6.6	107.9
Area 3	Avg.	22.4	70.1	6.9	1.3	32.0	1.0	15.5	6.8	6.9	113.3
Area 4	Avg.	9.3	5.6	2.1	3.3	1.1	1.1	4.8	8.6	6.1	30.9
Area 5	Avg.	15.2	18.4	4.7	0.5	0.6	3.4	6.1	16.1	6.8	57.1
Area 6	Avg.	19.5	26.6	4.1	2.4	0.8	0.9	2.8	20.7	6.4	66.4

One important question regarding the impact of in-stream extraction on the aquatic insects is whether or not the number of insects is reduced by the mining activity. Fig. 8 shows that the opposite is true. Areas 1-3, where mining occurred, had larger insect populations than Areas 5, located just downstream from a mining zone, and Area 6, The Control Area quite distant from any mined area. Data for the H.G.I. extraction site (Area 4) seem to contradict this conclusion, but special circumstances at this area actually make the data support the conclusion. As noted previously, the only portion of Area 4 with shallow enough water to allow for sampling happens to be at the far upstream end, where little or no extraction occurs. This area is thus like a second control, because the area upstream of the sampling sites is in a natural condition.

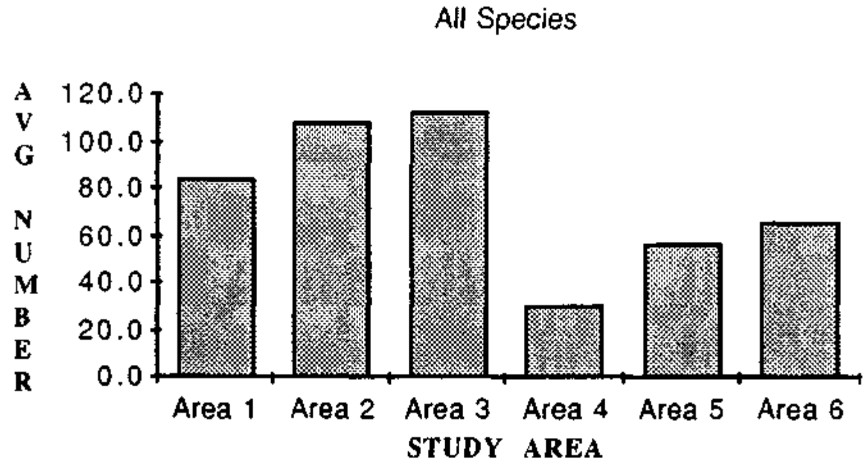


FIGURE 8. The average number of insects and other aquatic invertebrates per sampling site over all years.

A perusal of the data in Table 4 shows that two insect families (most probably a single species in each) account for most of this difference between mined and unmined areas. The first group, for which data appear in Fig. 9, is the Family Hydropsychidae, a group of Caddisflies known as the "Common Netspinners." The second group with considerably higher densities in the mined areas is the Family Simuliidae. These are the Black Flies of the Order Diptera (Fig. 10). The Planarian Flatworms show a similar pattern to a lesser degree (Fig. 11).

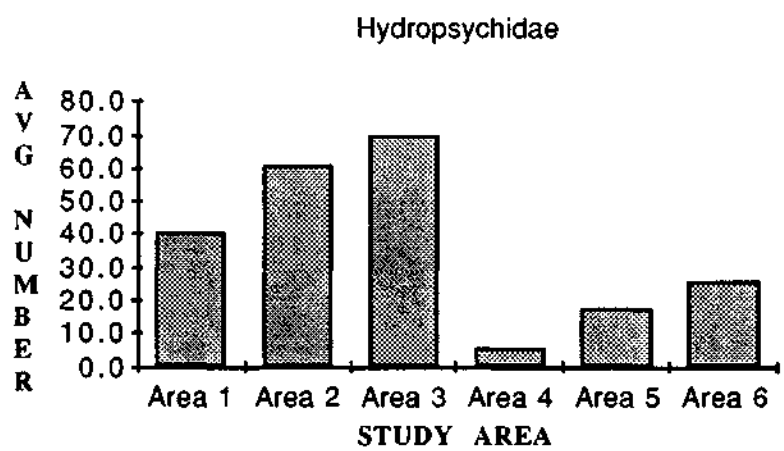


FIGURE 9. Average number of Net Spinner caddisfly larvae (Order Trichoptera, Family Hydropsychidae) per sampling site over all years.

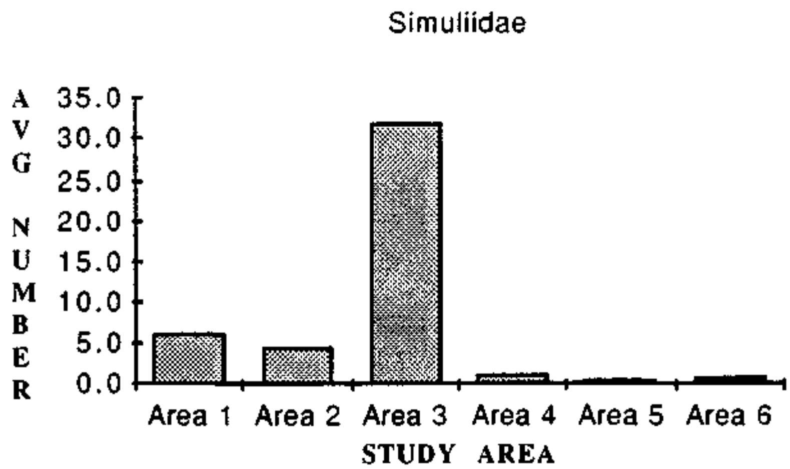


FIGURE 10. Average number of Black Fly larvae (Order Diptera, Family Simuliidae) per sampling site over all years.

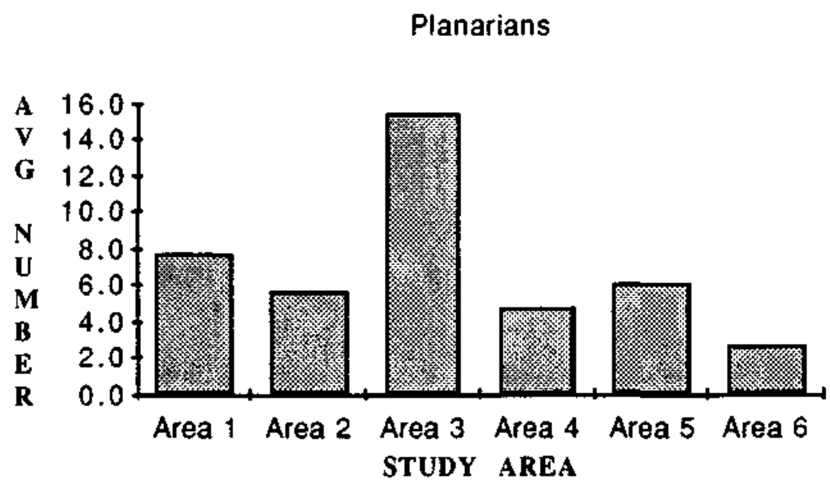


FIGURE 11. Average number of Planarian flatworms per sampling site over all years.

As Fig. 12 shows, when these three groups are subtracted from the data, the insect densities of the different sites are essentially similar. All sites have moderately high densities of common fast-current invertebrates in addition to those just described. Small Minnow Mayflies (Ephemeroptera/Baetidae) are quite common. These free-swimmers are available as prey for fish throughout most of the aquatic portion of their life cycle, in contrast with many species that are hidden in sediments or under rocks. Riffle Beetles (Coleoptera/Elmidae) were also common. These small larvae are well hidden among the sediments and their plant cover. The Crane Fly and Midge larvae (Diptera/ Tipulidae; Diptera/Chironomidae) were present in smaller numbers that nonetheless exceeded those of most other groups. These insects are also generally concealed, in the fine sediments.

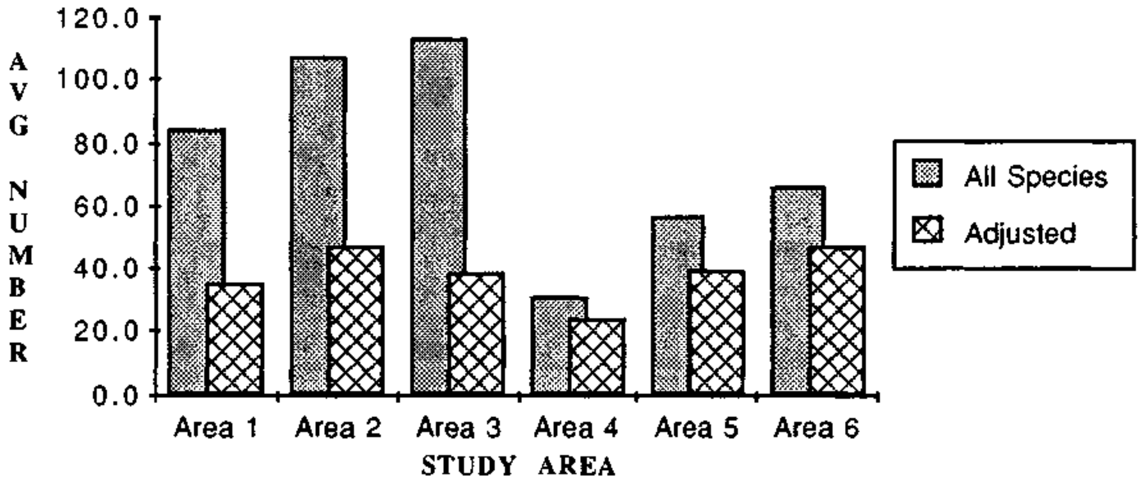


FIGURE 12. Number of aquatic insect species per sampling site with Hydropsychids, Simuliids, and Planarians subtracted out ("Adjusted") in comparison with sums for all species.

In order to see if any other differences between mined and unmined areas existed, I pooled data for several other groups (Table 5). No consistent patterns emerged, except that the large predatory Dragonflies and Damselflies (primarily the former; Order Odonata) did show a trend for being more common in undisturbed areas. Larger sample sizes would be necessary to evaluate this group.

TABLE 5. Data over all years on several other groups of aquatic invertebrates.

	Other Ephemeroptera	All Odonata	All Hemiptera	Other Trichoptera	Other Coleoptera	Lepidoptera: Pyralidae
Area 1	0.81	0.00	0.63	0.00	0.25	2.00
Area 2	8.00	0.38	1.56	1.06	1.13	4.50
Area 3	0.08	0.42	0.33	0.08	0.00	1.40
Area 4	0.88	0.94	1.31	0.31	2.13	1.00
Area 5	7.36	1.07	0.93	0.50	0.00	2.00
Area 6	5.14	1.64	0.64	0.29	0.21	1.20

The high numbers of Netspinners and Black Flies in the mined areas has a good explanation. Both of these insects trap organic debris that is swept past them by the water current. The Netspinners build a silk net and then surround themselves next to it with a case made of small gravel and other materials. The Black Fly larvae have an adhesive disc at the base of their abdomens and a set of long mouth brushes. They lie horizontally, head downstream, and trap food with the brushes (McCafferty, 1983). The gravel extraction activities, which have consistently occurred within the river channel itself in Areas 1-3, most probably stir up food for these species, and they survive in greater numbers as a result. The Planarians, which scavenge on organic debris may similarly be favored by annual disturbance in the channel, but this is a less powerful explanation for differences because several other groups with no differences among the study areas should have been similarly affected, but weren't.

At first glance, the higher numbers of Hydropsychids and Simuliids would seem to be a beneficial impact of mining, providing additional food for fish. I would caution against such an interpretation. Both do provide food but in the case of the Hydropsychids, this occurs in a short burst at the time the adults emerge from the pupal case and take up a terrestrial existence. At other times they are well hidden and protected from predators. The Black Fly larvae are more exposed to predators, and probably make a larger contribution to overall food chain. As terrestrial adults, however, they can cause serious problems for vertebrates, including humans. Not only do they suck blood as their main food source, which can be annoying and debilitating for many vertebrates, including humans, but they transmit a number of vertebrate diseases (McCafferty, I983). More importantly, the channel disruption that seems to encourage them has the adverse affect of removing the cover used by fish. Additional data on the association of these and other insect species with mining in the river channel would be valuable in order to see if the association holds up over time. If so, certain densities of these forms could serve as indicators of disturbance. In addition, monitoring after extraction has ceased would be valuable in determining to what degree beneficial changes occur, and at what rate.

RECOMMENDATIONS FOR THE MONITORING PROGRAM

Both gravel and insect portions of the monitoring program should be continued in order to provide additional long term data on the sediments and insects in the channel. So that data will be comparable with those of the past eight years, the same procedures should be used in the same areas. In addition, more information is needed on the effects of in-stream extraction on sections immediately downstream from the activity, since only one such area has been studied (Area 5). I recommend that two areas be added, if access is possible, downstream from two of Areas 1-3. To improve the analysis, samples should also be taken immediately upstream from these sites. The number of samples taken in the upstream and downstream areas should equal the number taken within the extraction zones, and three study sites with three gravel samples each (instead of four study sites with three samples each as at present) should be adequate. If extraction is terminated permanently at a given site, then the upstream/downstream comparators would no longer be necessary and samples can be restricted to the previously mined zones, with a purpose of tracking post-extraction trends. Specifically, I recommend a timetable as follows:

1991:	Dewitt (Area 2)	Nine sampling sites: 3 each above, within, and below
	H.G.I. (Area 4)	Three sampling sites instead of the present four. Consider this a second control site, but make sure samples are always upstream from activity.
	Mid. Reach (Area 5)	Nine sampling sites: 3 each above, within, and below
1992:	Piombo (Area 1)	Nine sampling sites: 3 each above, within, and below. If the site has been permanently abandoned, reduce to three.
	McCutchen (Area 3)	Nine sampling sites: 3 each above, within, and below
	Control (Area 6)	Increase from two sampling sites to three.
1993 and future odd years:		Same as 1991
1994 and future even years:		Same as 1992

VEGETATION ANALYSIS

INTRODUCTION AND METHODS

When the monitoring program was begun in 1982, it was thought that extraction of aggregates could have some impact on downstream riparian communities. To help evaluate this possibility, a long term monitoring program was established. The plan was to use two study areas, one immediately downstream from an active in-stream mining site and a second some distance from any disturbance. Area 5, which lies just downstream from the Syar instream site and is identified in the Aggregate Resources Management Plan as the "Point Bar Protection Area," was chosen to study indirect impacts. A site off West Soda Rock Lane on property now belonging to Roger Stuhlmuller was selected as a control and designated as Area 6. As it turns out, the two sites have comparable wooded communities, but the more open portions of the sites are substantially different. In Area 6, only course gravel and rocks exist on the bar; there has been no deposition of fine sediments. In addition, it has a simple, slightly mounded topography. To complicate matters, the owner removed all the vegetation from the bar in 1989. By contrast, Area 5 has a varied topography and a variety of soil textures, and has provided good information on the development of riparian communities, and a few hypotheses about how they may be affected by mining operations.

