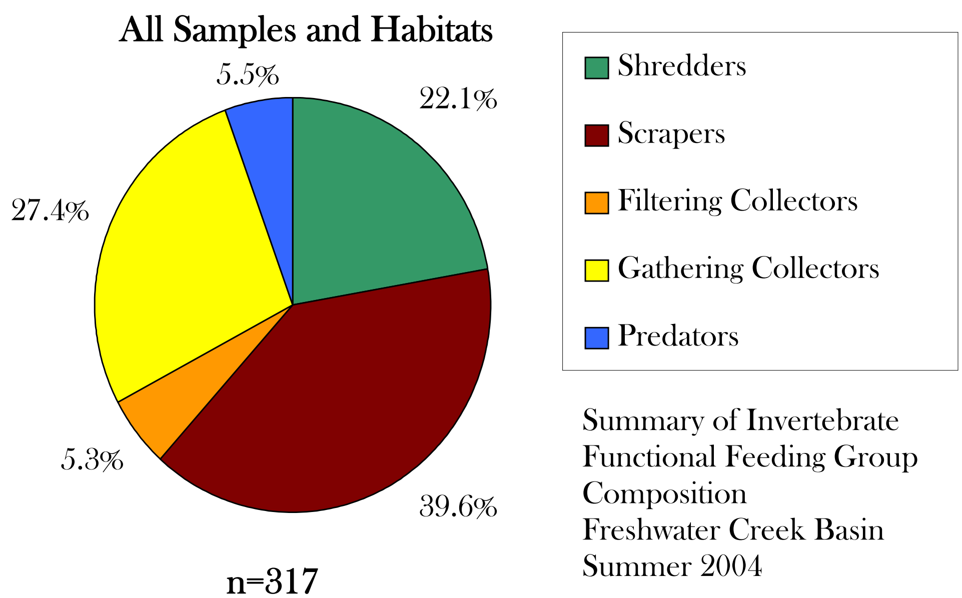
Using Macroinvertebrate Community Functional Organization to Predict Prey Base and Ecosystem Attributes Favorable to Juvenile Salmonid Growth and Survival in Freshwater Creek



Summary of Invertebrate
Functional Feeding Group
Composition
Freshwater Creek Basin
Summer 2004

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INVERTEBRATE FUNCTIONAL GROUP ANALYSIS
FOR THE
FRESHWATER CREEK WATERSHED

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Introduction

An invertebrate assessment using functional feeding group (FFG) classification (Cummins and Klug 1979; Merritt and Cummins 1996; Appendix I) was conducted in the Freshwater Creek Basin, Humboldt County, California in August and September 2004. Working in conjunction with the Institute for River Ecosystems (IRE), and California Department of Fish and Game (DFG) Anadromous Fisheries Research and Monitoring Program (AFRAMP) juvenile salmonid survey, an invertebrate survey crew from IRE sampled stream invertebrates at locations determined by a modified Hankin and Reeves (1988) protocol for the juvenile salmonid survey.

The juvenile salmonid survey crew followed a sequential protocol to monitor Freshwater Basin for juvenile salmonid species. First, habitat units were selected and flagged for later snorkel-dive, electrofishing, and invertebrate assessment surveys. With a few exceptions habitat units were classified as riffles (RI), shallow pools (SP), and deep pools (DP).. Riffles were not snorkel-surveyed but one-tenth of all flagged riffles were selected for electrofishing. One-third of all shallow pools were selected for snorkel-surveying. One-forth of the shallow pools that had been snorkel surveyed were selected for electrofishing. Thus, one-twelfth of all flagged shallow pools were selected for electrofishing. Invertebrates were sampled at every other electrofished unit. Because deep pools were snorkeled but not electrofished, no invertebrates were sampled at deep pool locations. The invertebrate survey crew worked up stream to the end of anadromy following the snorkel survey up. The electrofishing survey teams came up behind the invertebrate survey crew enumerating salmonid species. Salmonid stomach samples were taken from up to ten fish over one year old collected form those electrofishing sites where invertebrate samples were taken. This protocol allowed for a match between the juvenile salmonid stomach samples and invertebrate collections at all invertebrate sampling sites.

Functional Groups

The separation of stream invertebrates into functional feeding groups (FFG) is based on the mechanisms by which they acquire their food. Morphological and behavioral adaptations used in acquiring the food are generally easily observed in the field using live, freshly collected specimens. An example would be the large eyes, bright color patterns, and active movement that characterize the predaceous stonefly families. This combination of characters identifies these stoneflies as predators. The morphological characters used to place stream invertebrates into FFGs are given in the Key to FFGs in **Appendix I**. Feeding mechanisms, dominant food resources, and particle size ranges are summarized for each FFG in **Table 1**.

Field Methods

Header Information

At each unit, the Stream Name, Reach ID, and Drainage were recorded, as well as Habitat Unit Number and Type. Date, Water Temperature, and Time were also recorded. At every Unit where invertebrate sampling took place, stomach samples were collected by the electrofishing crew. The invertebrate crew left flagging to notify the electrofishing crew of the units where invertebrate sampling took place.

Invertebrate Data

In general, three samples were taken at every unit. Habitat sample type consisted of four categories; Cobble, Leaf Litter, Fine Sediments, and when available, Large Wood. For each sample, after the Header data were entered on the field form, individual invertebrates were field identified, sorted into functional feeding groups (FFG) and tallied. Field invertebrate taxonomy was generally to the family or genus level for insects and to the ordinal or class level for other invertebrates. In this method, separation of the invertebrates into functional feeding group was made in the field on fresh, live specimens. The FFGs used were: Shredders, Scrapers, Filtering Collectors, Gathering Collectors, and Predators (Cummins and Klug, 1979; Merritt and Cummins, 1996). The numbers of invertebrates contained in each FFG were tallied for every sample type. After FFG enumeration, the samples were labeled with data from the header of the field data form and preserved in 70% ethyl alcohol (ETOH) for return to the laboratory for analysis. In the laboratory, the invertebrates can be identified to a finer taxonomic level and the specimens measured to permit conversion of numbers to biomass using the software INVERTCALC (Cummins, Wilzbach, and Merritt, unpublished).

Invertebrate Sampling

Once the unit selection procedure and snorkel survey had taken place, units were sampled for invertebrates. The protocol **(Figure 1)** was to take one sample from each habitat type: Leaf litter, cobble, fine sediment, and wood. Availability determined whether all habitat types could be sampled at each site. If leaf litter was abundant, it would be collected first, followed by cobble, and then fine sediments and large wood. If fine sediment depositional areas or large wood were absent, two cobble samples were taken.

A 250 :m mesh D-frame dip net was used to sample all four habitat types. This allowed for the separation of insects from fine sediment and particles of organic debris. All D-frame dip net collections were made for 40 seconds. Leaf Litter was collected for 40 seconds, and then the leaves were rinsed to separate insects from leaves. Water soaked logs or large woody debris were sampled for 40 seconds by rubbing the surface of the wood by hand to dislodge the invertebrates into the net. Invertebrates were removed by hand scrubbing the cobbles in the streambed into the net for 40 seconds. Fine sediments were sampled in pools or backwaters when they were present by skimming off the upper 1-2 cm for 40 seconds. An example field data sheet is given in **Appendix II**.

After collection, each sample was washed into a shallow white tray for taxonomic separation, functional group assignment, and enumeration. Functional group determinations were aided by a laminated FFG field key (Appendix 1; Cummins, Wilzbach, and Merritt, unpublished). Following enumeration and data entry on to the field form, each sample was washed onto a 250 :m sieve and into a whirl-pak® scientific collecting bag, and preserved with 70% ETOH for later lab analysis. Each bag was labeled with the Header information from the corresponding field data form.

Fish Stomachs

At every other electro-fishing unit where the invertebrate sampling was done, the invertebrate sampling crew left a flag marker to alert the fish sampling crew that fish stomach (lavage) samples were to be taken. At each of these sites, up to ten 1+ year old juvenile salmonids were stomach-pumped. Stomachs were flushed with a syringe into a tray and the material preserved in whirl-paks® with 70% ETOH. The tip of the syringe needle was protected with fine, flexible plastic tubing to prevent damage to the fish esophagus and stomach. Each sample was labeled with information corresponding to that recorded on the invertebrate field data form header from that site. Fish stomachs collected in Cloney Gulch were analyzed in the laboratory. Invertebrates were separated into taxa and converted to biomass using INVERTCALC, a software program that converts lengths of individuals into taxa-specific biomass estimates (Cummins and Wilzbach, unpublished).

Results

Invertebrates were collected, using methods described previously, from each stream in conjunction with the (AFRAMP) juvenile salmonid survey. In this manner samples were collected from ratio- generated locations (units) on the Mainstem. Using the same ratios and sampling protocol, the six tributary streams were sampled upstream until the end of anadromy (i.e. until no more juvenile coho were encountered).

A total of 317 samples was taken from six tributary streams and the two sections of the Mainstem in the Freshwater Creek Basin. Upper and Middle Mainstem were delineated as above and below the confluence with the South Fork of Freshwater Creek. The number of invertebrate sample locations for each stream and Upper and Middle Mainstem are summarized, along with the total number of samples taken in each habitat at each location, in Table 2. The taxa encountered during the survey (including all 317 samples) are summarized in Table 3. Stoneflies (Plecoptera), mayflies (Ephemeroptera) and caddisflies (Trichoptera) were well represented in all tributary streams and in both sections of the mainstem. The number of Ephemeroptera, Plecoptera, and Trichoptera relative to the total number of invertebrates present in a sample (EPT index) has been used to indicate stream health (e.g. Karr and Chu 1999). Based on this criterion alone, all six tributaries and the two sections of the mainstem that were surveyed for invertebrates were in acceptable condition. However, as indicated above (e.g. Table 3), these broad ordinal level taxonomic categories obscure within taxa functional relationships. For example, there are scrapers and gathering collectors in the order Ephemeroptera (Table 3) and these two groupings of mayflies have very different nutritional requirements (Table 1). Scrapers depend upon attached, non-filamentous algae as a food resource (autotrophic food chain) and the gathering collectors depend upon fine particulate organic matter (FPOM) (heterotrophically based food web).