The first methods that I developed, and which appear in the original procedures manual, were based on a quantitative sampling of the entire study area. After two years of the program, it appeared that the results of the analysis were perhaps too abstract. Greg Carr of the Planning Department suggested that I develop a method that could relate findings more directly to identifiable parts of the site. I then began outlining the major units of the community on an aerial photograph each year, and using primarily qualitative descriptions of these units as a means of following trends. As the complexity of the vegetation increased, as well as my curiosity, my descriptions became more thorough. Each year I have measured and described the locations of prominent individual trees, as well as collecting some quantitative data on the average vegetation. Since trees are the predominant forms, my attention has been primarily on them. The annual reports thus are actually a source of data, the analysis of which I present here. For Unit VII of Area 5 and Unit VI of Area 6, I sampled the woodlands using the point-centered quarter method, which is describe more fully below under Area 5, Unit VII.

One form of analysis that has proven very useful presents the average size of the ten largest trees in selected units, which generally characterizes changes in their tree populations. This method was possible because I made a serious attempt each year to characterize the sizes of the largest representatives of a given species by measuring them with a Biltmore Stick, a meter stick scaled to enable one to take diameter measurements by placing it at arm's length against the side of a tree. In an occasional instance I have had to interpret written phrases in the reports with some latitude, especially for the smaller and extremely abundant Sandbar Willows. "About 25 individuals from 7-10 cm diameter," was used in the talley as "two 10's, two 9's two 8's." I do not think this distorts the major findings. For Cottonwoods and Red Willows, as well as diameter analyses of Black Walnuts and Box Elders for Units VIa and VIb of Area 5, all of the results do represent actual measurements of the ten largest trees, generally extracted from lists of measurements much longer than ten.

For a number of units, data are presented for young Box Elders and Black Walnuts, two species characteristic of more mature riparian woodlands that existed in the wooded areas from the start, but began appearing in areas closer to the river only in 1986 and 1987. These are not complete samples, but for all but the smallest individuals do represent actual talleys of what I observed in the various units. I have used common names throughout to make the text more readable for non-biologists, but have appended a species^ list. Following data that describes changes in the study areas, I discuss some hypotheses regarding the ecology of the areas. I then discuss possible impacts of the gravel industry, and present recommendations for further monitoring.

RESULTS-AREA 5

Unit I - The open bar at the upstream section of the study area.

From 1984-87 I considered this as a single unit; in the last two years I identified two segments as A and B, and these are discussed below. In 1985, gravel was removed from the bar, creating a flat, level terrain. Units IIa and IIb were left intact and a cut was made along the front of IIc/IIIb/Vc. In 1986, sediments had not filled in to their original levels, and I recorded a 30-90 cm drop from unaffected areas to the new deposits from the past winter. Extraction was performed again in 1987. There still exists a drop of about 50 cm from the height of the original bar to the present Unit I, which can be seen at the upstream point of Unit IIIa.

Ia. This is the open gravelly portion of the unit, and it has had little vegetation throughout the study. Forbs like Sweet Clover, and Cocklebur, and Jimson Weed have vegetated it sporadically.

IIa. This is a section of the unit in which finer grained materials have been deposited since the removal of gravel in 1987. It is becoming vegetated with tall forbs, Red, Arroyo, and Sandbar Willows and a few Cottonwoods. It resembles the way Unit Vb looked several years ago, and may undergo a similar development of wooded vegetation.

Unit II - Vegetated hummocks that lie adjacent to the river

IIa. This is the first of several hummocks that rise off a lower base to heights of several meters. It lies immediately adjacent to the stream channel and apparently lies parallel to the major flood currents. As a consequence, it has remained essentially the same topographically since 1984, and has not experienced major cross-cutting erosion. Furthermore, this unit has had some debris deposited in it by high waters, including a few large logs, but it has not developed any massive pile of debris as have several of the other areas. It appears that the high waters generally carry material to the east of the unit as water travels toward the outside of the concave bend at this point in the river.

This unit was described in 1982 as being covered predominantly by Cottonwoods on the top in the upstream section and by Red Willows in the downstream section, with a band of Sandbar Willows at lower levels. This basic species composition has remained, and the overall increase in the size of trees is shown in Fig. 13 below. From 1984 to 1989 the upstream portion of the unit was slowly depositing sand, and vegetation was colonizing it. Trees, predominantly Cottonwoods and Sandbar Willows were reaching heights of up to 5 m and diameters of 6 cm. Rather than gathering a large amount of material in a single year, the unit appeared to be growing by gradual accretion. The vegetation in its upstream plume was removed by bulldozer in the summer of 1990, but the original hummock remained.

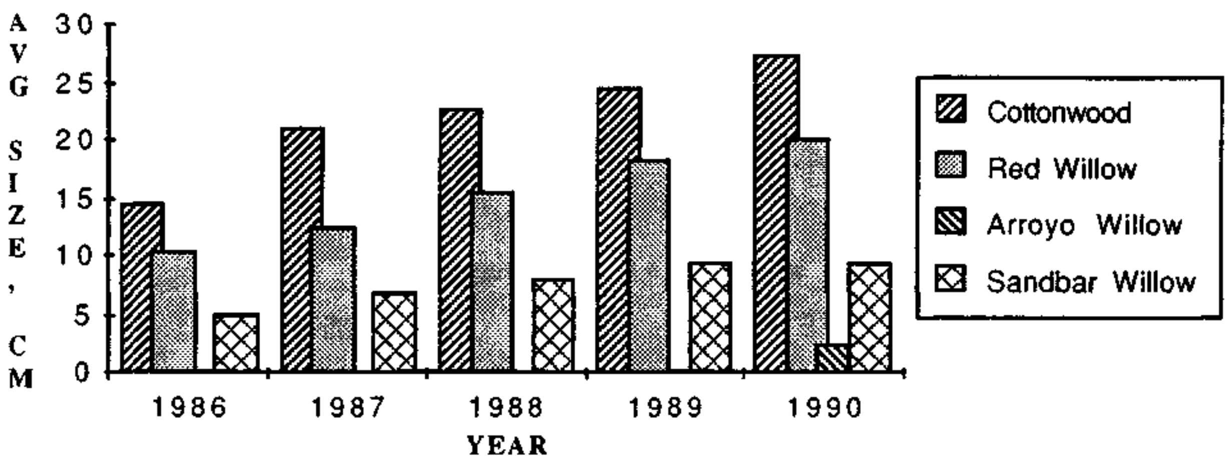


FIGURE 13. Average size of the ten largest trees of each species in Area 5, unit IIa.

Sandbar willows in the portions of the unit with deeper sediments have grown to above 10 cm, which is well above average for the species compared with the whole study area. Whereas Red Willows and Cottonwoods are vigorously invading new sediments around the base of the unit, along with a few Arroyo Willows, seedlings and saplings of these species are not found on the higher levels. It appears that the species with larger trees are in a stage where they are growing rapidly, but will decrease in density as competition, disease, and accident take a toll on individuals. On the river's side of the upper half of the unit, two White Alders have established themselves, and are now 2 and 6 cm in diameter. These trees could eventually play a large role in stabilizing this side of the unit.

Some Box Elder, Black Walnut, and Oregon Ash seedlings, as well as one Bay, have appeared in the unit in the last two years.

All of these are less than 1 cm diameter, as can be seen for the most common species, Box Elders and Black Walnuts, in Table 6. (I have included columns for larger sizes in this and subsequent tables to facilitate comparison among areas.) Whether these will survive future high water years is a major question to be followed in the program.

TABLE 6. Young Box Elder and Black Walnut trees observed in Area 5, Unit IIa.

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm					4	1	9	8
1 cm								
2 cm								
3 cm								
4 cm								
5 cm								

IIb. This mound lies just downstream from IIa, and could be considered part of the same feature. It is separated from IIa by a distinct notch that has had an open gravelly bottom and carries overflow from the main gravel bar of Ia into the river. It also has very similar vegetation, being strongly dominated by Cottonwoods and Red Willows, with somewhat fewer Sandbar Willows. For the first two species, the growth pattern of the largest trees is similar (Fig. 14), but the Sandbar Willows do not seem to be growing to as large a size as on IIa. It has also been invaded by a few small Black Walnuts and Box Elders (Table 7).

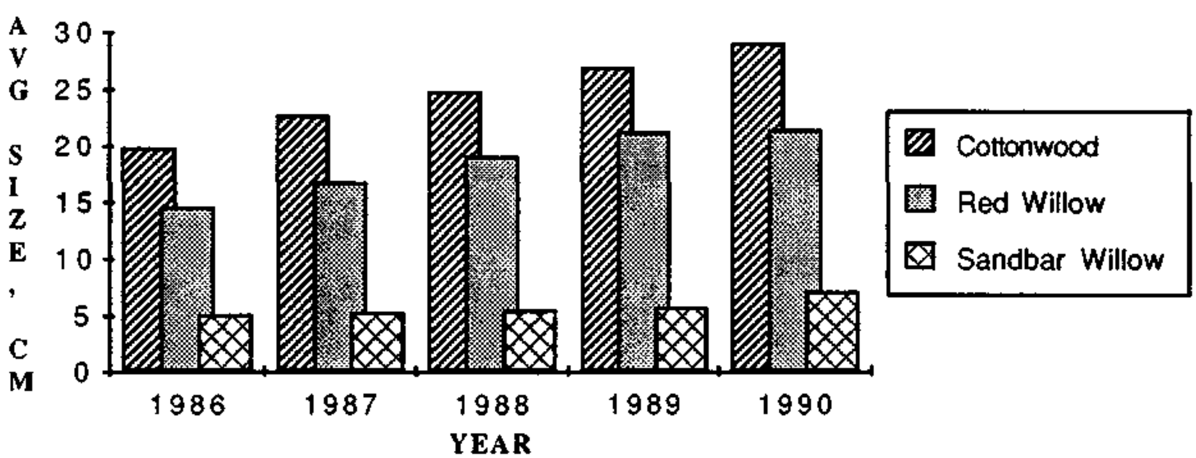


FIGURE 14. Average size of the ten largest trees of each species in Area 5, Unit IIb

TABLE 7. Young Box Elder and Black Walnut trees observed in Area 5, Unit IIb.

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm				1	3	5		5
1 cm						1		1
2 cm								1
3 cm								
4 cm								
5 cm								

At the head of this unit is a Red Willow that has sent up many shoots after being buried, a phenomenon observed with a number of Cottonwoods and willows in the area. In 1986 the largest of about 25 shoots was 2 cm, and by 1990, some had reached a diameter of 8 cm.

IIc. The hummock that constitutes this unit rises about twice as high on its eastern side as those of the previous two units. A possible explanation for this is that this unit, like several others in Unit III, has a large mass of sticks and logs that were trapped at its upstream end by a set of three large Cottonwoods. These trees may all be shoots from a single tree. I have come to refer to such Cottonwoods as "sentinels" because they stand out prominently from a distance. I will refer to the mass of logs as a "logjam." The unit as a whole, perhaps based on these interactions between vegetation and debris, was effective in trapping sand during the wet years that preceded the study. This is inferred from the open, dune-like, sandy hillside on the downstream end of the unit that has since been colonized by Sandbar Willows and forbs.

Another topographic feature of this unit is that since 1987 it has progressively eroded along the center of its main axis, creating a long hollow with several deep holes. Between this hollow and the river lies a second line of vegetation that has resisted erosion even though many of the Cottonwoods in its upstream section have been thrown to a horizontal position. The unit thus helps clarify the degree to which rooted trees can protect the river's bank, while themselves surviving the force of flood waters.

Vegetatively, the unit is like IIa and IIb. It is dominated by larger Cottonwoods and Red Willows of a slightly smaller size. In contrast, it does have a grove of Arroyo Willows, at its downstream end, and Sandbar Willows around its base and up its sides have only grown to about 5 cm maximum. Its "sentinels" are about 15 cm diameter larger than any Cottonwoods in IIa or Mb. The wood in the logjam is rotting, and has a lacing of California Blackberries over it. Its margins are being invaded by Giant Reed and small Red Willow stems. Fig. 15 shows growth of the unit's largest trees, while Table 8 provides data that show some growth of a few Box Elders and the invasion by Black Walnut seedlings in the last two years.

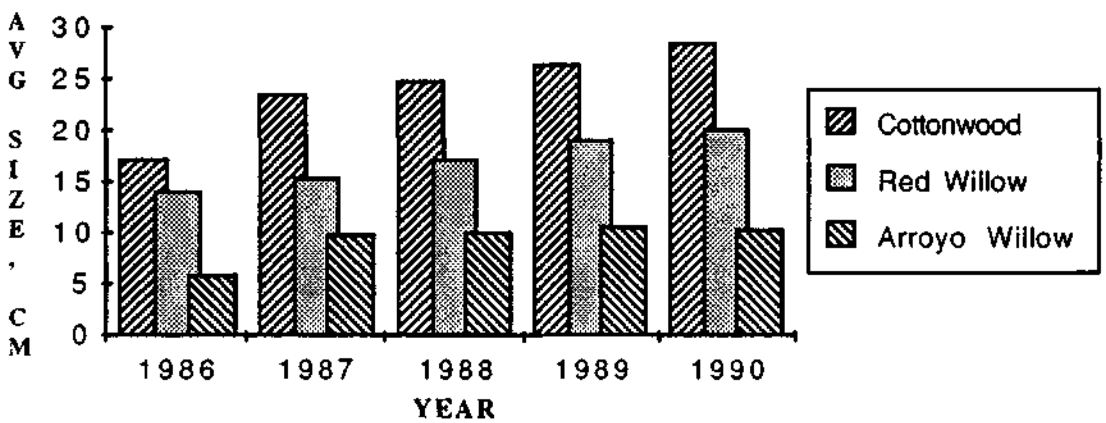


FIGURE 15. Average size of the ten largest trees of each species in Area 5, Unit IIc

TABLE 8. Young Box Elder and Black Walnut trees observed in Area 5, Unit IIc.

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm				3		1		12
1 cm			1		2			
2cm							3	
3 cm							2	
4 cm								
5 cm								

IId. This unit has lower relief than the upstream Unit IIc, and also lies just west of where the overflow channel of Va enters the river. It thus takes the brunt of the force of flood waters that do not make their exit in Va itself. As a consequence, it is dissected in three major channels, each 1-4 m wide, that carry water to the river from Va, as well as several secondary channels. The locations of these cuts have been the same since first closely observed in 1986. Another affect of the flood waters has been to push back, topple, or bury individual trees in the unit. Few are fully upright, and many may represent sprouts from now buried trunks. There is little evidence of death from this disturbance, however. One of the two larger (30 cm) Cottonwoods now has the top m of its root system fully exposed, yet it continues to grow.

The species composition is generally balanced among the four major species discussed thus far. The whole unit has very dense growth, and though species exist in small clusters, there are no major zones for them except for small Sandbar Willows along the margin of the unit at Va. As can be seen in Fig. 16, Cottonwoods have shown a size increase, although not quite as great as in the previous three units. Red Willows have reached approximately the same size, but both Arroyo and Sandbar Willows have remained small. Seven White Alders from 4-11 cm diameter (not shown) exist at the river's margin near the middle of the unit, indicating the immediate bank of the river is stable. As with all units described so far, these has been an increase in seedlings of Box Elder and Black Walnut the past two years (Table 9), and one Bay seedling was noted.