A general overview of the invertebrate and juvenile salmonid surveys in the Freshwater Creek Basin is shown in Figure 2. The actual sampling locations for the invertebrate FFG data are depicted in Figure 3. From this figure it is clear that the basin coverage was quite broad and complete. The pie charts summarize relative percents of the functional groups averaged over all samples from each tributary and the mainstem sections. The estimated mean number of juvenile salmonids per running meter of stream length are also given for the study tributaries and mainstem reaches in Figure 2 and arranged by rank in Table 4. Using the autotrophy/heterotrophy index, or P/R ratio (Table 5), the tributaries and two mainstem reaches were classified as autotrophic or heterotrophic. As shown in Table 5, an FFG ratio is used as a surrogate for P/R with a threshold value of >0.75 indicating an autotrophic system with foodwebs based on in-stream algal primary production. Scrapers were the dominant FFG in four of the tributaries (Graham Gulch, Little Freshwater Creek, South Fork Freshwater Creek, and Falls Gulch). These four tributaries ranked 4th through 6th in terms of juvenile salmonid abundance. Heterotrophic based FFGs, shredders or collectors, were dominant in four tributaries and mainstem reaches (Middle and Upper Mainstem, Cloney Gulch, and McCready Gulch, Table 4). Shredders were dominant in Middle Mainstem and Cloney Gulch which were ranked 1st and 3rd in juvenile salmonid abundance (Table 4). Upper Mainstem, ranked 2nd for fish abundance, and McCready Gulch, ranked last for fish abundance, were both dominated by collectors (Table 4). Thus, the general pattern was for heterotrophic tributaries and Mainstem reaches to support the highest juvenile salmonid densities. McCready Gulch, with its heavily silted substrates, constituted the exception (Table 4).

The results are summarized for all 317 tributary and mainstem samples combined and by each of the four habitats (cobble, litter, fines, and wood) in **Figure 4** (i.e. a summary of all data shown in Figure 2). The average (by numbers) over all samples showed scrapers to be the dominant group (approx. 40%), followed by total collectors (approx. 30%), and then shredders (approx. 20%). The separation by habitat makes it clear that scrapers dominated cobble (riffle) samples, shredders dominated litter samples, and collectors made up half or more of the numbers collected from fine sediment and wood samples (Figure3). Filtering collectors ranged from 0 (fine sediments) to 8% (cobbles), clearly reflecting the importance of surface attachment sites for this functional group. Gathering collectors accounted for over 60% of the invertebrates in fine sediment collections, indicting the abundance of their FPOM food resource in this habitat.

Examples of single Mainstem Reach or tributary analyses of FFG community organization are shown in **Figure 5** (Upper Mainstem), **Figure 6** (Cloney Gulch, and **Figure 7** (McCready Gulch). Data for the remaining tributaries and the Middle Mainstem are presented in **Appendix III**. The average FFG composition for Upper Mainstem Freshwater Creek was approximately half collectors, including 10% filtering forms, a third scrapers, and about 10% shredders. The Upper Mainstem, cobble habitats averaged approximately half collectors and half scrapers, litter approximately 40 % each collectors and shredders, and fine sediments and wood both had about 50% collectors (Figure 4). Cloney Gulch averaged half shredders and about a quarter each gathering collectors and scrapers, with filtering collectors essentially absent. Cobble habitats had 50% scrapers and approximately 20% each gathering collectors and shredders. Litter habitats had almost 90% shredders and fine sediments and wood with about half collectors (Figure 5). McCready Gulch samples averaged about 50% collectors and ,of that, about a third were filtering collectors. These were the largest filtering collector populations found anywhere in the Freshwater Creek Basin. This was reflected in the cobble samples with a third of the total being filtering collectors and about half scrapers; both these groups require the stable surfaces represented by cobble. Litter samples were about half collectors and a third shredders. Fine sediments and wood had 40 to 60% collectors. Filtering collectors were not found on fine sediments, reflecting the unstable surfaces characteristic of this habitat (Figure 6).

Fish stomach samples collected in Cloney Gulch were analyzed in the laboratory to determine the FFG composition of the diet and to convert invertebrate numbers to biomass estimates and categorize the invertebrates as either behavioral or accidental drifters. Cloney Gulch samples were selected as an example to illustrate the type of information that can be obtained from such analyses. The results of the analyses of the 35 juvenile salmonids are given in **Table 6**. Using the genetic analyses of juvenile salmonids collected in Cloney Gulch in 2003 as an indication of the accuracy with which field crews are able to correctly separate steelhead and cutthroat trout, an error of less than 20% would be expected in the data from 2004. Field crews made no errors in identifying coho juveniles. This was based on fish > 80 mm in length, which is the lower size limit suitable for stomach pumping. Therefore, because the field identification of juveniles is quite reliable, the data are presented by species in Table 5. On average, cutthroat trout were the largest and coho the smallest fish stomach-pumped on. The mean cutthroat stomach contained the most invertebrate biomass, but the fewest individuals. The average weight of an individual invertebrate in cutthroat stomachs was ten times that in the other two species. When the material in the stomachs is expressed as mg invertebrates per gm of fish, the coho and cutthroat were the same and steelhead trout significantly less. Half of the steelhead and about a third of the coho and cutthroat had no terrestrial food in the stomachs. All fish stomachs contained aquatic invertebrates.

The mean ratio of accidental to behavioral drifters (Table 5), an index of a reliable diurnal food supply of drift feeding juvenile salmonids, has been calculated for the fish stomachs collected in Cloney Gulch (Table 7). The ratios are above the threshold of 0.50, judged to indicate a suitable food supply for drift-feeding juvenile salmonids (Table 5), calculated using either invertebrate numbers or biomass (Table 7). The ratios could be calculated for only 17 of the 35 fish stomachs, because of zeros in either the numerator or denominator of the ratio. The heterotrophic streams (Middle and Upper Mainstem, Cloney Gulch, and McCready Gulch) had high shredder densities in late August – early September that were dominated by small, early instar lepidostomatid caddisflies. It is likely that very early instar caddis larvae that construct organic cases, such as *Lepidostoma*, have a much higher probability of exhibiting a diurnal pattern of entering the drift than their later instars which have much heavier wood cases. If *Lepidostoma* is included in the calculations of the behavioral to accidental drift ratio, 14 of the zeros are removed and the mean ratio, either by invertebrate number or biomass, is several orders of magnitude above the threshold (Table 7). However, the ratio calculated for each individual fish, rather than averaged over the entire sample, is only above the threshold in approximately 1/3 of the fish. . That is, the phenomenon is discernable at the population level, but because many fish have little or no material in their guts, specific individual fish may not fit the average pattern.

Discussion

The invertebrate functional feeding group (FFG) analysis conducted in the Freshwater Creek demonstrated the utility of the method in providing a rapid, field-based evaluation of the composition of benthic invertebrate communities at the basin scale. A major advantage of the FFG procedure is that the sampling crew leaves the field with the data. This is in contrast to standard procedures which preserve samples for return to the laboratory where much more time consuming analysis is conducted. In the present investigation, the samples were preserved after the field enumerations and returned to the lab, so they are available for further analysis if desired.

Using the statistical sampling design established for juvenile salmonid survey work appears to be an optimal method for selecting sampling sites for the invertebrates. Invertebrate sampling need not be done at the same time as the fish surveys, but combining the two provided the opportunity to collect complementary fish stomach samples. Although there was complete correspondence between invertebrate and juvenile salmonid sample units, the habitat survey data collected by CDFG did not match the locations. It should be noted that this was not as originally agreed upon between all the parties involved in the project.

The general picture for the Freshwater Creek Basin (all samples from all habitats from all tributaries and mainstem sections) is that at the basin is nearly in balance between heterotrophy (i. e. dependent upon riparian inputs) and autotrophy (i. e. dependent upon light-controlled in-stream primary production). Indeed, the tributaries and mainstem reaches sort out as half heterotrophic and half autotrophic (Table 4). Given that the three tributaries/mainstem reaches with the highest estimated fish densities (Upper and Middle Mainstem, and Cloney Gulch) were characterized as heterotrophic using the invertebrate surrogate P/R ratios (Table 4 and 5), protection of the riparian habitat along these channels would be recommended. The collector functional group (gathering and filtering) exhibited a rough correspondence with the density distribution of juvenile salmonids in the six tributaries and the two mainstem reaches (Figure 8). Cloney Gulch presents an interesting case, with gathering collectors most abundant above the point along the drainage where juvenile salmonid populations declined to near zero (unit 161, Figure 3). When the relative composition of FFGs are plotted for each sample unit separately for Cloney Gulch (Figure 9), a general shift from FFG composition with shredders most abundant to collectors and scrapers becoming more abundant can be seen. The most likely explanation is a change in habitat (both in-stream and riparian) near sample unit 161. Thus, it is likely that in some instances the invertebrate respond to different habitat features than do the fish. A case in point is McCready Gulch which is fine sediment enriched and had the lowest juvenile salmonid densities but the highest gathering collector percentages (Figure 8). Clearly, McCready Gulch habitat was adequate to support large collector populations, but was not suitable for juvenile salmonids. Further, McCready Gulch had significant populations of filtering collectors. At the basin scale, only McCready Gulch and the Upper Mainstem had significant populations of filtering collectors (Figure 2). These two tributary/mainstem reach systems apparently were the only ones with sufficient quantity and quality of suspended load to support notable populations of filtering collectors. This is of interest because many of the invertebrates that are behavioral drifters are filtering collectors.

Recommendations

The FFG assessment method applied at the basin scale is rapid, efficient, and informative and would be most valuable if it were repeated on a seasonal basis. One census period in August-September coupled with the juvenile salmonid survey and one in the spring, April-May, to correspond with the likely period of maximum growth for the juvenile salmonids are recommended. The first would adequately sample the summer generations and the second the winter generations of the macroinvertebrates. By such repeated annual sampling, trends in invertebrate communities related to land use and hydrologic year would be apparent and could be followed efficiently at the basin scale

Habitat measurements should be made at the same time as the August-September fish/invertebrate survey work and match exactly the sites mapped out for the fish survey. Without this correspondence, direct interpretation of habitat effects will not be possible.

The field crew conducting the FFG survey should rate each unit sampled as to the % cover of each of the habitat types (Cobble/gravel riffles, depositional fine sediment/pools and backwaters, litter accumulations, and large woody debris) to allow appropriate weighting of the FFG collections.

Juvenile salmonid stomach samples should be collected at all the units where invertebrate FFG samples are taken. Laboratory analysis of these fish stomach samples is necessary in order to enumerate invertebrates consumed and to calculate invertebrate biomass.

Laboratory analysis of the FFG samples is advisable so that comparisons with the fish stomach data can be accomplished on a biomass basis.

References

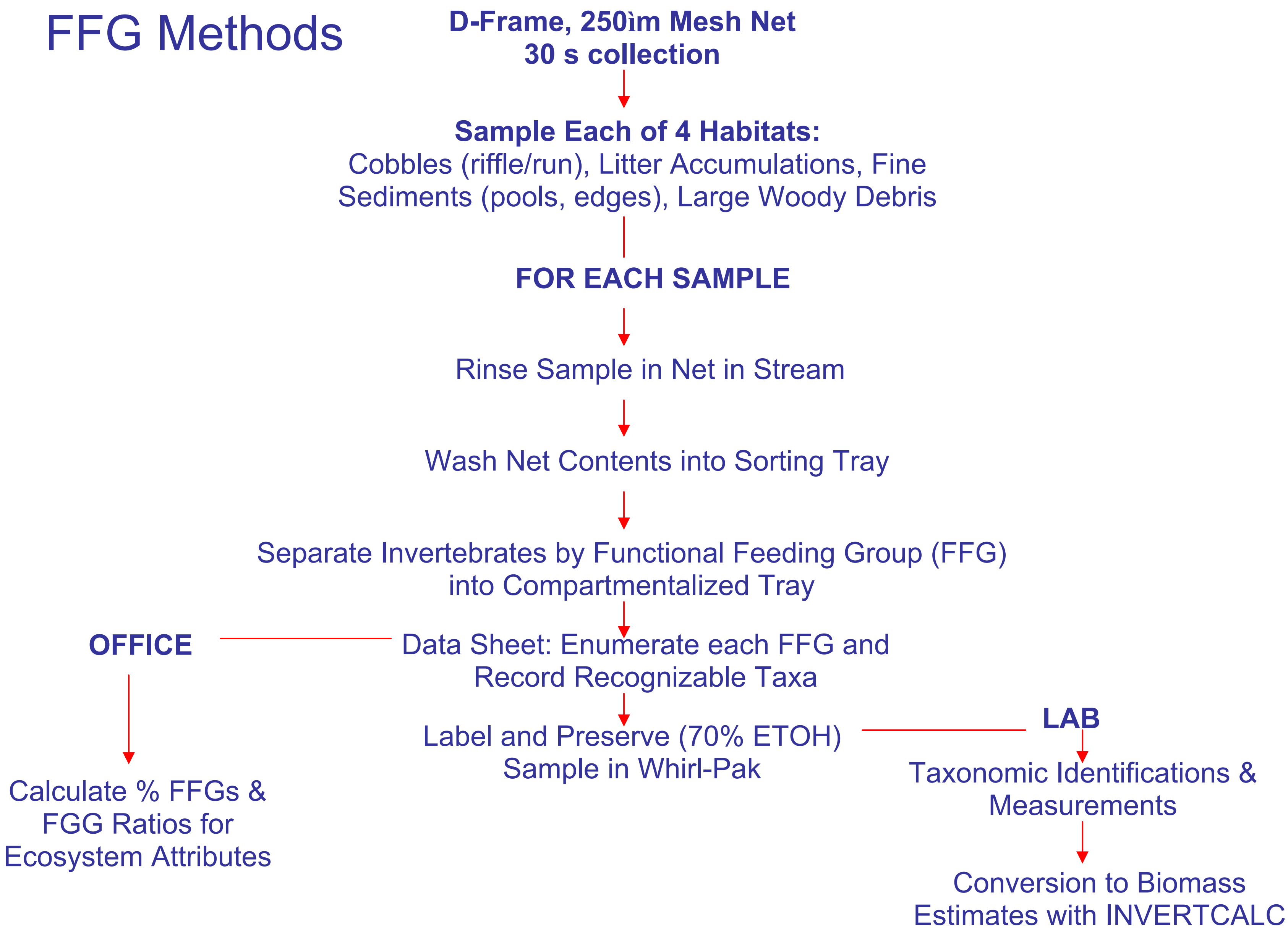
Cummins, K. W. and M. J. Klug. 1979. Feeding ecology of stream invertebrates. Annual Review of Ecology and Systematics 10: 147-172.

Hankin, D.G., and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45: 834-844.

Karr, J.R., and E.W. Chu. 1999. Restoring life in running waters: Better biological monitoring. Island Press, Washington, D.C

Merritt, R. W. and K. W. Cummins. 1996. An introduction to the aquatic insects of North America. Kendall/Hunt, Dubuque, IA, 862 pp.

Figure 1


FFG Methods
D-Frame, 250ìm Mesh Net
30 s collection
Sample Each of 4 Habitats:
Cobbles (riffle/run), Litter Accumulations, Fine Sediments (pools, edges), Large Woody Debris
FOR EACH SAMPLE
Rinse Sample in Net in Stream
Wash Net Contents into Sorting Tray
Separate Invertebrates by Functional Feeding Group (FFG) into Compartmentalized Tray
Data Sheet: Enumerate each FFG and Record Recognizable Taxa
OFFICE
Calculate % FFGs & FGG Ratios for Ecosystem Attributes
Label and Preserve (70% ETOH) Sample in Whirl-Pak
LAB
Taxonomic Identifications & Measurements
Conversion to Biomass Estimates with INVERTCALC