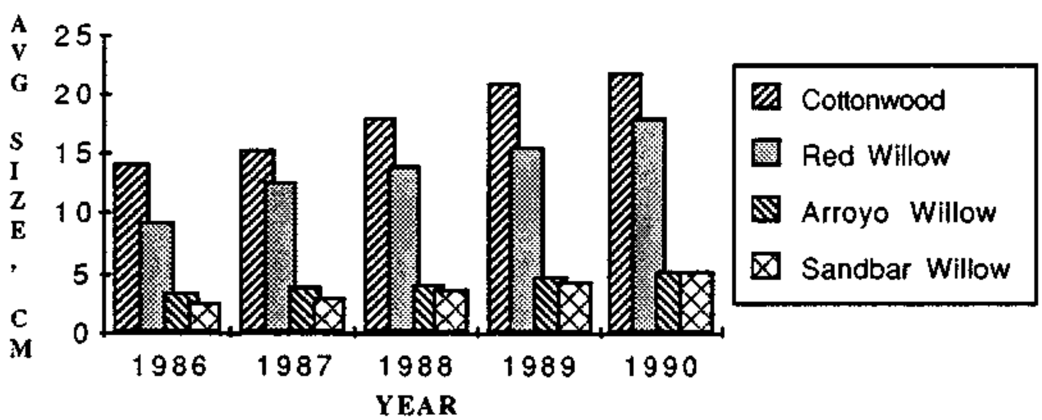


FIGURE 16. Average size of the ten largest trees of each species in Area 5, unit IId

TABLE 9. Young Box Elder and Black Walnut trees observed in Area 5, Unit IId

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm					1	5	8	15
1								
2cm								1
3 cm								
4 cm								
5 cm								

IIe. The topography of this unit is less dramatic than of any of the units discussed so far. It is elevated a meter or two above Unit Vc to its east. It was originally set apart fro IIf by a clear, little vegetated areas between the units. This feature was very evident in 1984 and 1985, but has become impossible to locate precisely in the field as the vegetation has grown. There is some debris accumulation along its contact with the back channel designated as Unit Vd, but this is not of the same magnitude as in several other hummocks, and probably has not played a major role in the units development. I suspect that the hummock has risen by the gradual and even accumulation in its vegetation as a whole. It has been strongly eroding along its contact with the river since at least 1986. Undercutting as waters swing past the newly forming bar across the river has produced a sharp bank along IIe and the upstream part of IIf, and have dropped several clusters of Cottonwood trees down the bank.

The unit is strongly dominated by clusters of tall Giant Reed, which make walking through some sections impossible. In addition, Himalaya Berry, with its strong spines, impedes travel. As can be seen in Fig. 17, Cottonwood is the largest tree species, but sizes of its largest trees don't match those of other units. In contrast with IIa-IId, where most of the large trees in the sample were the same from year to year, however, the loss of some trees down the bank means that different individuals make up the sample each year in IIe. The same may be true for the Red Willows, because it is difficult to be sure the unit has been traversed the same way from year to year. Nonetheless, my sense from being on the site is that Cottonwoods and Red Willows do not grow particularly well on this unit, for reasons not yet clear. By contrast, a localized population of Sandbar Willows, found near the upstream head of the unit, shows continued growth. Table 10 shows considerable invasion by Box Elders in the past year. Obviously, the larger trees grew from smaller ones (fewer small trees were noted in 1989 than larger ones in 1990); I suspect the dense ground cover makes it difficult to see these trees until they reach a certain size.

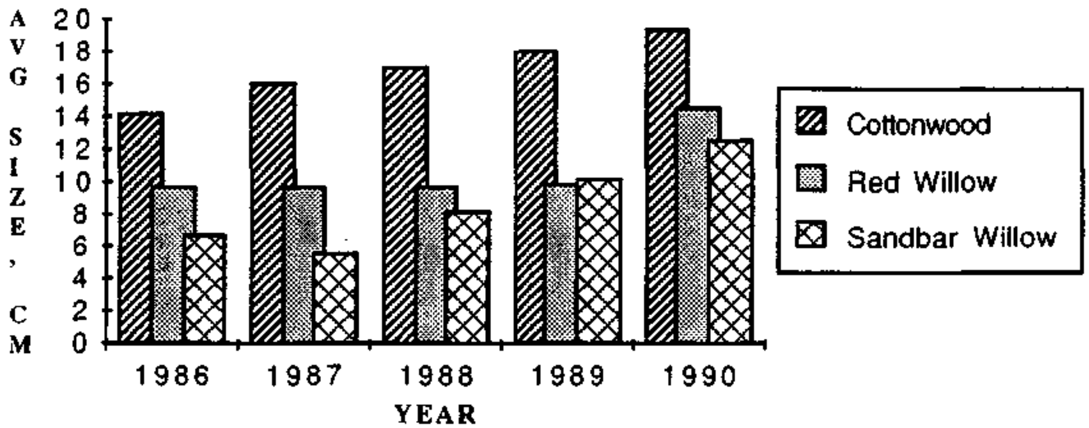


FIGURE 17. Average size of the ten largest trees of each species in Area 5, unit IIe

TABLE 10. Young Box Elder and Black Walnut trees observed in Area 5, Unit IIe

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm					3	2	6	7
1 cm							1	
2cm							1	2
3 cm								
4 cm							1	
5 cm+							3	

IIf. This is part of the same or a very similar topographic unit as IIe, so the above comments apply here as well. It is also covered with dense stands of Giant Reed in parts and is not easily accessible in those portions. Its bank along the river for most of its length represented *a* slump down which one could walk, rather than a steep bank. It is distinguished from IIe by its rounded bank where its western side meets a gravelly bar west of the study area.

The vegetation is likewise similar. My records for Red Willows were not complete enough in 1986 and 1987 to provide an estimate of the average diameter of the ten largest trees. It does appear, as shown in Fig. 18, that the Red Willows are somewhat larger than Cottonwoods in maximum size. The unit has also begun to develop populations of small Box Elders and Black Walnuts, as indicated in Table 11.

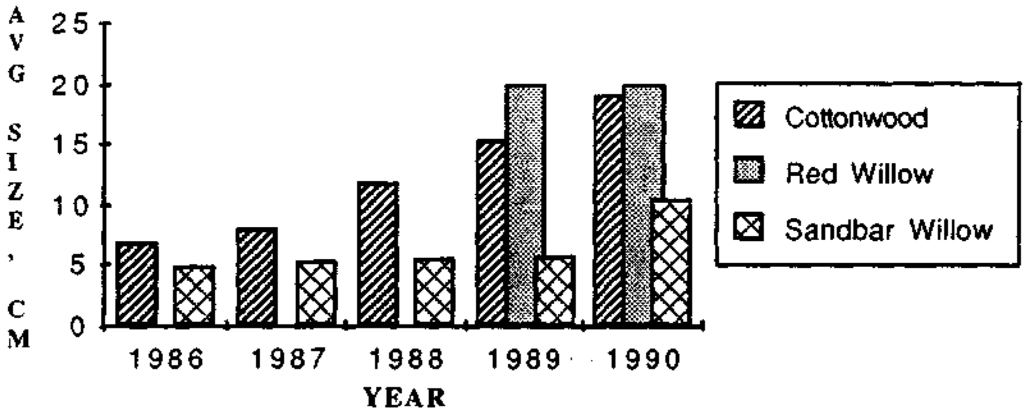


FIGURE 18. Average size of the ten largest trees of each species in Area 5, unit IIf

TABLE 11. Young Box Elder and Black Walnut trees observed in Area 5, Unit IIf

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm						20	8	23
1							1	1
2cm							1	1
3 cm								
4 cm								
5 cm								

Unit III - Vegetated hummocks that lie away from the river's main channel but west of the currently active back channel (Units Vb and Vd)

IIIa. This small unit lies within the rather compact gravel/rock bed of a small back channel (Unit Va). It consists of a line of mid-sized Cottonwoods that have been trapping sand an debris in a noticeable manner, thus influencing the construction of a the hummock. It had some upstream Cottonwoods removed when the main bar (Unit I) was mined in 1985. During a similar mining year in 1987, some of the upstream trees of the unit were partially uprooted. Growth of trees shown in Fig 19 is based on six trees for Cottonwoods and eight for Red Willows. The Cottonwoods appear to be growing slightly, on average, despite the disruptions. Red Willows have been a less important species in the unit, and most of those shown in the graph occupy a plume of sand that has been built by the Unit during the study period. The same is true of Sandbar

Willows. Though it is small, data on the unit are important because it is changing dramatically from year to year. One two cm diameter Black Walnut was noted in 1990.

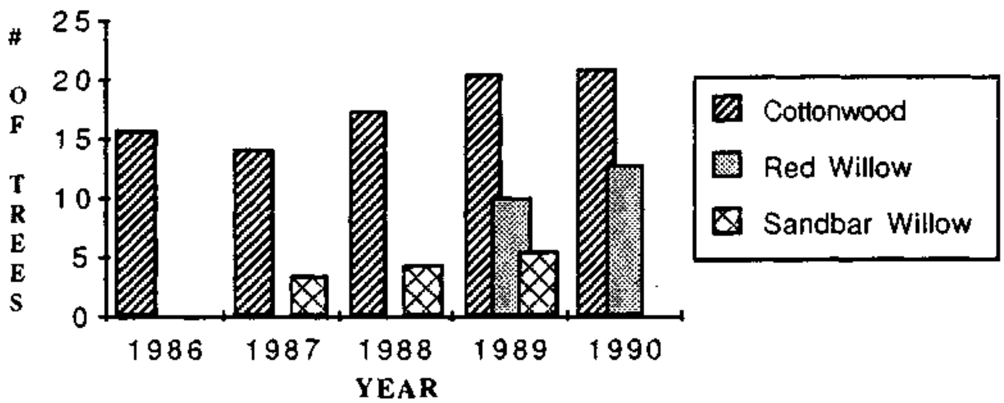


FIGURE 19. Average size of the ten largest trees of each species in Area 5, unit IIIa

IIIb. This unit is slightly higher in comparison to the surrounding terrain than any in Unit II. It lies immediately downstream from the center of the gravel bar of Unit I. It thus not only would receive flood waters "head on" but would also divide them into two secondary channels north and south. I did not find any single "sentinel" Cottonwood on the top of the upstream point of this unit, but did note a crown from a larger fallen Cottonwood in this location. Like IIc traps sand that otherwise might have been deposited in IId, this unit apparently does the same with respect to IIId, which is much lower in topography and lies immediately downstream from it.

Much of the vegetation of the unit, both on its margins and top, consists of dense Sandbar Willows, which in 1985 were identified as being about 70 % of the cover, with Red Willows making up most of the remainder. I indicated that there were a few, emerging Cottonwoods in that year. At the present time some of the Sandbar Willows are dying, while others continue to grow. Red Willows probably outnumber Cottonwoods just slightly. One small grove of Arroyo Willows exists. Data in Fig. 20 support the idea that Cottonwoods are just now beginning to equal Red Willows in size. As with other units discussed thus far, some small Box Elder and Black Walnut trees are seeding in the unit (Table 12).

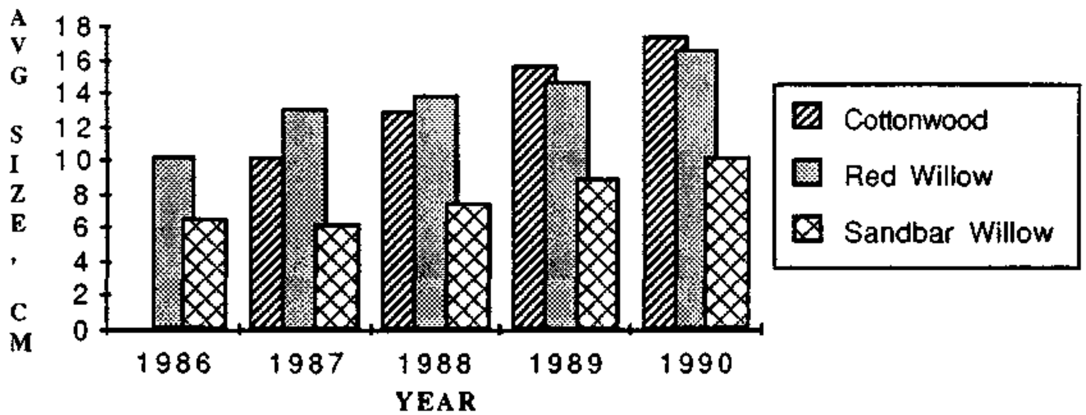


FIGURE 20. Average size of the ten largest trees of each species in Area 5, unit IIIb

TABLE 12. Young Box Elder and Black Walnut trees observed in Area 5, Unit IIIb

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm							7	8
1							5	4
2cm						2		
3cm								
4 cm								
5 cm								

IIIc. This was a line of small Cottonwoods east and upstream from IIId that was removed in the 1986 removal of gravel. No important trends were noted in the two years it was available for study.

IIId. This section of the study area is fan-shaped and rises from a few meters above the level of the back channel (Vb) to the beginning of Units IIIe and F, which lie downstream from it. It is rather uniformly covered by Sandbar Willows in most areas, and these have grown little from 1984 to 1990, at which time a few reached 8 cm diameter. About one-third of its area, at the highest, central regions, is covered with tall clumps of Giant Reed. What was an open area where the unit adjoins IIIb has been invaded heavily by tall forbs, Giant Reed, and Sandbar Willows, but a few little vegetated sections remain. Conspicuous clumps of mid-sized Cottonwoods and of Mid-sized Red Willows have existed near the northern boundary since the study began. Diameters shown in Fig. 21 are for the largest four of the Cottonwoods, and the nine Red Willows. Note that there is relatively slow growth. In fact, between 1989 and 1990 all but two of the Cottonwoods fell down and are probably dead.

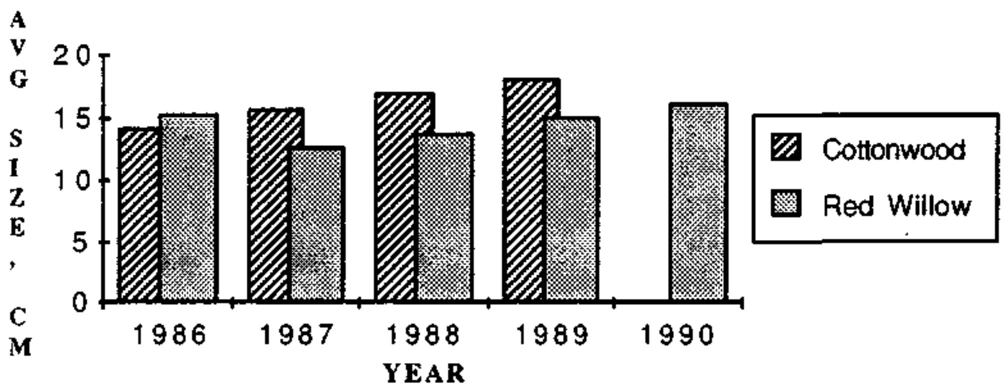


FIGURE 21. Average size of the four Cottonwoods and nine Red Willows in Area 5, unit IIId

By contrast, establishment and growth of a group of Box Elders and Black Walnuts has been earlier in this unit than in all of Unit II and in IIIa and B. This is shown in Table 13. The largest of these trees are now about 5 m tall, and have little other vegetation growing around them. Northwest in the unit, adjacent to Unit Va, there has been seeding and growth of young Cottonwoods and Red Willows in a few dense groves. The largest trees are now about 12 cm diameter.

TABLE 13. Young Box Elder and Black Walnut trees observed in Area 5, Unit IIId

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm		7	1	1				5
1		4		4		3		3
2cm				4		3	1	
3 cm					2	3	1	2
4cm						1		
5 cm							1	4
6cm								1

IIIe. This and the following unit are the two most prominent, and highest in elevation, in the study area. Both have massive logjams on the upstream end, held in place during floods by large Cottonwoods and now beginning to decompose. Some of the largest Sandbar Willows are found along the western slope of IIIe, but as seem in Fig. 22, these seem to be slowing in growth. The Cottonwoods of the unit are not numerous, and some of the smaller ones have died during the last few years, but the large healthy individuals continue to grow, and average about 10 cm larger than most of the subunits in Units II and III. Red Willows are also growing, and like Cottonwoods have suffered some mortality.

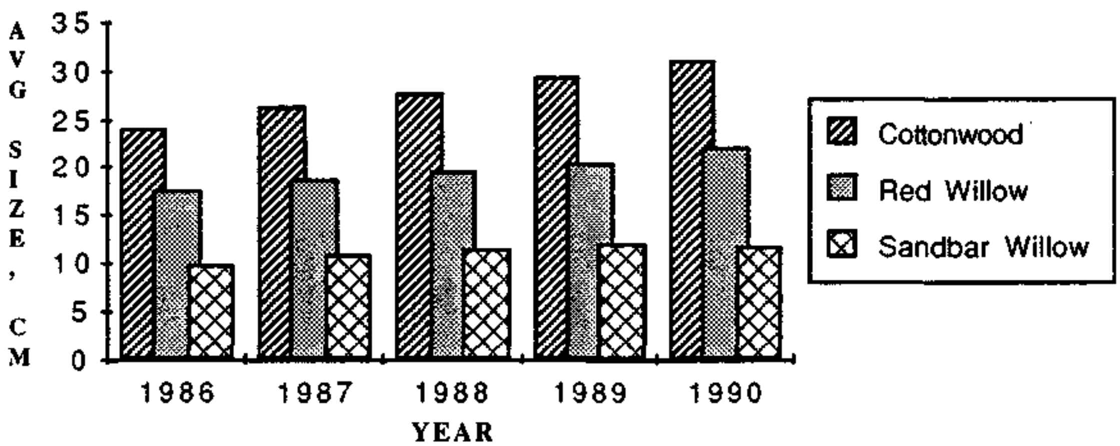


FIGURE 22. Average size of the ten largest trees of each species in Area 5, unit IIIe

Unit IIIe is similar to IIId, which lies just north and is connected to it, in the presence of a growing number of small Black Walnut and Box Elder trees. These are not in large number yet, but may begin reproducing within a few years providing an immediately available source of seed. Table 14 gives data for the unit.

TABLE 14. Young Box Elder and Black Walnut trees observed in Area 5, Unit IIIe. Black Walnuts greater than 6 cm included individuals of 7 and 16 cm. The Box Elder in this category was 6 cm.

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm								
1 cm	1			2	1	7	2	
2cm		1	1	2	1	1	2	4
3cm							1	
4 cm					1	2	1	1
5 cm								
6 cm+						1	1	2

IIIf. This unit is equivalent in height, size, and dominant species to IIIe. It is unique in that it has two log jams spaced apart in its upstream half. In 1989 I noticed a thin layer of silt on top of the logs, which indicates that floods have deposited some material. No major deposition of logs or other debris has occurred, however, such as is the case for Units IIIa and IId, which lie at lower elevation and closer to the river.

The mid to large-sized Cottonwoods and Red Willows for which growth of the larger trees is graphed in Fig. 23, mostly occur in the upstream half of the unit. Its lower sections are dominated by tall forbs, Giant Reed and Sandbar Willows, many of which died in 1989-90. They reached a maximum diameter of 13 cm. Box Elders have established themselves in this unit at a somewhat faster pace than Black Walnuts, and the numbers I observed generally match those for Units IIId and E (Table 15.)

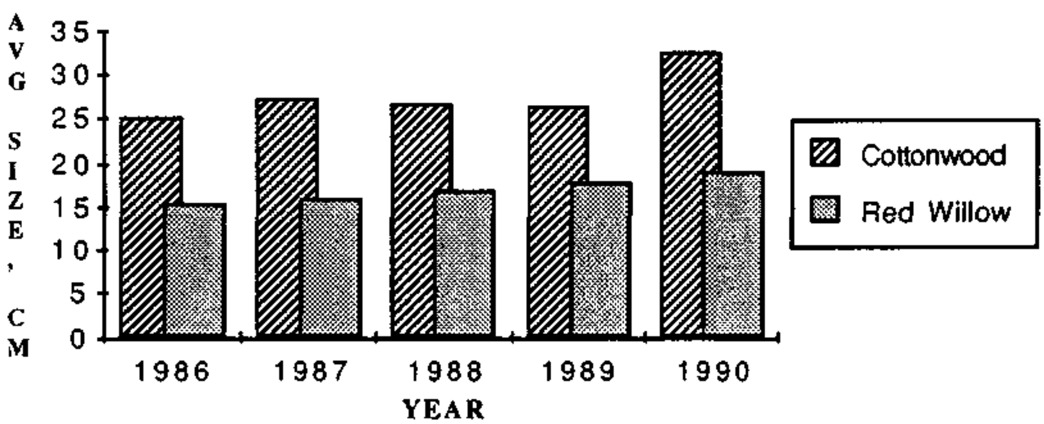


FIGURE 23. Average size of the ten largest trees of each species in Area 5, unit IIIf

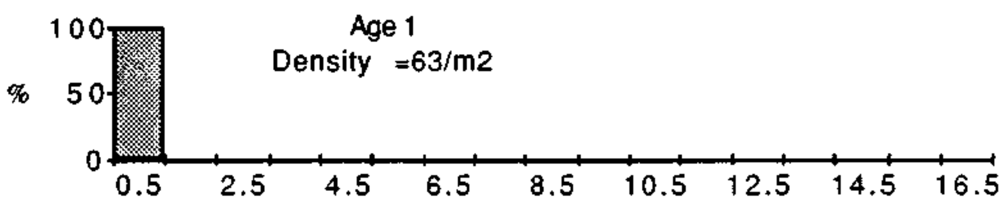
TABLE 15. Young Box Elder and Black Walnut trees observed in Area 5, Unit IIIf. Box Elders above 5 cm were one at 7 cm in 1989; two at 7 cm and one each at 8 and 9 cm in 1990.

	1986		1987		1989		1990	
Size	Box E	B Wal	Box E	B Wal	Box E	B Wal	Box E	B Wal
.5 cm		3		2		1	1	1
1 cm						2		
2cm				1		5		2
3 cm				1		2		2
4 cm	1	1	1		5	1		2
5 cm			1		1		2	
6 cm+	1		1		1		4	

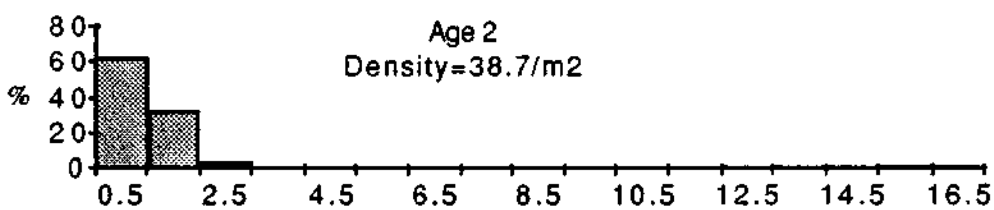
Unit IV - A relatively uniform stand of Red Willows that began growing on a silty terrace below VIa in 1982. Densities of the Red Willows have been tracked since 1984, and size distributions since 1986. In 1985, a similar stand of Red Willows developed in Unit Vb adjacent to IV on a slightly lower terrace. I have designated this set of trees as Unit Vc, and will discuss it now in conjunction with Unit IV.

Vc. This stand of trees occupies a crescent-shaped area 40 m long. In 1986, when data were first taken, all the trees were less than a cm in diameter and had heights of about 2 m. Samples consisted of one m2 plots placed in a semi-random manner in the center of the stand. The number of such plots increased with successive years as the stand became less dense, and probably somewhat less uniform: 1986-4 plots; 1987-6 plots; 1989-10 plots; 1990-20 plots.

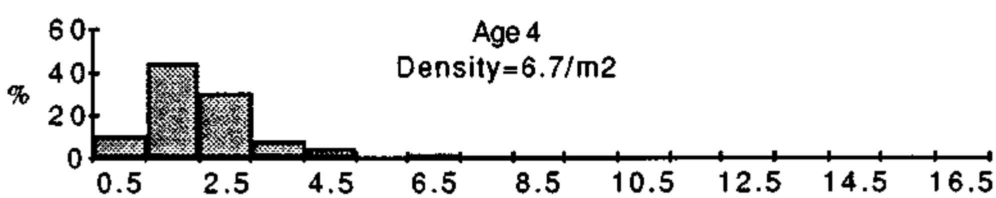
1986



1987



1989



1990

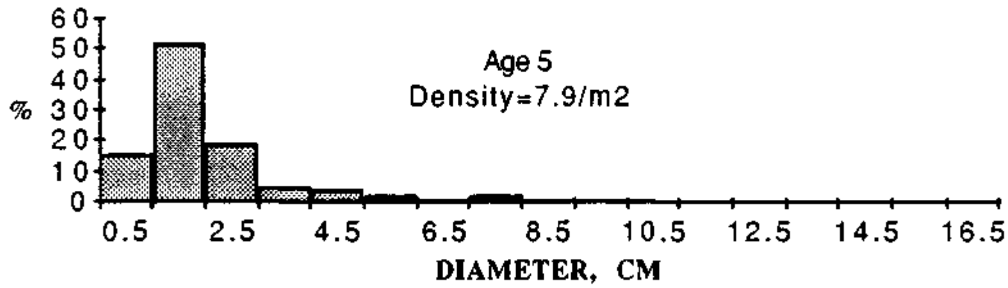
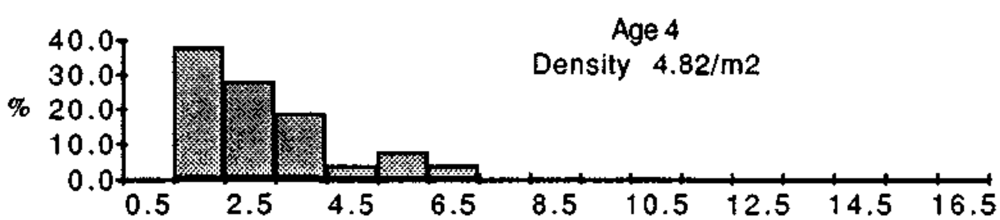


FIGURE 24. Size distributions of Young Red Willows in Unit Vc. No data were taken in 1988.

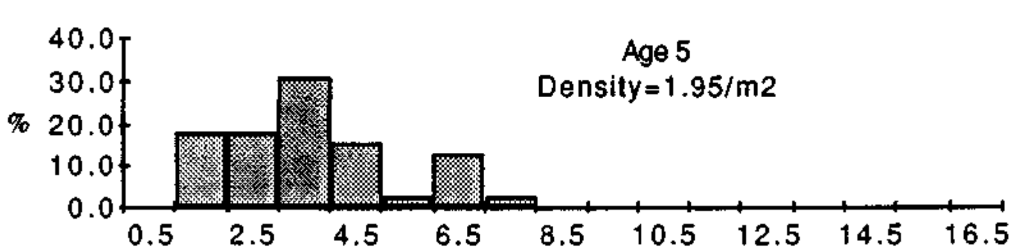
Note in Fig. 24 above the increasing skew of the distribution as time progressed. This indicates that a few individuals were becoming disproportionately large at age increased. I would have expected a more noticable decrease in density from 1989 to 1990. The 1990 sample larger; it may have required a greater sample size in 1989 to adequately reflect density. Alternatively, there may have been essentially no mortality between these two years.

IV. Sampling for Red Willows was based on 11 m2 plots in 1986, 20 m2 plots in 1987, 25 circular plots of 3.14 m2 in 1989, and 44 plots of 4 m2 in 1990. It can be seen in Fig. 25 that the sizes of trees had already become bimodal in 1986 in Area IV, and that this tendency increaded through age eight in 1990. The smaller trees did continue to survive and grow, however, as can be seen from the change in the peak on the left of each part of the Figure.

1986



1987



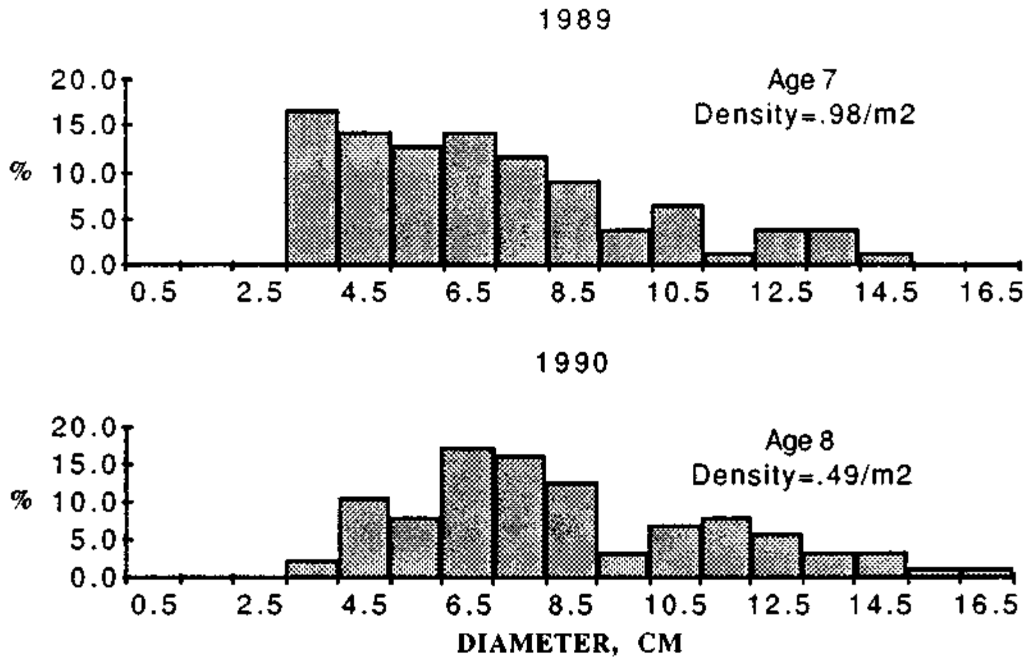


FIGURE 25. Size distributions of young Red Willows in Area 5, Unit IV from 1986-90. No data were taken in 1988.

It is interesting to examine the large changes in density accompanying the "self-thinning" process the Red Willows have undergone. In Fig. 26 I have used available values from the two sites, and averaged them for the two years in which the sites had trees of the same ages. The data fit a logarithmic plot very well, so I interpolated logarithmically to get values for ages 3 and 6, for which data did not exist. The final plot has a linear axis, however, because this shows the trend most clearly.