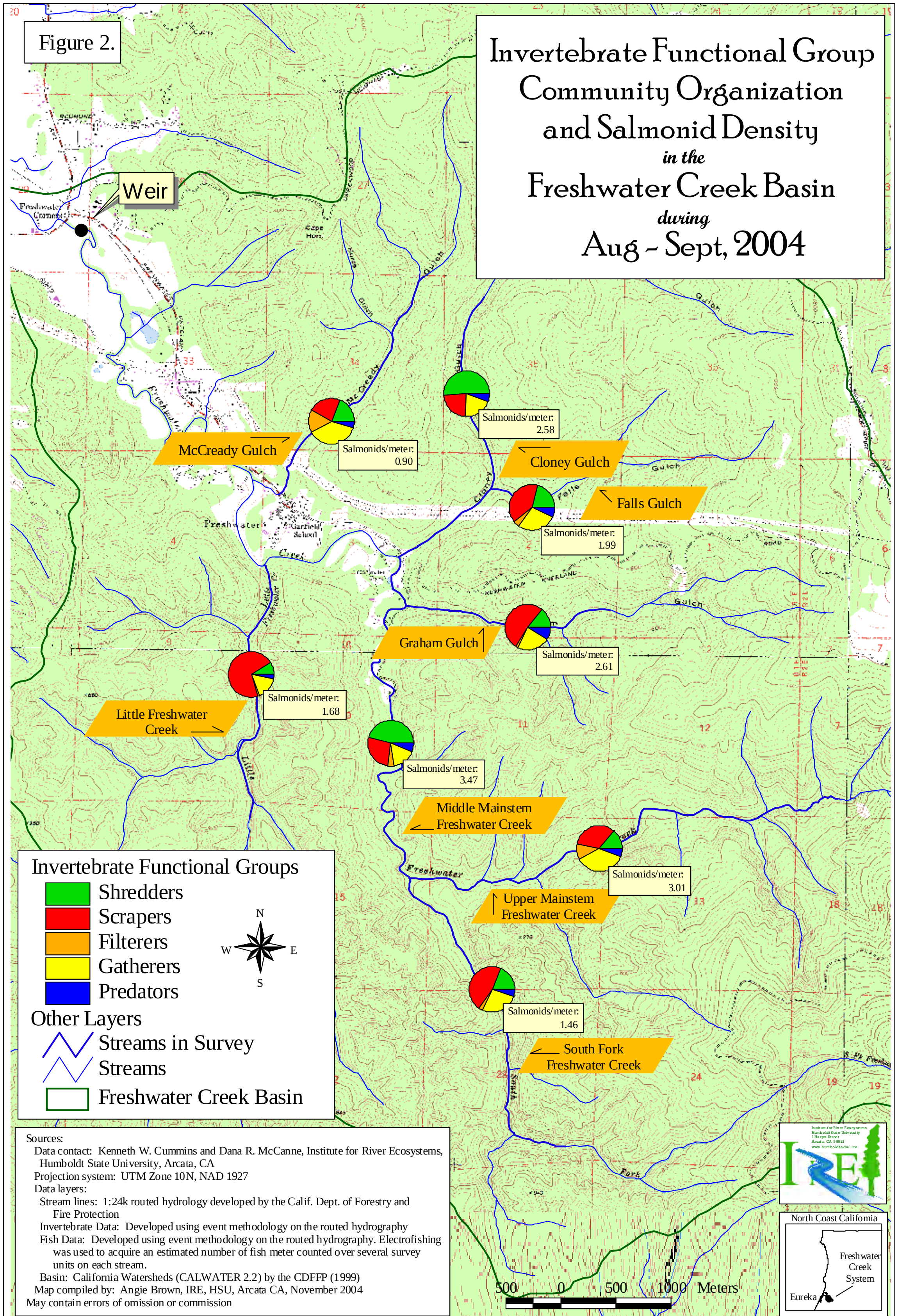


Figure 2.
Invertebrate Functional Group
Community Organization
and Salmonid Density
in the
Freshwater Creek Basin
during
Aug - Sept, 2004
Weir
McCready Gulch
Salmonids/meter: 0.90
Cloney Gulch
Salmonids/meter: 2.58
Falls Gulch
Salmonids/meter: 1.99
Graham Gulch
Salmonids/meter: 2.61
Little Freshwater Creek
Salmonids/meter: 1.68
Middle Mainstem Freshwater Creek
Salmonids/meter: 3.47
Upper Mainstem Freshwater Creek
Salmonids/meter: 3.01
South Fork Freshwater Creek
Salmonids/meter: 1.46
Invertebrate Functional Groups
Shredders
Scrapers
Filterers
Gatherers
Predators
Other Layers
Streams in Survey
Streams
Freshwater Creek Basin
N
W
E
S
500 0 500 1000 Meters
North Coast California
Freshwater Creek System
Eureka
Sources:
Data contact: Kenneth W. Cummins and Dana R. McCanne, Institute for River Ecosystems, Humboldt State University, Arcata, CA
Projection system: UTM Zone 10N, NAD 1927
Data layers:
Stream lines: 1:24k routed hydrology developed by the Calif. Dept. of Forestry and Fire Protection
Invertebrate Data: Developed using event methodology on the routed hydrography
Fish Data: Developed using event methodology on the routed hydrography. Electrofishing was used to acquire an estimated number of fish meter counted over several survey units on each stream.
Basin: California Watersheds (CALWATER 2.2) by the CDFFP (1999)
Map compiled by: Angie Brown, IRE, HSU, Arcata CA, November 2004
May contain errors of omission or commission

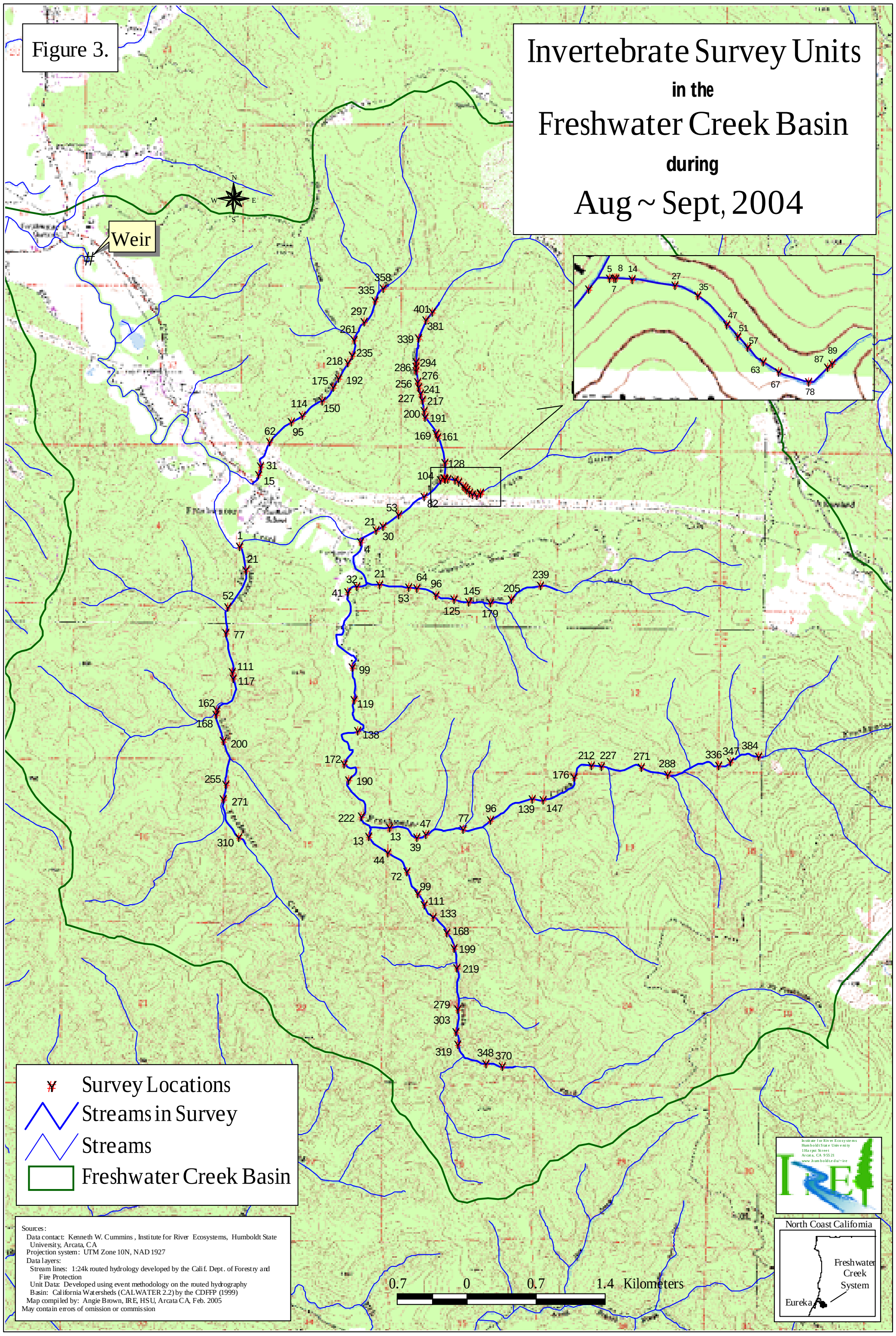


Figure 3.
Invertebrate Survey Units
in the
Freshwater Creek Basin
during
Aug ~ Sept, 2004
Weir
Survey Locations
Streams in Survey
Streams
Freshwater Creek Basin
Sources:
Data contact: Kenneth W. Cummins, Institute for River Ecosystems, Humboldt State University, Arcata, CA
Projection system: UTM Zone 10N, NAD 1927
Data layers:
Stream lines: 1:24k routed hydrology developed by the Calif. Dept. of Forestry and Fire Protection
Unit Data: Developed using event methodology on the routed hydrography
Basin: California Watersheds (CALWATER 2.2) by the CDFFP (1999)
Map compiled by: Angie Brown, IRE, HSU, Arcata CA, Feb. 2005
May contain errors of omission or commission
0.7 0 0.7 1.4 Kilometers
North Coast California
Freshwater Creek System
Eureka

Figure 4
Invertebrate Functional Feeding Group (FFG)
Percent Composition, Freshwater Creek Basin (Summer 2004)