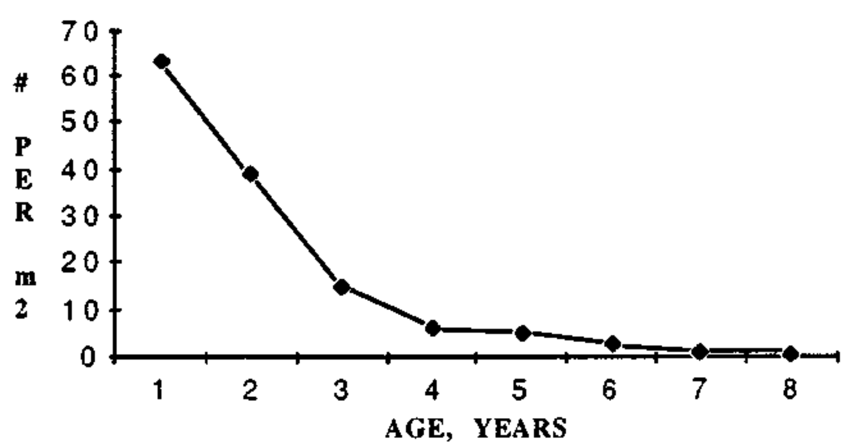


FIGURE 26. Changes in density for young Red Willows in the even-aged stands of Units IV and Vc.

An interesting comparison can be made between the density of trees in Unit IV at age eight (1990) and the density of the more mature woodland of Unit VII, which will be discussed shortly. The density of .49 trees/m2 in these Red Willows is 4,900/hectare, or about five times the density of all trees in the older forest in 1984. If one were to assume that the smaller trees below 9.5 cm diameter were to die out eventually, leaving only the larger trees as the entire population, the resultant density would be 1600 trees/ha, a value relatively close to the density of Unit VII in 1984. (These larger trees were 29 out of 87 total trees in 1990.) It will be interesting to discover if the predicted changes do occur.

Unit IV has other trees on its western margin. There, dense Arroyo Willows exist, and these are being increasingly invaded and overgrown by vigorous young Cottonwoods. In 1986, these ranged in size from 3-6 cm. By 1990, the approximately 400 trees of this species that I examined ranged from 3-19 cm. In contrast with the Red Willows, the Cottonwoods did not ever form a uniform stand, and it is very probably that their different sizes represent different ages. This suggests that the Cottonwoods progressively invade relatively young communities over a period of years. My observations to date suggest that both Red Willows and Sandbar Willows tend to seed primarily in clear, new material.

Unit V. Open back channels that serve as conduit for overflow waters.

Va. Vegetation in this unit has remained essentially the same during the course of the study. Upstream, very compact stones and gravel in the vicinity of Unit IIIa have remained as such. Downstream from there, approximately from the upstream point of Unit IId, a population of very small, scattered Sandbar Willows has continuously populated the channel. The only major development in the unit, which may be the result of changes in overflow pattern, is that it has developed a continuous line of trees along the river's shore. By 1990, these trees had reached diameters up to 8 cm, and consisted primarily of Red Willows, then Cottonwoods. A single 5 cm White Alder was among these.

Vb. This section of the unit has been covered with silt or sand for the duration of the study, and has been invaded by clusters, and some nearly continuous stands, of small Red, Arroyo, and Sandbar Willows as well as Cottonwoods. A few White Alders are growing on the immediate bank of the river. In 1987, I described these as being at heights of up to 4 m. By 1990, the largest trees reached 17 cm diameter. These trees date from about the same seedling year as those just described for Unit IV, 1982-83. During this period, one could walk across the unit as if it were a prairie, with the saplings below waist height.

Vc. This unit was just described above.

Vd. Throughout the years of study, this unit has remained a very open, compact rocky channel in its center, with low terraces supporting forbs and small Sandbar Willows on all sides.

Unit VI. This consists of higher, open terraces that were primarily vegetated with tall forbs in 1984. Units VIa and VIb were established for convenience, using a small trail between them as a dividing point. They aren't a natural unit, however, so I have combined them for analysis.

VIa and VIb. These units occupy a terrace within the river's overflow channel, and several meters below the upper terrace now covered by vineyards. In 1984, one could walk relatively easily in the units, except in portions of VIb were Giant Reed existed. The most common vegetation was tall forbs, particularly Mugwort. VIb and the southwestern part of VIa have been covered primarily by a dense stand of Arroyo Willows. VIa has had several prominent groves of larger trees, including one of very large Red Willows in its southern end, and smaller, scattered groves of Cottonwoods. Many of these clusters may have arisen from one or a few buried trees. Black Walnuts, Box Elders, as well as a few Oregon Ash and Eucalyptus trees have been invading the open areas. At the same time, some portions have been covered by dense thickets of Himalaya Berries and California Blackberries that use the small Arroyo Willows for support. Coyote Brush has also developed a tall stand of 3-4 m tall bushes in most of VIa. The units can fairly easily be evaluated with the same method employed above for Units II and III, namely to trace size changes in the ten largest individuals of each common species. Even though they constitute just three individuals, I have included average sizes of the Eucalyptus trees to provide some idea of their growth rates. Data are not given for Red Willows because except for one large grove, in which individuals could not all be reached because of the Himalaya Berries, only a few individuals were scattered in the stand.

Fig. 27 provides information on Willows and Cottonwoods. The latter seem to be leveling off in their growth, and Cottonwoods are not reproducing anywhere in the units. The data for Sandbar are included because they show what appears to be a maximum size for the species. A single grove of old trees exists in Unit VIb. These values represent just four remaining viable trunks from about three times that number in 1984. I find the values for Arroyo Willow interesting. The species dominates parts of the closed area of the units numerically, and I had expected individuals to be approaching senescence, much like Sandbar Willows in some parts of the study area. In fact, they seem to be growing well, and are themselves invading some of the open areas. In contrast to Red and Sandbar Willows, they seem to be able to reproduce where a considerable amount of organic matter exists on top of the soil.

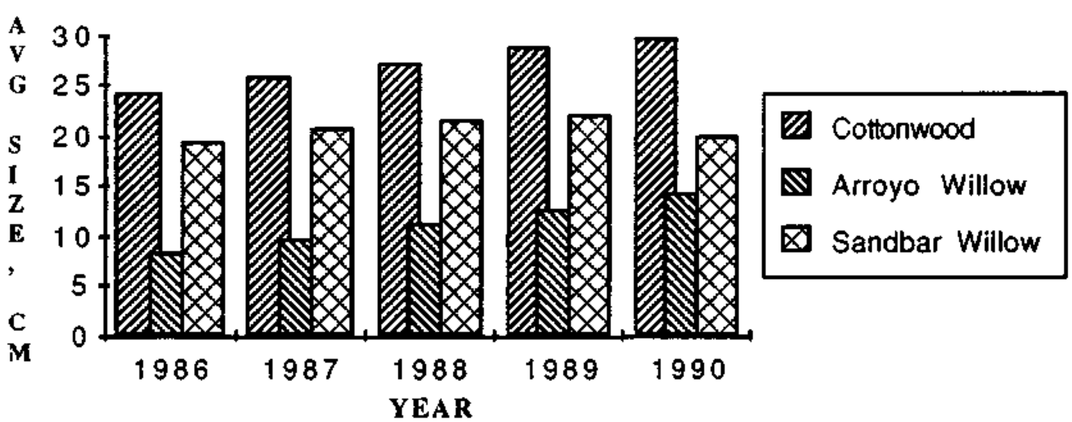


FIGURE 27. Average sizes for the ten largest Cottonwoods and Arroyo Willows for Area 5, Units VIa and B, along with the average size of four large, senescent Sandbar Willows from these units.

Data for Black Walnuts, Box Elders, and Eucalyptus shown in Fig. 28 indicate growth for all three species. Black Walnuts outnumber Box Elders at least five to one on the site, and they are growing more rapidly. Their ability to thrive in open sunlight, which predominates in most of this unit, combined with similar growth and reproduction in the wooded area of Unit VII (below), puts them in a good position to become the dominant species in the future. Data for Eucalyptus are somewhat alarming. I know of only eight trees of this species in all of Area 5, but if they continue to survive, and if the trees now on the site become a seed source, they could seriously threaten native trees.

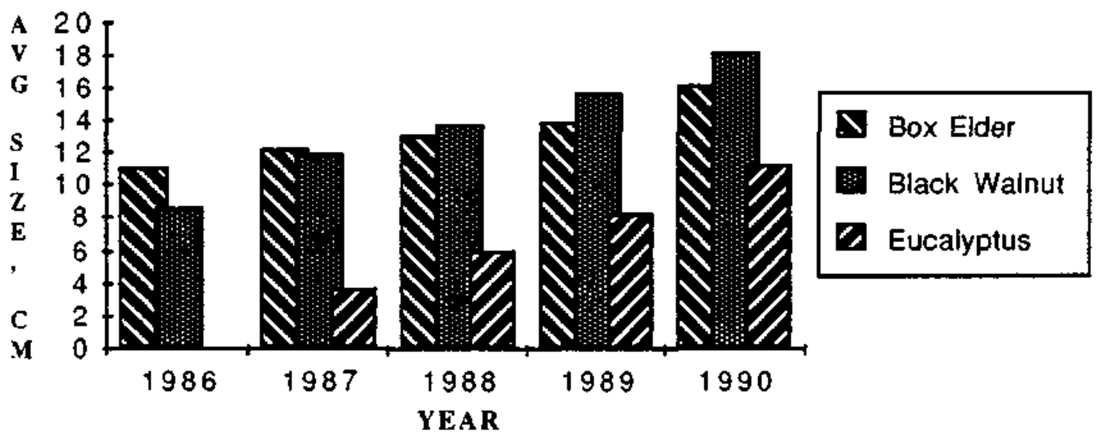


FIGURE 28. Average sizes for the ten largest Box Elders and Black Walnuts for Area 5, Units VIa and B, along with data for three Eucalyptus trees in the units.

VIb. This unit has similar topography to VIa and VIb, but is fundamentally different in its ecology. Whereas the first two units have undergone progressive development of wooded communities, VIc has undergone deterioration. From the start, it has been an open area, populated in the main by forbs such as Mugwort and Poison Hemlock. In 1984 there were scattered Sandbar Willows in its downstream section, but now these are nearly all dead. The few clumps of Giant Reed scattered about in this area likewise are not healthy. In the upstream section, where the unit narrows between IIIe and IIIf, there still exists a dense, scrubby "miniature forest" of Sandbar Willows that reach a maximum of 8 cm diameter. Along the river, between Units Va and IIe, the Sandbar Willows are taller and still alive, but of the same approximate diameter. A few small groves of Cottonwoods also exist there. This unit obviously has some very harsh soil conditions, and elucidating them would be a valuable undertaking since they may relate to effects of the gravel industry.

Unit VII

This unit consists of a wooded band that lies on the edge of the study area, just downslope from the agricultural terrace to the east. It has a somewhat varied topography that includes a low region that may at one time have been a principal secondary channel of the river. Other areas are level or mounded up slightly. Overall, it is the highest ground of Area 5. Since the work began in 1982, it has had a stand of tall trees. In the first few years of the work, this woodland was rather distinct from the areas west of it in Unit VI, which were vegetated primarily with forbs and grasses. Recently, the boundary between the units has become more obscure as trees invade Unit VI. The most conspicuous trees early in the study were Red Willows and Cottonwoods of medium size. Major questions have been how these trees might withstand competition from other species and whether or not the woodland will eventually be populated by forms capable of sustaining themselves by continued reproduction.

Since 1984, I have sampled it annually using the point-quarter method. In this technique one stops at predetermined points on a line (in my case every ten steps along a zig-zag path through the unit) and measures the distance to the nearest tree in each 90 degree quartile of area along the line of transect. Distance information is converted to density. Data are also taken on the species and diameter of each tree in the sample. With 30 sampling points, each year's data are based on 120 trees. Ten cm was the criterion for "tree." hence only trees of that size or larger were included. The same tree may occasionally occur in two successive samples, so the data should be seen as a statistical representation of the stand rather than a set of measurements on entirely different trees. At the far eastern margin of the unit are a few very large Cottonwoods, which appear occasionally in the data. In order not to completely skew data given below on average diameters, I did not include these in the calculations. My attempt has been to sample the central portion of the unit, away from the contact zones with neighboring areas. Table 16 provides basic information on the numbers and average diameters on an annual basis. (Diameters were calculated using the weighted average of the number of trees in successive 10 cm intervals, complete data for which appear in the annual reports.)

TABLE 16. Summary data on total density in trees per square meter, numbers of trees of a given species (Num), and average diameter for this species based a weighted average for 10 cm class intervals (Diam.). Species include Red Willow, Arroyo Willow, Cottonwood, Box Elder, Black Walnut, Prune, and Oregon Ash.

Year	Trees/ m2	R.Wil Num	R.Wil Diam.	AWil Num	AWil Diam.	Cott Num	Cott Diam.	Box Num	Box Diam.	BWal Num	BWal Diam.	Prune Num	Prune Diam.	OAsh Num	OAsh Diam.
1984	0.1	61	26.6	5	25.0	7	30.7	32	17.5	10	23.0	5	15.0	0	0.0
1985	0.05	62	27.3	0	0.0	9	39.4	36	16.7	9	18.3	2	15.0	2	25.0
1986	0.098	59	28.2	7	23.6	2	40.0	35	15.9	15	17.7	2	15.0	0	0.0
1987	0.074	51	27.4	10	19.0	4	37.5	36	16.4	16	18.8	0	0.0	2	25.0
1988	0.072	58	28.4	7	16.4	7	37.9	30	15.7	16	19.4	1	15.0	1	25.0
1989	0.045	45	28.1	9	17.2	6	45.0	35	15.6	22	19.1	1	15.0	0	0.0
1990	0.039	41	29.6	11	20.5	7	43.6	32	16.6	27	17.6	2	15.0	0	0.0

Data on density can be expressed in a relative sense ("relative density"), as shown in Fig. 28. One can note that the percentage of Red Willows has declined, while that for Black Walnuts has increased. Arroyo Willow seems to be somewhat more common in the stand, but in small numbers, while percentages of other species have remained more or less constant. For a given year, one can also see which species is numerically dominant. Note that Red Willow has declined by more than 15%, while Black Walnut has climbed by a similar value.

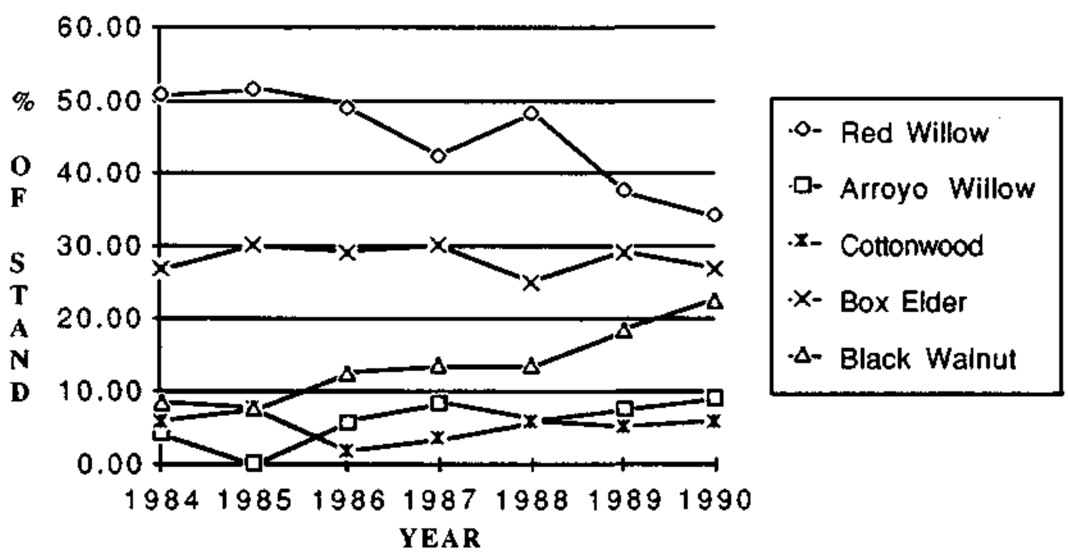


FIGURE 28. Species composition in the woodland of Unit VII, Area 5, over a seven year period

Another way of examining trends in this woodland is to see how the absolute density has changed from year to year. In Fig. 29, where these values are plotted, I have expressed density in trees per hectare. (One ha equals 2.471 acres.) The radical dip in values in 1985 can safely be ignored as a methodological error. I must have used an inaccurate or uncalibrated range finder to obtain data on distance. (None of the other data on the trees would have been affected by this anomaly.) This aside, there is a large decrease in the density of all trees during this time period, from close to 1000/ha to about 400. Much of this decline is due to decrease in Red Willows. In the last few years, standing and fallen dead trees of this species have been a conspicuous feature. Some openings have been created that have been exploited by large mounds of California Blackberry. Much study would be required to determine the causes of this mortality in Red Willows, but it appears to me to be primarily due to failure to compete for light or moisture or perhaps to natural senescence.

Among other species, Box Elder density declined at a rate somewhat lower than that for Red Willow. Since the individuals of this species are small, the affect of this decline on the community as a whole has been much less important that the decline in Red Willows. I suspect that Box Elders are actually just beginning to reproduce in the community and have suffered mortality of young trees, while in the Willows it is mid-sized to larger trees that have been dying. Black Walnut density has remained steady. Values for Cottonwoods and Arroyo Willows, species that have been less abundant over all years, also appear to have changed little.

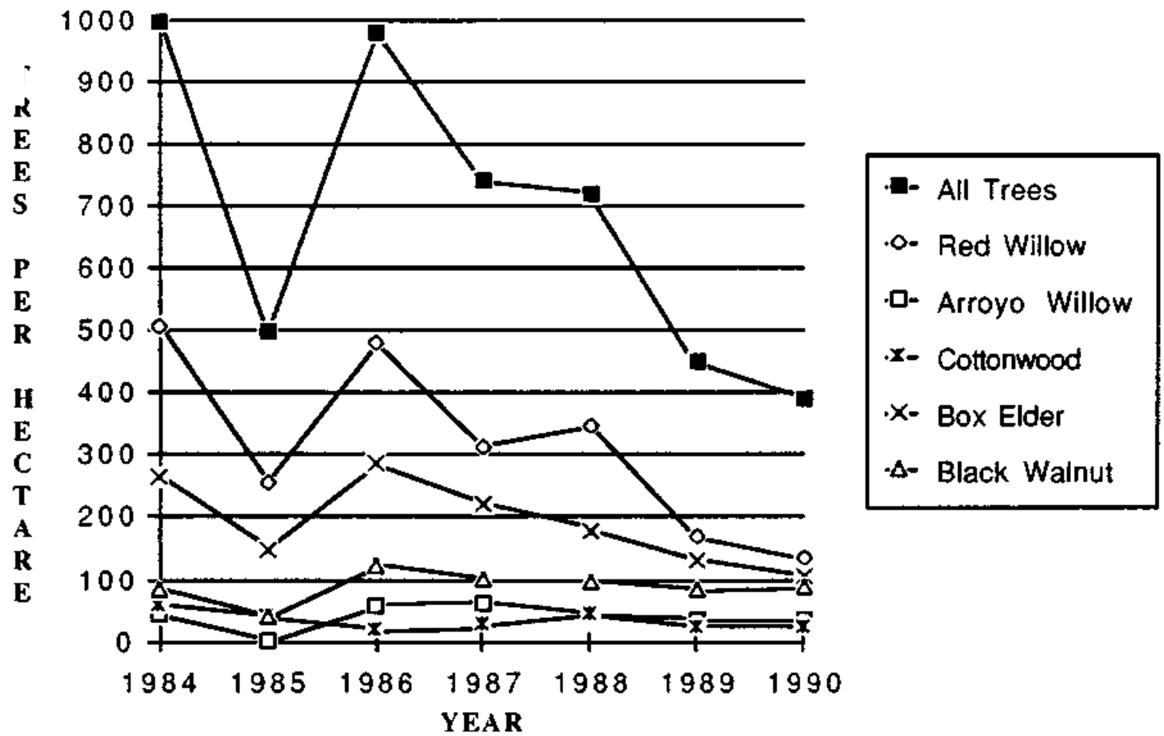


FIGURE 29. Changes in absolute density over a seven year period in Unit VII, Area 5

A good method for examining the causes of these density and composition changes is to examine the population structure of the individual species . To do this, I have created a series of figures based on the numbers of individuals in 10 cm diameter classes, ignoring the occasional very large trees from the periphery of the stand. Data for one year are sometimes not representative, especially for species whose absolute numbers are low. Data must therefore be pooled over several years to see the major trends. Since the same number of years must be included in each pool, I did not include 1984, and show sums of tree numbers by size category for 1985-87 and 1988-90.

First, note that Cottonwoods (Fig. 30) have not had any small trees in the samples. Clearly this species is not reproducing, though the individuals that do exist are surviving and growing. The bimodal nature for the data in both time intervals suggests that there may be two different age classes in the population. For Red Willows (Fig. 31), there is a decline in all age classes, but this is greatest in the 15 cm (10-20cm) class. During field work, one does not see young trees of this species in the stand; the smallest size class will probably not exist in a few years. One should be careful not to interpret the similarity in numbers of Red Willows in the two time intervals, or such numbers for the other species, as meaning that the absolute numbers of trees in the whole stand have changed little. These size distribution figures do not carry information about density as do Figs. 28 and 29. The method always takes data on the same number of trees per year (120 here). Knowledge about the average distance between a given tree and its neighbor is necessary before density interpretations can be made. This distance has increased over the years in Unit VII, hence the decline in the total density of trees.

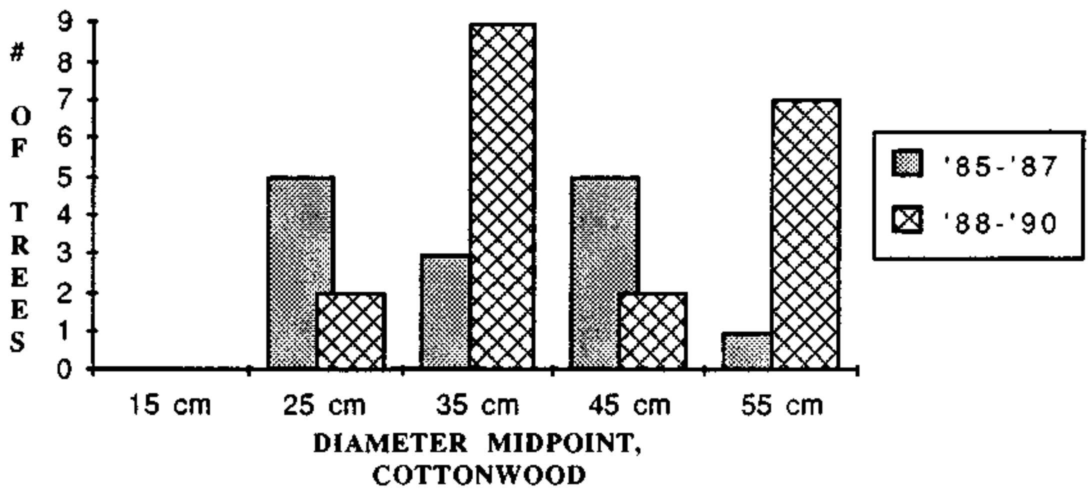


FIGURE 30. Distribution of Cottonwoods by size in two time intervals. Area 5, Unit VII.

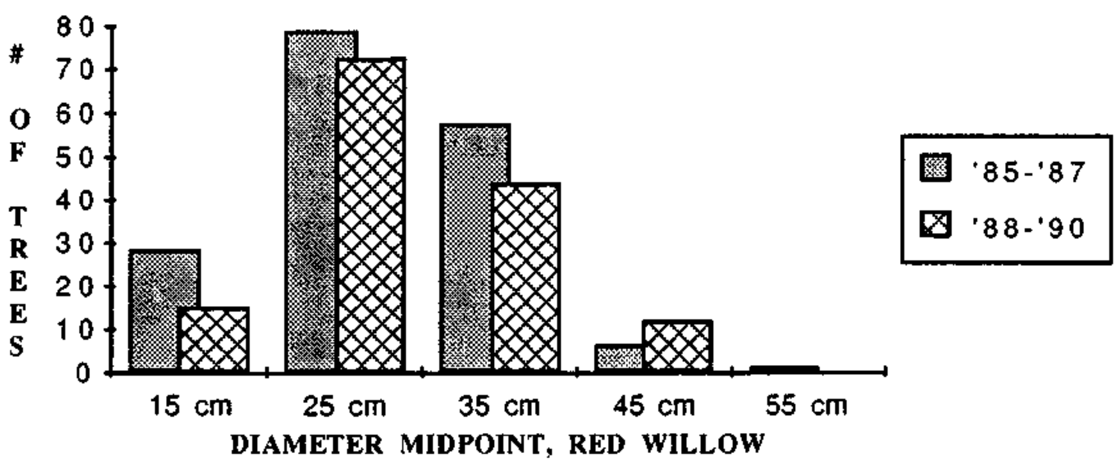


FIGURE 31. Distribution of Red Willows by size in two time intervals. Area 5, Unit VII.

The other tree species common enough to allow for analysis of population structure have sizeable numbers of small trees in their populations. For Arroyo Willow (Fig. 32) the number of small trees has apparently increased, but the samples are small. Little growth is indicated for the 25 cm trees. This species is known to reach smaller maximum sizes than Red Willow, so the current size distribution is likely to remain in the future. Recruitment of small trees via reproduction may or may not be occurring.

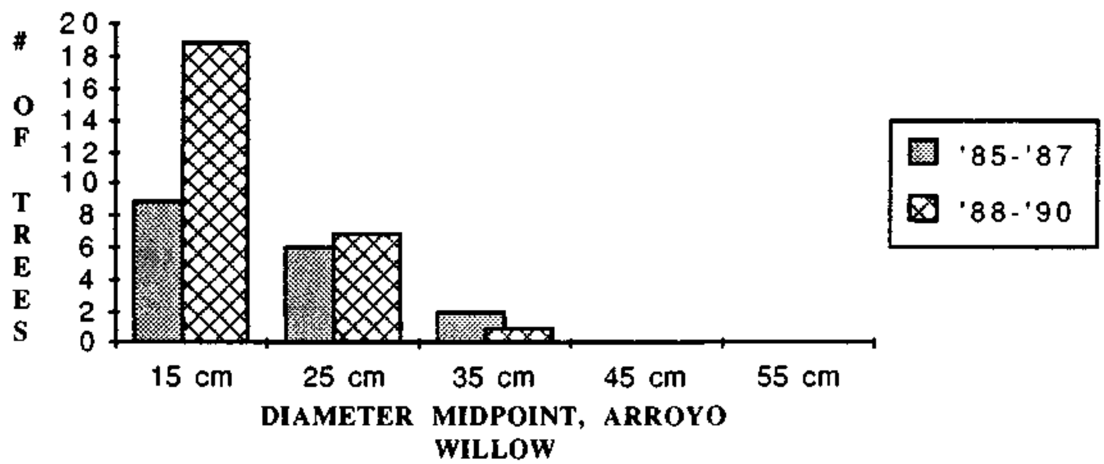


FIGURE 32. Distribution of Arroyo Willows by size in two time intervals. Area 5, Unit VII.

Box Elder (Fig. 33) has the largest number of small trees of any species in the samples in both time intervals, but shows little evidence of growth. It may be that 25 cm trees are dying and are being replaced by growth from below, or that the trees grow so slowly that a three year interval doesn't capture changes. Recall that the overall density of the species has declined. Black Walnut (Fig. 34) shows an increase in all size categories, indicating that it has a population in which growth of existing individuals and recruitment of new ones are both occurring. This species has the potential to grow large and to live to an old age, so it may now be establishing itself as the new dominant species. It will be valuable to learn from future work if it continues to show good seedling establishment as the population ages, in contrast to the Red Willows and Cottonwoods that first established the woodland.

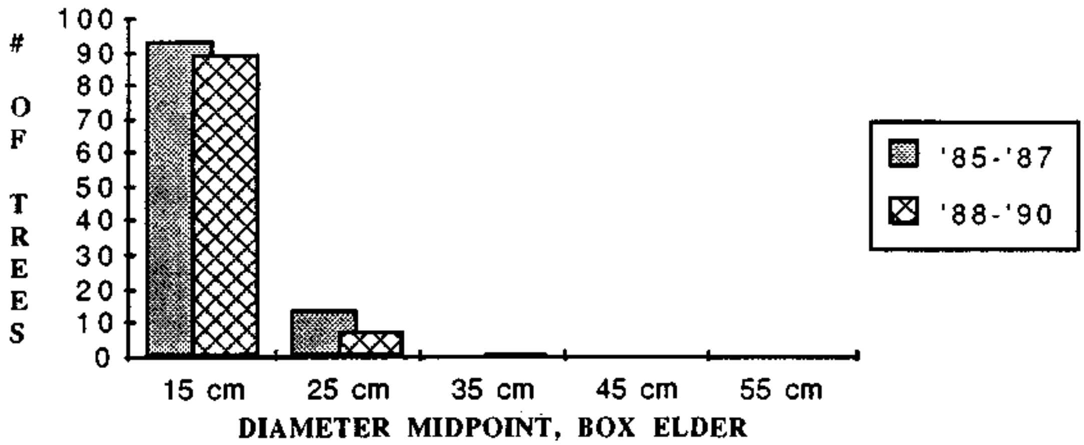


FIGURE 33. Distribution of Box Elders by size in two time intervals. Area 5, Unit VII.