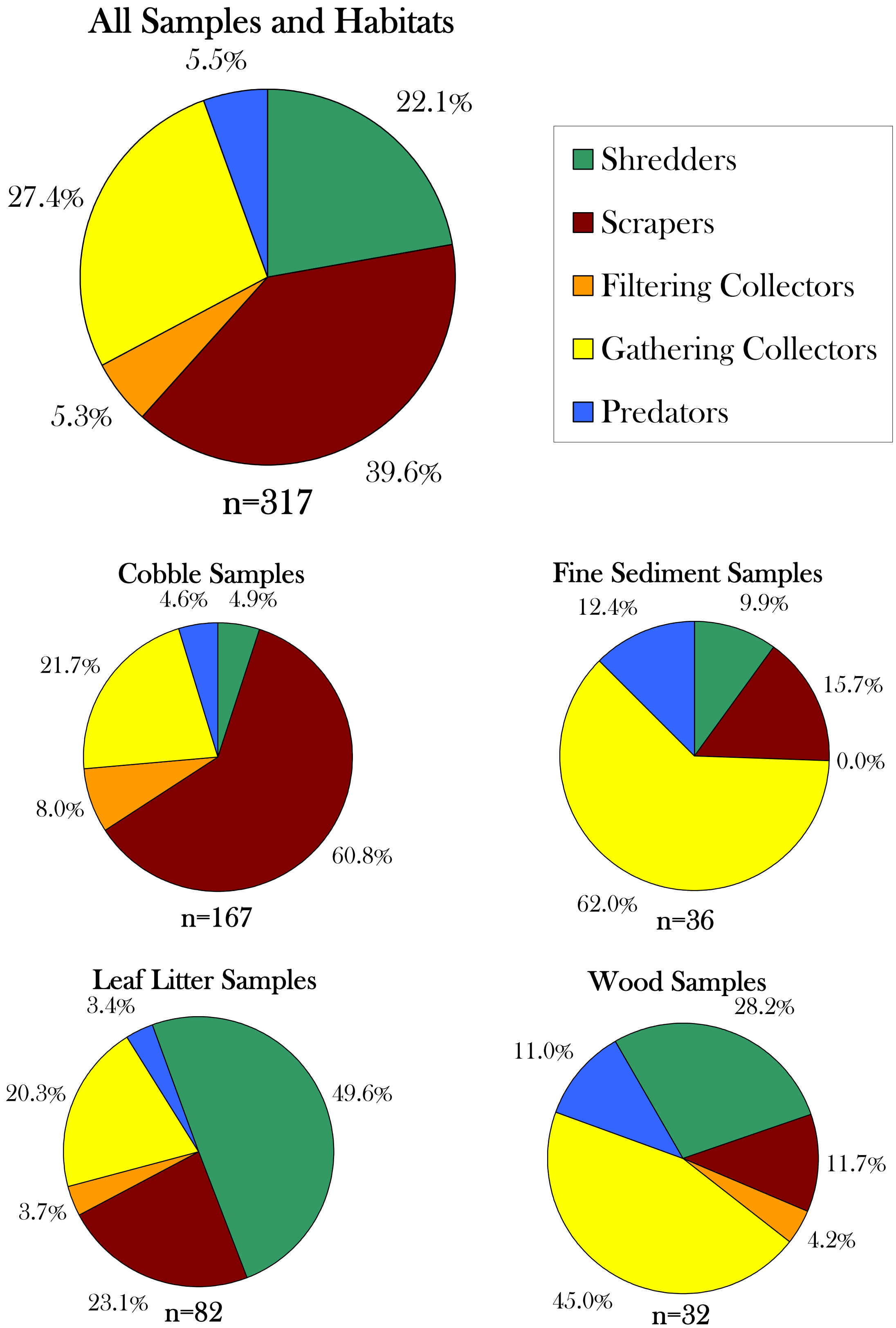
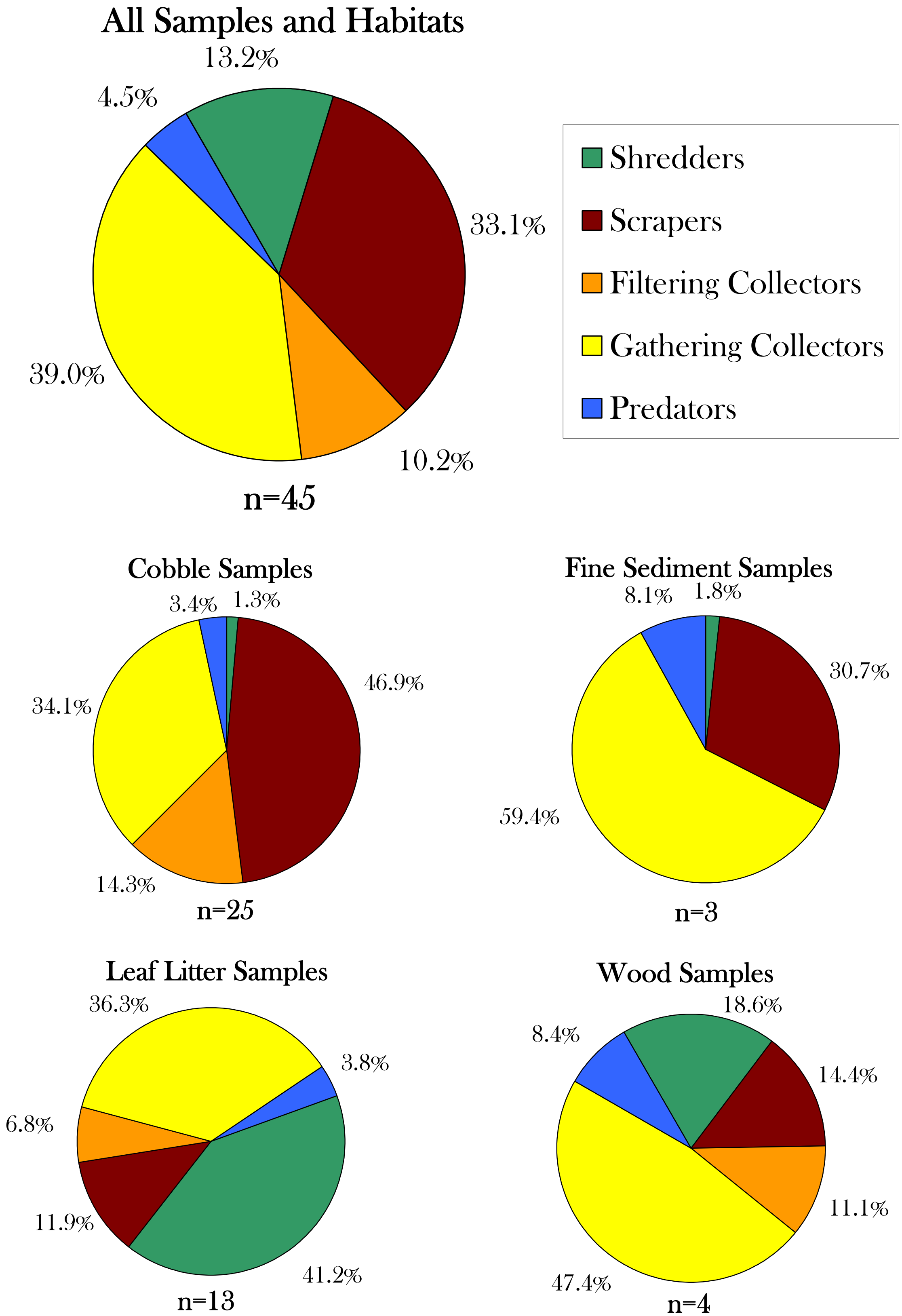
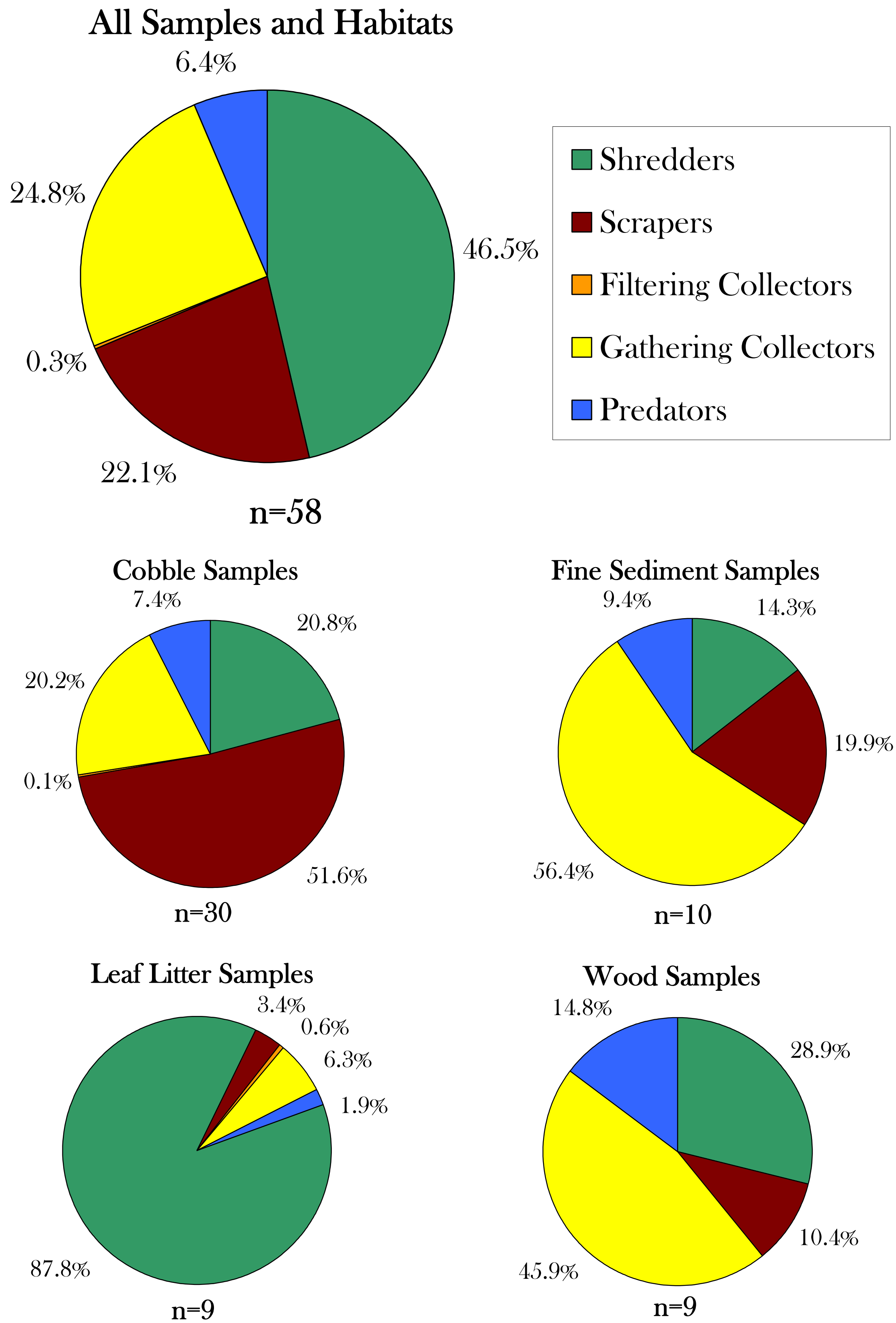


Figure 5
Invertebrate FFG Percent Composition
Upper Freshwater Creek, Freshwater Basin (Summer 2004)



Juvenile Salmonids per Meter: 3.01 Length of Upper Freshwater: 4.51 km

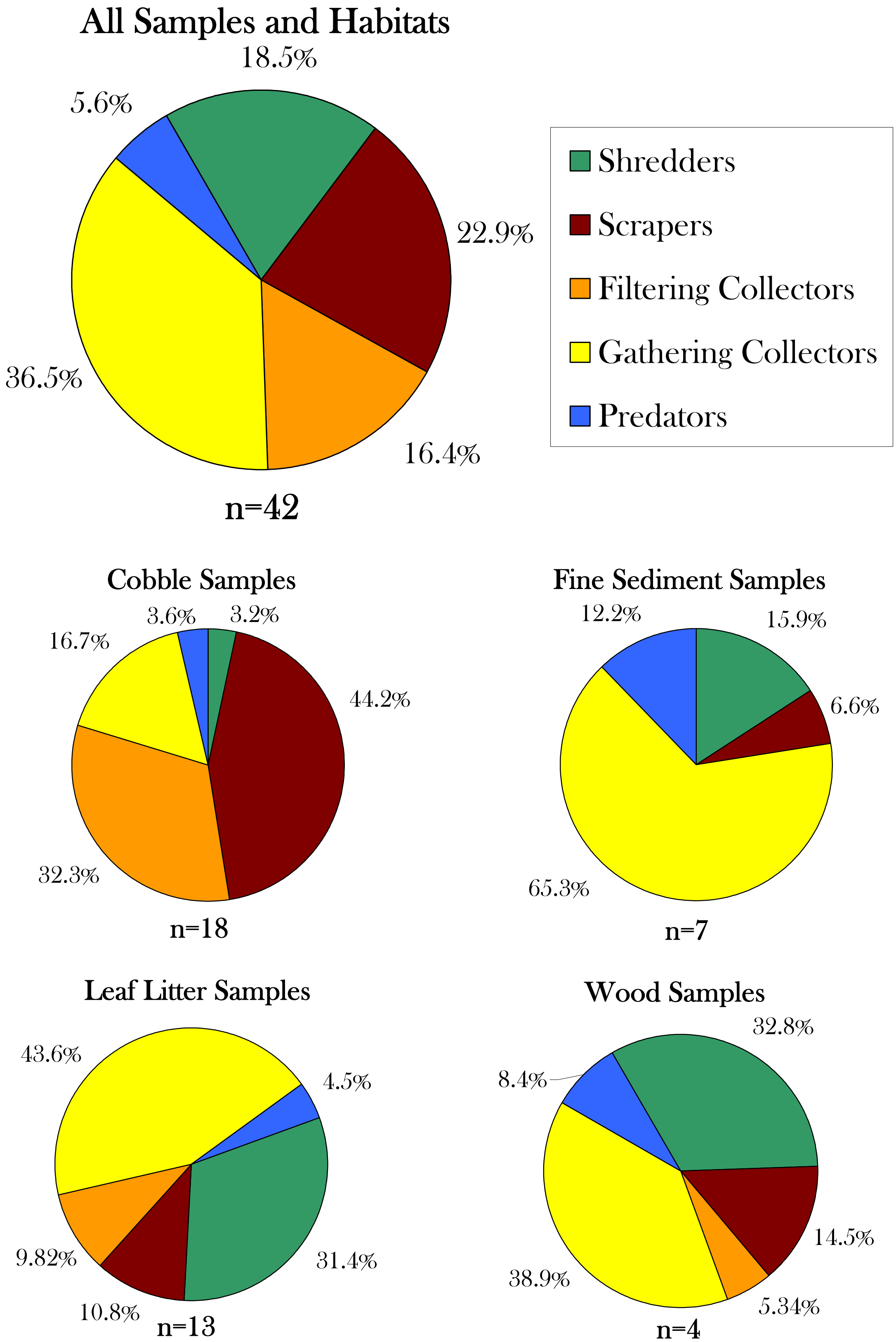
Figure 6
Invertebrate FFG Percent Composition
Cloney Gulch, Freshwater Basin (Summer 2004)



Juvenile Salmonids per Meter: 2.58 Length of Cloney Gulch: 2.95 km

Figure 7

Invertebrate FFG Percent Composition
McCready Gulch, Freshwater Basin (Summer 2004)



Juvenile Salmonids per Meter: 0.90 Length of McCready Gulch: 3.31 km

Figure 8
Freshwater Creek Basin
Gathering Collector Percentages
and Juvenile Salmonids per Meter

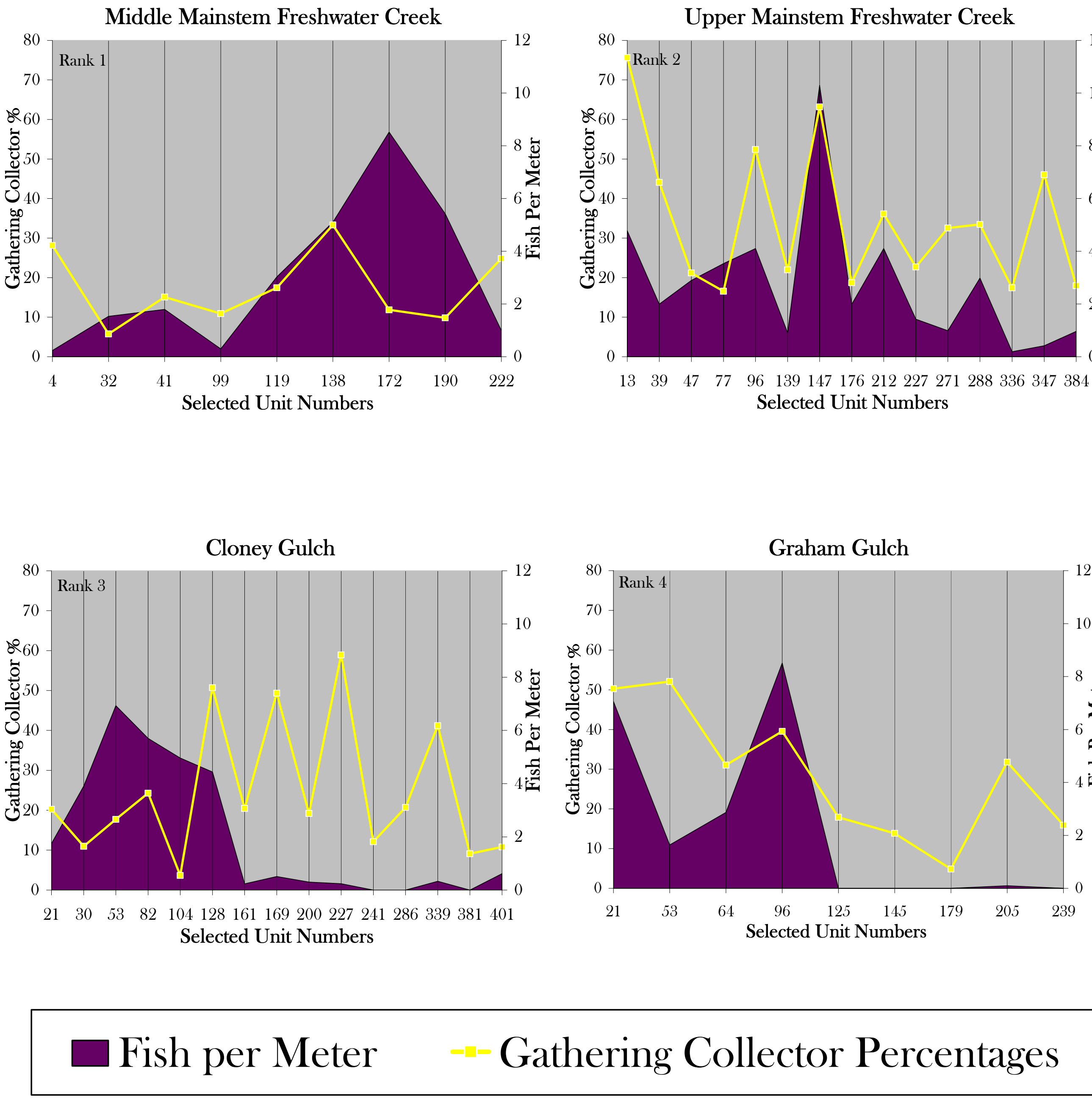


Figure 8
Freshwater Creek Basin
Gathering Collector Percentages
and Juvenile Salmonids per Meter