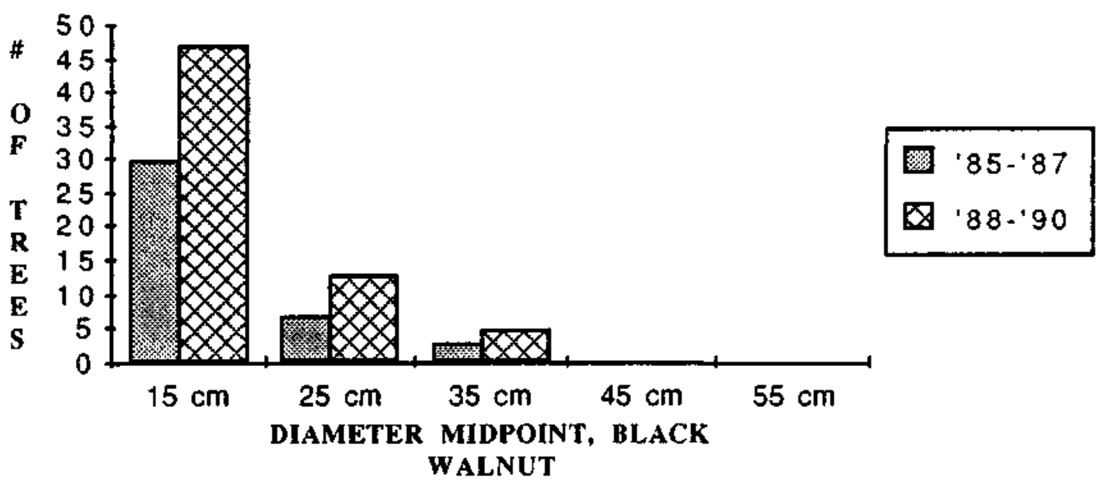


FIGURE 34. Distribution of Black Walnuts by size in two time intervals. Area 5, Unit VII.

PATTERNS OF GROWTH

The descriptive data taken from year to year for Area 5, especially from 1986 to 1990, provide the basis for analyzing the growth patterns of the individual species. In the annual descriptions, it is possible to identify individual trees by size, location, and often by some other aspect of the description. For each such tree, the growth increment in cm for each year (defined as the diameter in cm of the next year minus the diameter of the year in question) can be tabulated. The data can then be tabulated by size class to develop a picture of the species. I have done this for

Cottonwoods from Unit II to show the potential of the method. Table 17 gives the numerical results of the analysis.

TABLE 17. Growth increments for Cottonwood trees in Area 5, 1984-1990, expressed in terms of diameter and cross-sectional area increases.

Diameter Class	Midpoint, cm	Sample Size	Mean Annual Diameter Increment	Mean Annual Area Increment
1-4 cm	2.5	6	1.65	8.61
5-8 cm	6.5	24	2.20	26.31
9-12 cm	10.5	28	1.61	28.66
13-16 cm	14.5	43	1.88	45.61
17-20 cm	18.5	40	2.64	81.98
21-24 cm	22.5	25	2.89	108.57
25-28 cm	26.5	23	2.21	95.92
29-32 cm	30.5	19	1.79	88.47
33-36 cm	34.5	3	3.70	211.16
37-40 cm	38.5	0	0.00	0.00
41-44 cm	42.5	3	1.30	88.07

Diameter increments are shown as a histogram in Fig. 35, where it can be seen that the average growth in cm is rather similar from size class to size class, and is approximately 2 cm per year. (For the graphs I have not included data based on small sample sizes.) The growth of the tree in terms of cross-sectional area is much greater for larger trees, however, because of the non-linear relationship of diameter to area. Fig. 36 shows this relationship. It actually appears that the growth pattern accelerates and then levels off in the "logistic" pattern of population biology. I would like to have data for larger trees, however, before I concluded that this is a real pattern. One should also keep in mind that the growth pattern in three dimensions (volume) would also be non-linear.

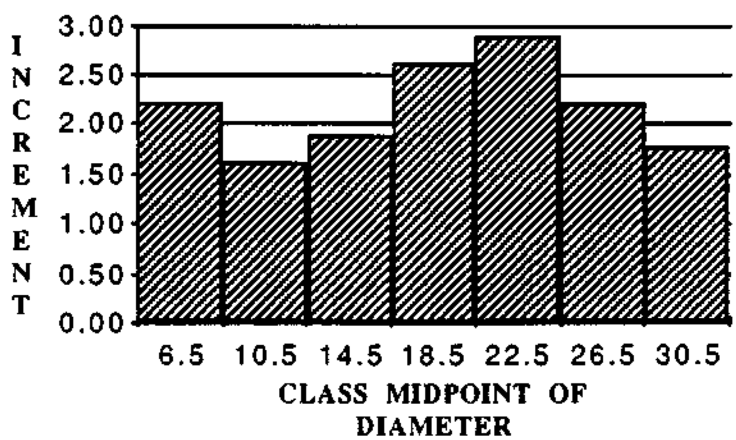


FIGURE 35. Average diameter growth increments in cm for Cottonwood trees in Area 5

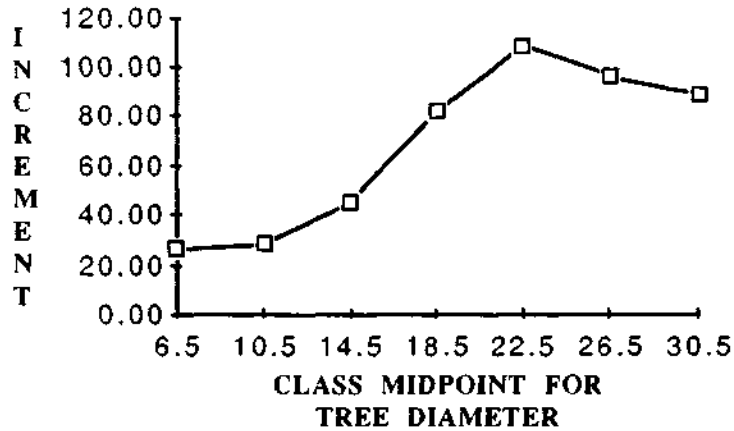


FIGURE 36. Average cross-sectional area growth increments in cm2 for Cottonwood trees in Area 5

These data on average growth increments provide a potentially powerful method for comparing growth rates in other areas with those for this area as a "standard." For example, if reclamation is established in some section in and along the channel, or even surrounding an exhausted gravel pit, the mean growth rates of trees can be obtained in the new area in one or a few years by taking increment data on a sample of the trees to compare with the "standard." Simple statistical tests can be used, or one can assign a percentile "grade" to the new area using information contained in the standard deviation values for the "standard." Figure 37plots all growth increment data for 4-24 cm Cottonwoods in Area II in the form of a frequency distribution. Note that the data are somewhat skewed to the right, and would have to be scaled to use the most powerful statistical tests. Also note from the size of the standard deviation in comparison with the mean that there is considerable variability in the data. (67% of values in the whole distribution lie within one standard deviation unit above and below the mean.) I interpret negative values and values over seven cm as sampling error; a tree has a variable cross-section, and one cannot always measure it from exactly the same angle.

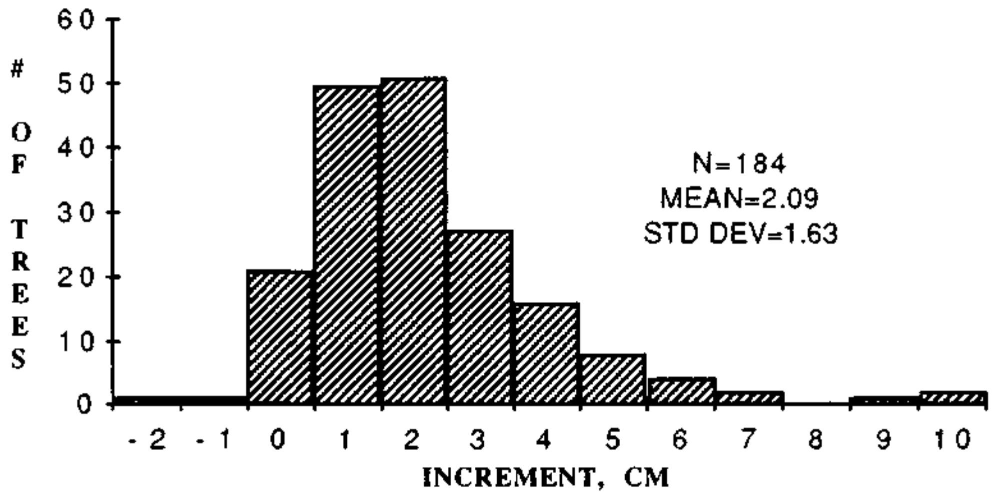


FIGURE 37. Distribution of growth increments for all Cottonwood trees of 4 to 24 cm in Area 5, Unit II, from 1984 to 1990

RESULTS - AREA 6

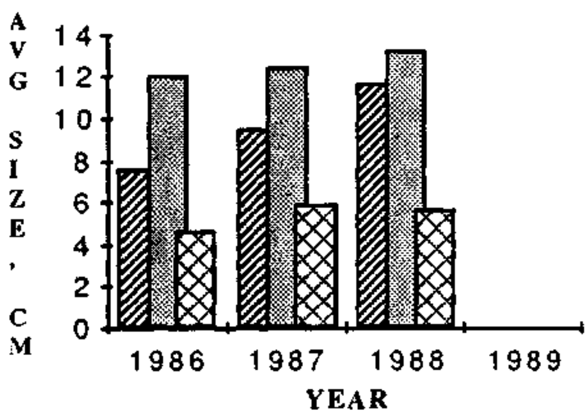
As described in the introduction above, this study area has not been a real "control" in the sense of allowing one to see how a community equivalent to that of Area 5 responds to lack of disturbance. It does provide a very important basis of comparison in its wooded area (Unit VI); indeed, this forest seems to represent a later stage in succession for the woodland of Unit VII in Area 6. The rest of the area is largely sparsely vegetated gravel bar equivalent to Unit I of Area 5. Unit II of the study area consists of groves of Red Willows, Sandbar Willows, and Cottonwoods establishing themselves on the open gravel bar. They are thus equivalent to Unit IIIa of Area 5. I did break this unit up into subunits in the annual reports, but since they are small it makes sense to combine them here.

Unit I-Open bar

This Unit was very sparsely vegetated, rocky gravel bar. Scattered forbs, Coyote Brush, and stunted clumps of Giant Reed to about two meters height were located on it.

.ines of trees on the open sections of lower half of the bar

dividual sections of the vegetation tended to be dominated by >cies. For example, Unit Ha closest to the river had nearly all arger Red Willows and a few of the larger Cottonwoods. A lall Unit (lie) about in the center of the bar had the other half larger Cottonwoods. Other units had predominantly Sandbar . Fig. 38shows growth of the ten largest trees. Despite the itly harsh conditions, Cottonwoods were growing well. Had been left unchanged they could have begun to accelerate the ; of sediment deposition downstream by trapping debris, as itly occurred in Units II and III of Area 5.



IGURE 38. Average diameters of the ten largest trees of three species in Unit II, Area 5. 1989 data were not plotted because bulldozing activity by the landowner had removed or disrupted many trees.

This unit in 1984 and 1985 consisted of very small woods and willows near the river side of the upstream of the bar. In 1987, the unit was thoroughly bulldozed to all vegetation, and it did not regain trees for the course of idy.

'. A small, open terrace on the western side of the back 3! constituted this unit. Throughout the study, it was ted by Coyote Brush, tall forbs, and a few Sandbar Willows.

This was the generally unvegetated back channel of the area.

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the woodland, but the individuals and not as large as for Black Walnut, as will be seen below.

Absolute density of all trees showed a general decline in this study area as it did in Area 5. The starting value of about 500 trees/ha was about half that for the stand in Area 5 (Fig. 40). Note that Black Walnut increased in absolute density, but showed a decline in 1989. This may be due to the discing of the woods by the landowner. I noticed many dead Black Walnuts in the last year. Perhaps their feeder roots are sensitive to disturbance if they have not accomodated to it over the years, as would be true in an orchard.

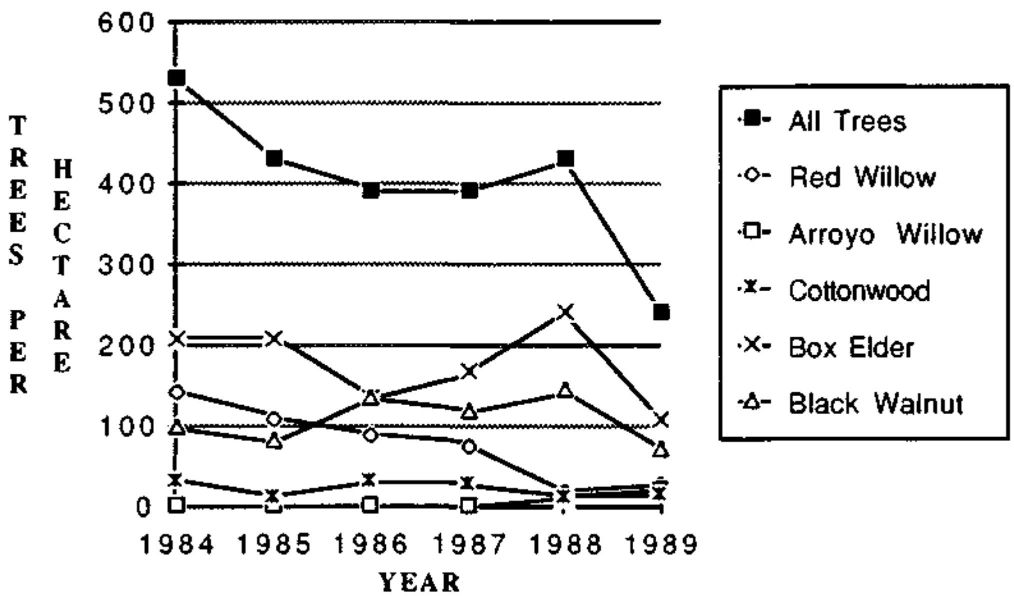

FIGURE 40. Absolute density for all trees and for individual species in Area 6, Unit VI

To analyze the size distributions of the several species, I pooled data in three year intervals of 1984-86 and 1987-89. Graphs of the information appear in the figures below.

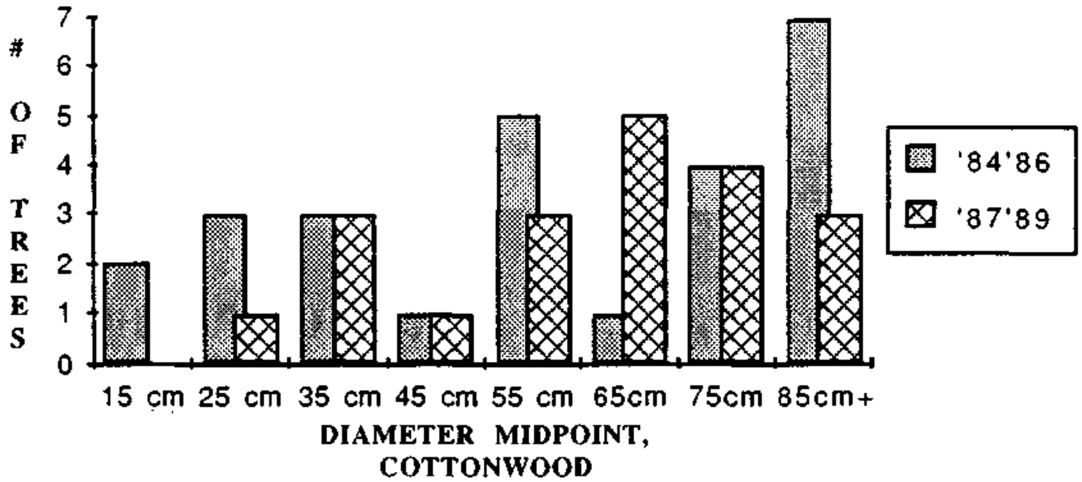

FIGURE 41. Size distribution of Cottonwoods in two time intervals in Area 6, Unit VI.

Cottonwoods were represented by a small number of individuals, thus the picture isn't entirely clear. More of the very large individuals were included in the data in the earlier years. It does seem clear, however, that smaller individuals are no longer present, as was the case in Area 5.

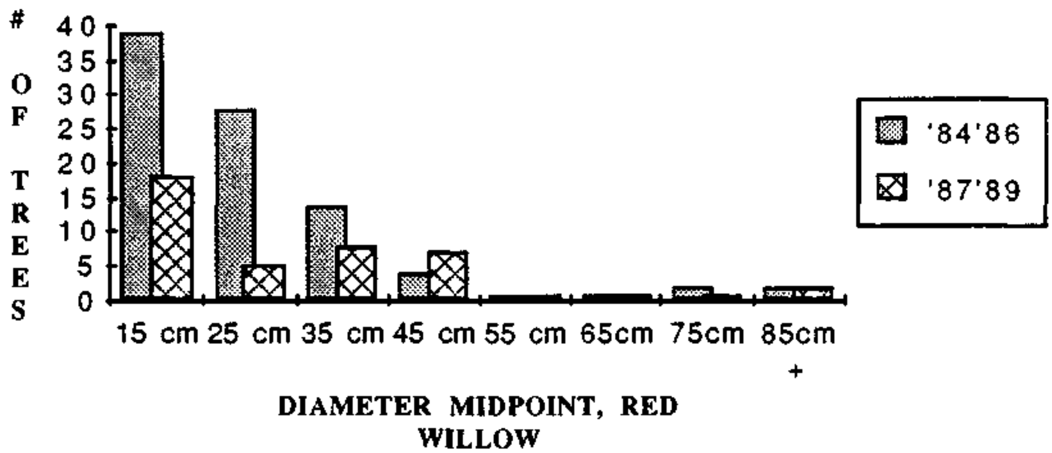

FIGURE 42. Size distribution of Red Willows in two time intervals in Area 6, Unit VI.

In the figure above for Red Willows, one can see a sharp drop in smaller members of the species, even while a few continue to grow. Very few trees above about 50 cm were present in the samples.

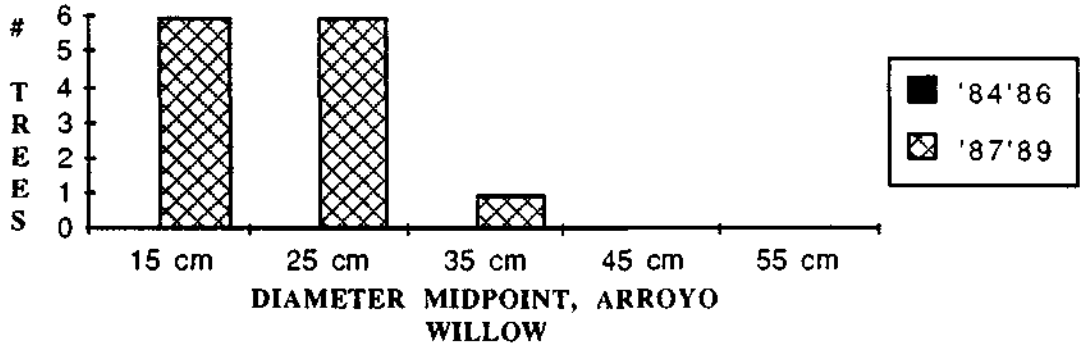

FIGURE 43. Size distribution of Arroyo Willows in two time intervals in Area 6, Unit VI.

I discussed above several observations that suggest that Arroyo Willows (Fig 43) can invade established communities. Their appearance in the samples here may be additional evidence of this. It is possible that the decreasing density of the trees in the whole woods forced me to include some peripheral Arroyo Willows not included in the earlier years. More study will be needed to elucidate this problem.

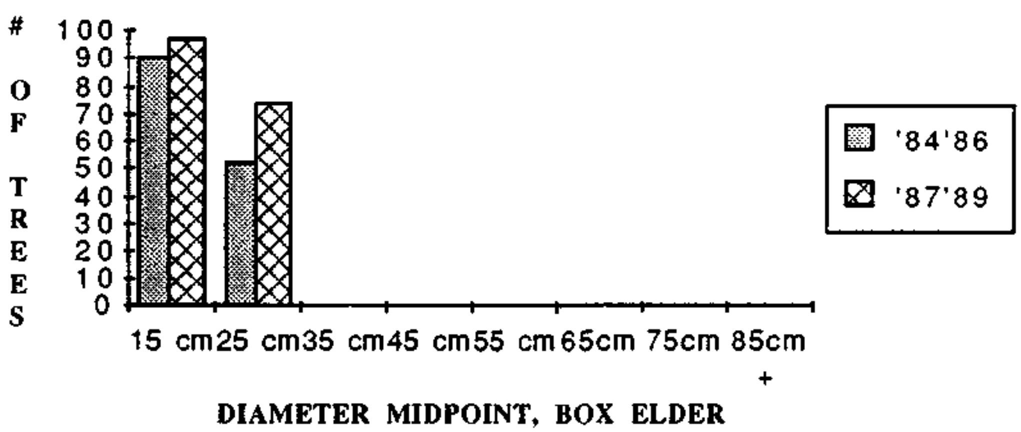

FIGURE 44. Size distribution of Box Elders in two time intervals in Area 6, Unit VI.

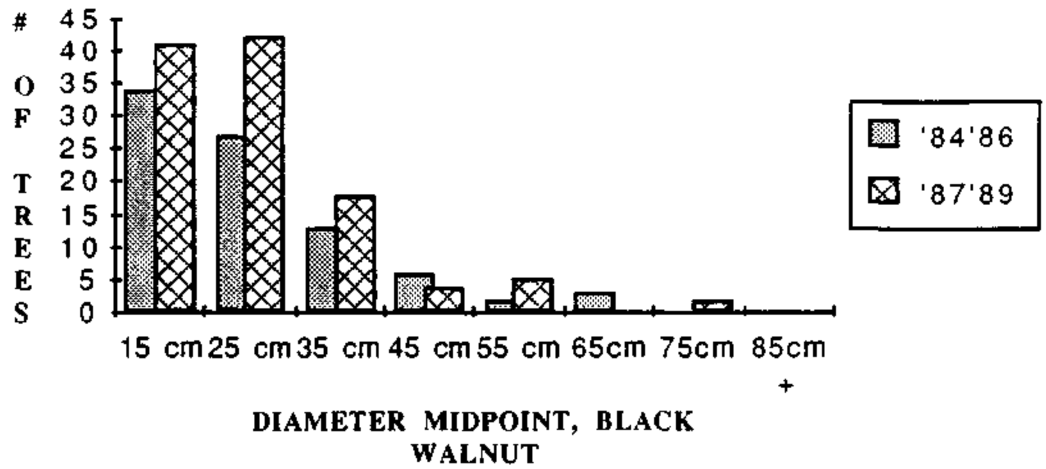

FIGURE 45. Size distribution of Black Walnuts in two time intervals in Area 6, Unit VI.

Data above showed the increasing numerical dominance of the community by Box Elders and Black Walnuts. Figs. 44 and 45 indicate that these changes were also accompanied by considerable increase in the sizes of the trees. Significantly, small individuals are still an important part of the population, indicating that the trees are reproducing well.

DISCUSSION

The immediate effect of gravel removal on the downstream plant communities has been minimal. On the two occasions in which Unit I of the Indirect Impact Area was utilized, the remaining vegetation continued to grow, with the exception of a very few individuals immediately adjacent to the cuts. Inasmuch as gravel extraction from within the channel can change both the level of the river bed and the pattern with which sediments are moved and deposited during times of flood, the impact of the industry, and possibly of an immediately upstream operation could have significant long-term affects.

A first possible impact is to retard the development of new terraces, upon which the mature riparian forest may ultimately depend. By lowering the river channel and diverting more of the flood waters away from higher levels within the channel, sediments that historically may have raised the soil level of growing plant communities and ultimately built new terraces may be washed all the way through the system or deposited at levels below where they be utilized by the climax species. Brady et. al. (1985) presented \lodel of terrace building that seems to match the conditions found Area 5. He gave the name "nursery bar" to the small hummocks of sediment that build behind an obstruction on a gravel bar, which \W young plants to establish themselves. With growth of the \nts, more sediment is trapped. Eventually, in a system that is grading, these nursery bars fuse to become a higher terrace, arly, this model fits the construction of vegetated hummocks in >a 5.

We have seen that several species of the mature riparian \odland, including Box Elder, Black Walnut, with Oregon Ash Bay a lesser extent, have established themselves in lower elevations the Area 5, including Units II, III, parts of IV and VI. \ablishment of seedlings and saplings, however, is not evidence of \sntual success. Such plants may routinely grow to a certain size \d then die back with a succession of high water years, or perhaps nutrient limitations are met in the less mature soils of these \ung topographic features. It is very important, therefore, to gain knowledge about the fate of these plants over the long run, through a variety of conditions. It may not be possible to regain in prehistoric conditions of flooding, terrace building and extensive woodlands, particularly with the construction upriver of dams that trap sediments, but it may be possible to foster development of a river system that "husbands" the sedimentary resources that it does have.

In this respect, it is possible that the sediment removal from lit I of Area 5 may have adversely affected the deposition of fine sediments in the study area itself. Following the removal of 1987, \e main bar did not regain its original level. As a consequence, fine sediments have been accumulating in the hollow along its downstream side, hence the growth of vegetation in what I now call \lit Ia. If the original bar were still intact, perhaps some of these aterials would have been deposited in higher levels of Units II, III, and VI. The puzzling lack of growth in Unit VIc may be due to the ilure of such sediments to deposit. (The unit lies, in effect, in the and shadow" of IIId-F, however, and these units may prevent \eposition regardless of the availability of the resource.) One could \gue that the growth of new vegetation in Ib more than \ompensates for reduction in nutrient availability for other areas. he communities that develop rapidly following such disturbance are \ot equivalent to the mature woodlands that should be allowed to develop wherever possible, however. Perpetual creation of stands of argh!

sampled at all because of the steepness of the bank. The west bank has been used in several places as a depository for aggregate materials and possibly overburden. This is especially true of the southwest corner, where pea gravel has been placed. Neither the north nor the eastern shores have developed much vegetation despite a lack of disturbance.

The South Pond lies south and east of the headquarters, and is larger and more diverse ecologically. Its north shore, like that of the other pond, had never developed any significant riparian growth. Its northwest shore had a healthy stand of Cottonwoods in the first three years of the study. These were dead by the fall of 1985 as the water level in the pond had risen about their bases. Similar deaths were noted among willows on the east and south shores.

A small cove occupies the southwest corner of the site. This area has typically had some marsh vegetation around it, and is frequented by the American Coot and other waterfowl. East and north of the cove, a delta is forming where fine sediments are being fed into the pit. Mallards and other dabbling ducks feed in the shallow water. Open areas of the water have heavy use by the Belted Kingfisher, Western Grebe, and Double-Crested Cormorant, all fish-eaters.

A narrow belt of vegetation stretches around the pond. On the east, Arroyo Willows are dominant, but some Cottonwoods and Red Willows exist, and Box Elder, Black Walnut, and one Valley Oak have invaded the area during the course of the program. The South shore, and that of the cove have a mix of these species, with no species clearly dominant. Fig. 46 below treats the whole pond as a unit to evaluate sizes of the ten largest trees of Cottonwood, Red Willow, and Arroyo Willow each year, an analysis that has been done above for study areas along the river. Black Walnuts, Box Elders, and Sandbar Willows were not present in large enough numbers to allow for a reliable analysis. Arroyo Willows have been growing faster than in any of the units along the river, and Red Willows and Cottonwoods show equivalent growth. The drop in Cottonwoods for 1990 was due to removal of three large trees. Individual trees appear to fair just as well along the margins of the South Pond as along the river. The difference in the habitats, however is that only a limited amount of woodland can be accomodated around a pond of characteristics like this one.

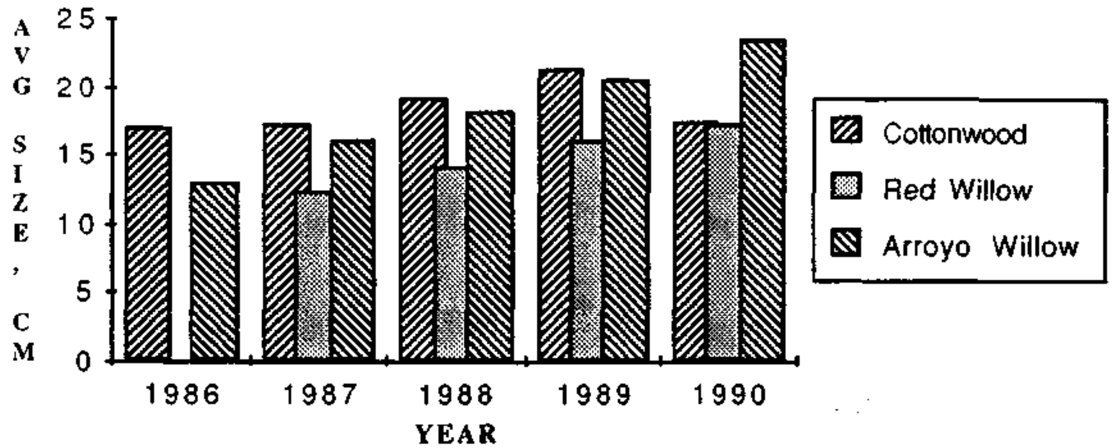

FIGURE 46. Average sizes of the ten largest trees of three species from Area 7, South Pond

Although the South Pond seems to be left as an aquatic habitat, activities around its banks had had large consequences regarding the extent of vegetation. A major grove of mature Red Willows on the southern side of the west shore was removed during the monitoring period so that the area could be used for a deposit of soil, which not makes a steep shore in this area that has not been invaded by any riparian species. A second wide band of soil was deposited along the south shore, but none of the trees in the narrow band along the pond proper were disrupted. This past year about half of the trees on the southwest side of the cove were taken out, possibly to make way for another soil deposit.

It is not a goal of the Aggregate Resources Management Plan to manage finished terrace pits as plant and animal habitat, so the coincidental establishment of some growth around such a pit and use of a pond by wildlife can be seen as unplanned benefits. Inasmuch as any pit is likely to exist for a period of time regardless of what its ultimate fate is, however, it would seem desirable to have more knowledge about the best ways to allow natural habitat to develop in and around such excavations. From the limited work done so far in this monitoring program it is clear that a pit should not have its water level rise drastically after riparian trees have established themselves, if such can be accomplished by design. Additionally. I would suggest that alternative sites for the storage of aggregates and overburden be evaluated prior to the use of pond margins. Alternative designs in terms of bank grade and soil type could be developed to optimize even short term use of such areas by plants and animals. I recommend that some evaluation of use of wildlife in and around the ponds be added to the monitoring program so that data can be developed to guide the reclamation process.

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