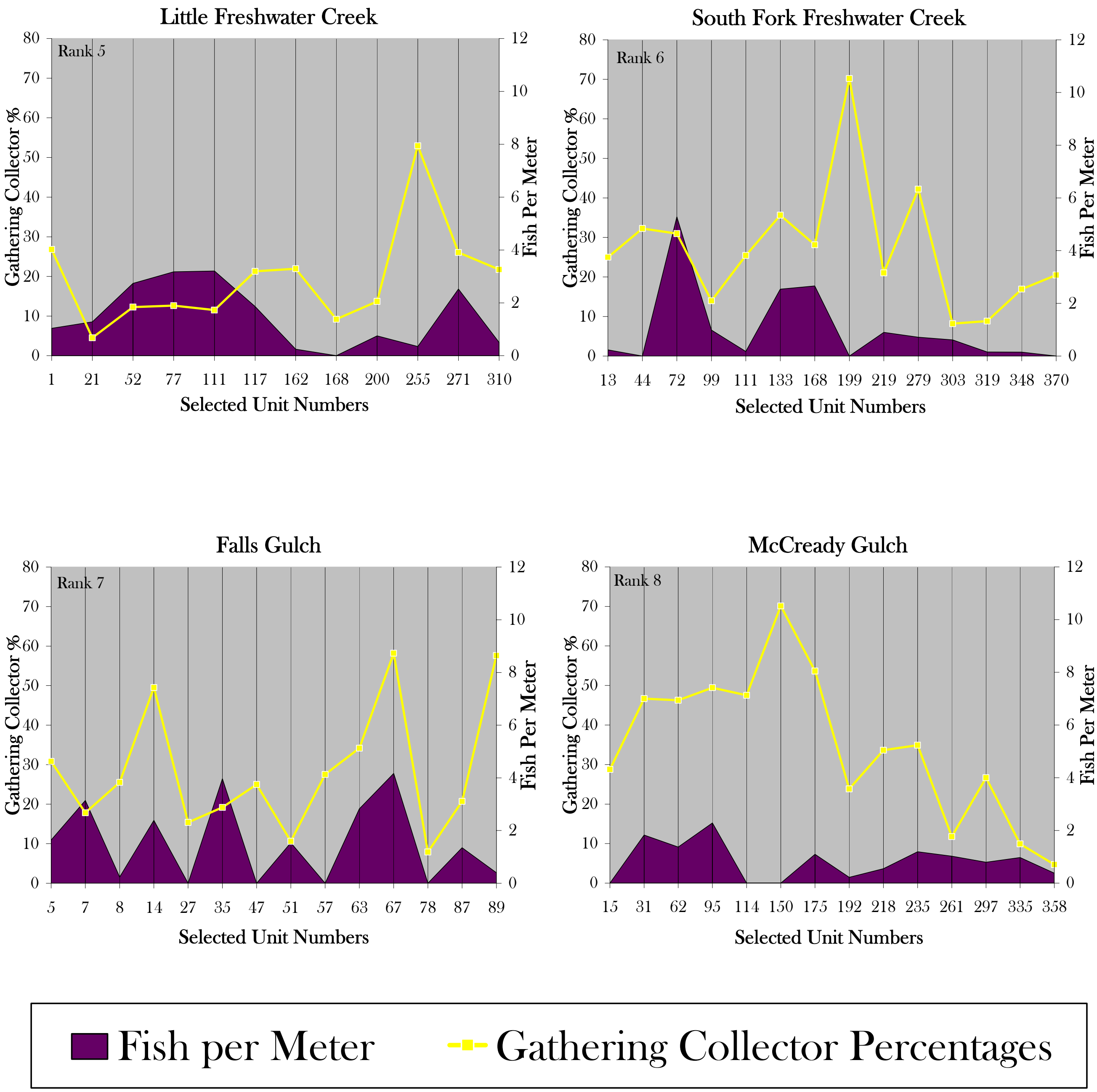


Figure 9

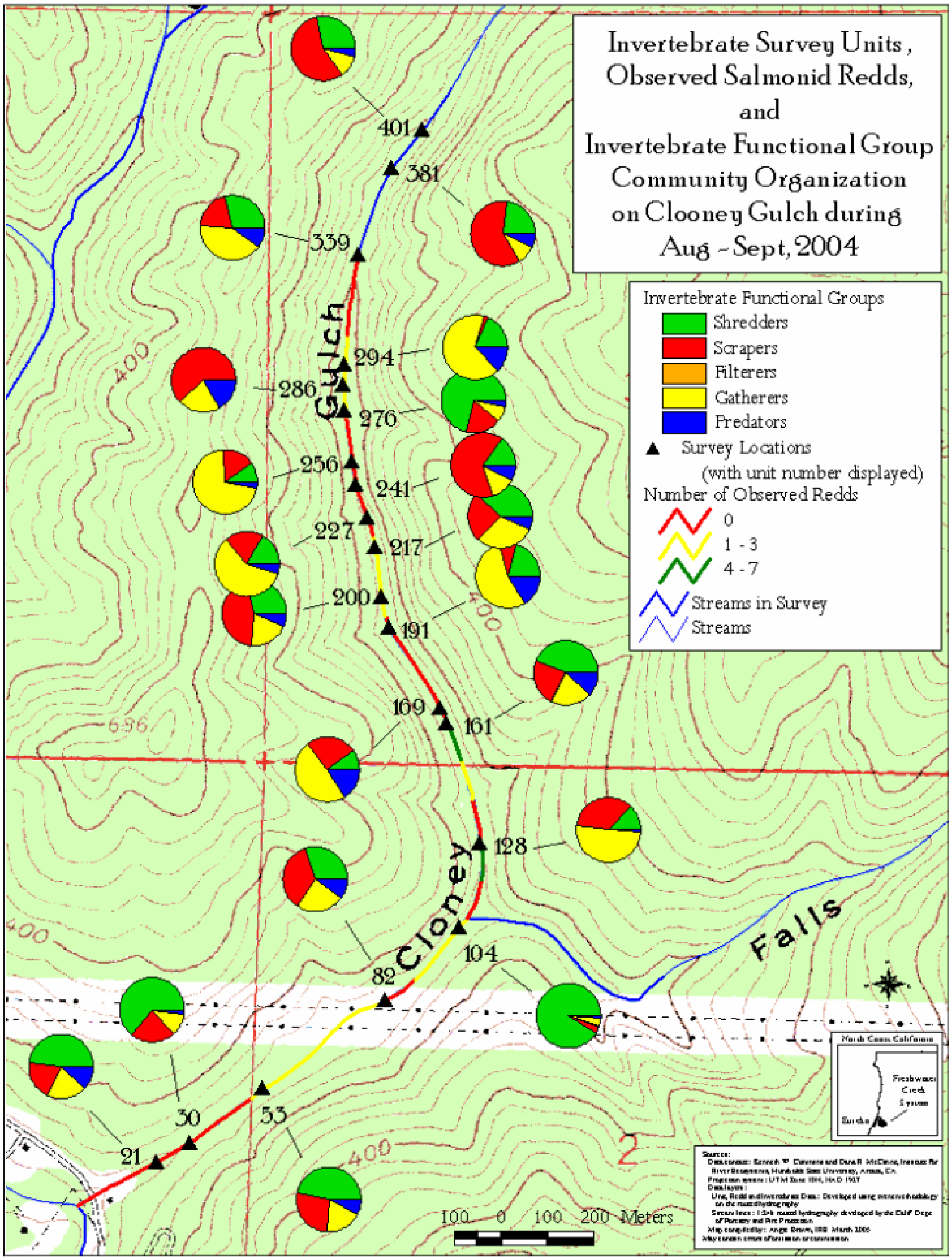

Invertebrate Survey Units, Observed Salmonid Redds, and Invertebrate Functional Group Community Organization on Clooney Gulch during Aug - Sept, 2004
Invertebrate Functional Groups
Shredders
Scrapers
Filterers
Gatherers
Predators
Survey Locations
(with unit number displayed)
Number of Observed Redds
0
1 - 3
4 - 7
Streams in Survey
Streams
Clooney
Gulch
Falls
401
381
339
294
286
276
256
241
227
217
200
191
169
161
128
104
82
53
30
21
400
100 0 100 200 Meters

Table 1

Functional group categorization and food resources
(from Merrit and Cummins 1996).
CPOM= Coarse Particulate Organic Matter;
FPOM= Fine Particulate Organic Matter

Functional Groups	Particle Size Feeding Mechanisms	Dominant Food Resources	Particle Size Range of Food (mm)
Shredders	Chew conditioned litter or live vascular plant tissue, or gouge wood	CPOM-decomposing (or living hydrophyte) vascular plants	> 1.0
Filtering Collectors	Suspension feeders- filter particles from the water column	FPOM-decomposing detrital particles; algae, bacteria, and feces	0.01-1.0
Gathering Collectors	Deposit feeders- ingest sediment or gather loose particles in depositional areas	FPOM-decomposing detrital particles; algae, bacteria, and feces	0.05-1.0
Scrapers	Graze rock and wood surfaces or stems of rooted aquatic plants	Periphyton-attached non-filamentous algae and associated detritus, microflora and fauna, and feces	0.01-1.0
Predators	Capture and engulf prey or tissue ingest body fluids	Prey-living animal	>0.5

Table2

Summary of the number of locations and invertebrate samples taken from the six tributaries and two Main-stem stream sections in the Freshwater Creek Basin.

Stream ID Number	Steam Name	Sample Locations	Samples taken	Number of Samples Taken per Sample Type			
				Leaf Litter	Cobble	Fine Sediment	Wood
198	Middle Main	9	27	9	17	0	1
199	Upper Main	14	45	13	25	3	4
201	McCready Gulch	14	42	13	18	7	4
203	Little Freshwater	12	36	10	18	3	5
204	Cloney Gulch	20	58	9	30	10	9
205	Falls Gulch	14	41	10	23	5	3
206	Graham Gulch	9	26	7	12	5	2
207	South Fork	14	42	11	24	3	4
	Totals	106	317	82	167	36	32

Table 3

Taxa encountered in the FFG invertebrate survey in the Freshwater Creek Basin and the FFG assignments used for each.

Mollusca	
Gastropoda (Snails)	SCRAPERS
Crustacea	
Isopoda (Aquatic Pill Bugs)	SHREDDERS
Amphipoda (Side Swimmers)	SHREDDERS
Ostracoda (Seed Shrimp)	GATHERING COLLECTORS
Arachnoidea	
Hydracarina (Aquatic Mites)	PREDATORS
Oligochaeta	GATHERING COLLECTORS
Insecta	
Odonata	
Anisoptera (Dragonflies)	PREDATORS
Plecoptera (Stoneflies)	
Setipalpians	
Perlidae	PREDATORS
Chloroperlidae	PREDATORS
Perlodidae	PREDATORS
Filipalpians	
Nemouridae	SHREDDERS
Peltoperlidae	SHREDDERS
Leuctridae	SHREDDERS
Ephemeroptera (Mayflies)	
Baetidae	GATHERING COLLECTORS
Ameletiidae	GATHERING COLLECTORS
Ephemerellidae	
Serratella	GATHERING COLLECTORS
Timpanoga	GATHERING COLLECTORS
Leptophlebiidae	GATHERING COLLECTORS
Heptageniidae	SCRAPERS
Trichoptera (Caddisflies)	
Glossosomatidae	SCRAPERS
Rhyacophilidae	PREDATORS
Hydropsychidae	FILTERING COLLECTORS
Philopotamidae	FILTERING COLLECTORS
Polycentropidae	FILTERING COLLECTORS
Calamoceratidae	
Heteroplectron	SHREDDERS
Limnephilidae	default [SHREDDERS]
Hydatophylax	SHREDDERS
Ecclisomyia	SHREDDERS – early instars SCRAPERS – late instrs
Apataniidae	
Apatania	SCRAPERS
Sericostomatidae	

Gumaga	SCRAPERS
Uenoidae	
Neophylax	SCRAPERS
Neothremma	SCRAPERS
Lepidostomatidae	SHREDDERS
Brachycentridae	
Micrasema	SHREDDERS
Trichoptera – undetermined	default [SHREDDERS]
Megaloptera (Helgrammites)	
Sialidae (Alderflies)	PREDATORS
Coleoptera (Beetles)	
Psephenidae	SCRAPERS
Elmidae (Larvae)	
Optioservus	SCRAPRERS
Lara	SHREDDERS
Dytiscidae (Adults)	PREDATORS
Haliplidae (Adults)	SHREDDERS
Diptera (True Flies)	
Tipulidae	PREDATORS
Simuliidae (Black Flies)	FILTERING COLLECTORS
Dixidae (Dixid Midges)	GATHERING COLLECTORS
Psychodidae (Moth flies)	GATHERING COLLECTORS
Chironomidae (Midges)	default [GATHERING COLL]
Orthocaldiinae	GATHERING COLLECTORS
Chironominae	default [GATHERING COLL]
Tanytarsini	GATHERING COLLECTORS
Tanypodinae	PREDATORS
Ceratopogonidae (Biting Midges)	PREDATORS
Athericidae (Snipe Flies)	PREDATORS

Table 4

Comparison of fish abundance ranking and FFG characteristics in six tributaries and two sections of the Mainstem of the Freshwater Creek basin*.

Stream	Fish per meter	Fish Rank	Dominant FFG (%)	P/R	Heterotrophy Vs Autotrophy
Middle Main Stem	73.4	1	Shredders (46)	0.39	Heterotrophic
Upper Main Stem	42.7	2	Total Collectors (48)	0.54	Heterotrophic
Cloney Gulch	32.0	3	Shredders (47)	0.31	Heterotrophic
Graham Gulch	28.8	4	Scrapers (53)	1.40	Autotrophic
Little Freshwater	16.3	5	Scrapers (71)	2.70	Autotrophic
South Fork	12.9	6	Scrapers (46)	0.93	Autotrophic
Falls Gulch	12.1	7	Scrapers (41)	0.74	[Autotrophic]
McCready Gulch	5.4	8	Total Collectors (52)	0.32	Heterotrophic

*Fish per m (mean fish per linear meter of stream); Fish rank (ranking of fish per m); Dominant FFG (%) (dominant group and its mean relative %); P/R (ratio of Scrapers to total collectors + shredders, a surrogate for ratio of gross primary production to community respiration); Heterotrophy vs Autotrophy based on a P/R threshold of > 0.75 = autotrophic).

Table 5

Invertebrate functional feeding group (FFG) and behavioral drift ratios as surrogates for stream ecosystem attributes

ECOSYSTEM ATTRIBUTE	DESCRIPTION	FFG RATIO
P/R	*Autotrophy/Heterotrophy Index* Gross Primary Production Total Community Respiration	Scrapers Shredders + Total Collectors (Threshold: 0.75)
CPOM/FPOM	*Shredder-Riparian Index* Benthic CPOM Benthic FPOM	Shredders Total Collectors (Threshold: Fall-Winter 0.50; Spring-Summer
TFPOM/BFPOM	*Suspended Load Index* FPOM in Transport Benthic FPOM	Filtering Collectors Gathering Collectors (Threshold: 1.00)
STABILITY	*Substrate Stability Index* (Cobbles + Wood)	Scrapers + Filtering Collectors Shredders + Gathering Collectors (Threshold: 0.60)
SALMONID FOOD	*Juvenile Salmonid Food Index* Predictable Invertebrate Supply Unpredictable Invertebrate Supply *Approximation of Index:	Behavioral Drifters* Accidental Drifters (Threshold: 0.50) Filtering + Gathering Collectors Scrapers+Shredders+Predators (Threshold: 0.50)

Table 6

Juvenile salmonid gut analyses from Cloney Gulch.
SH = steelhead trout, n = 10;
CT = cutthroat trout, n = 12;
CO = coho salmon, n = 11

Fish	Mean Fish wt (gm)	Mean No. Inverts per Stomach	Mean total wt Inverts per Stomach (mg)	Mean wt per individual Invert (mg)	mg Inverts per gm Fish	Mean total wt (mg) Aquatic Inverts per Stomach	Mean total wt (mg) Terrestrial Inverts per Stomach	% Fish without Terrestrial Inverts
SH	15.7	18.7	7.7	0.4	0.49	5.1	5.3	50
CT	24.7	8.3	55.3	6.7	2.24	25.8	44.3	33
CO	6.0	20.6	14.1	0.7	2.35	10.1	5.5	36
Total	15.5	15.4	27.1	1.8	1.75	14.2	17.0	39

Table 7

Ratio of behavioral drifter to accidental drifter invertebrates in juvenile salmonid stomach samples collected in Cloney Gulch.
(Threshold for adequate food supply of behavioral drifters for drift-feeding fish taken as $\geq$ 0.50.)

Number of Fish Stomachs	Number Ratio	Weight Ratio	With Caddis* Number Ratio	With Caddis* Weight Ratio
17	0.73	0.52		
31			2.23	3.00
% Fish Above Threshold	29	23	26	32

* *Lepidostoma* with organic case and < 4 mm length included as behavioral drifters

<u>Appendix I</u>

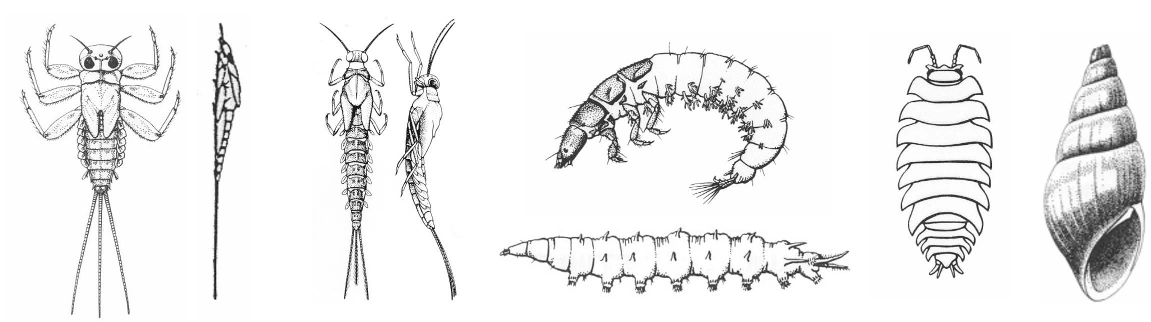
Field Key used in the study of the Freshwater Creek Basin

KEY TO INVERTEBRATE FUNCTIONAL FEEDING GROUPS

Ken Cummins, Interim Director
Institute for Forest and Watershed Management

Peggy Wilzbach, Assistant Leader
California Cooperative Fishery Research Unit

Rich Merritt, Chair
Department of Entomology, Michigan State University



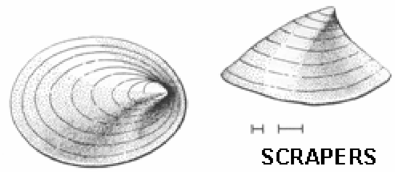
Ken Cummins
kwc7002@humboldt.edu
June 2003

IRE
592 14th Street
Arcata, CA 95521

KEY TO FUNCTIONAL FEEDING GROUPS

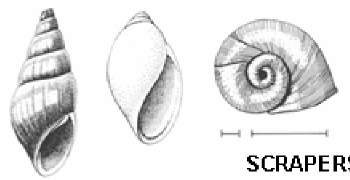
⊢ ⊢——⊣ Indicates size or range of sizes

1. ANIMALS IN HARD SHELL (Phylum Mollusca)
   a. LIMPETS (Class Gastropoda)



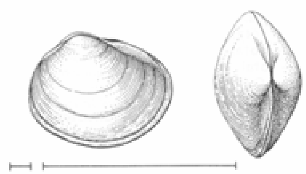
SCRAPERS

   b. SNAILS (Class Gastropoda)



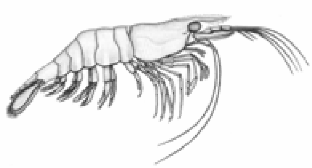
SCRAPERS
Snails are generalized (facultative) feeders and can also function as Shredders.

   c. CLAMS OR MUSSELS (Class Pelecypoda)

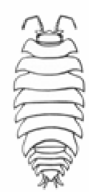


FILTERING COLLECTORS

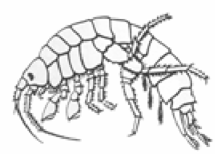
2. SHRIMP-LIKE ANIMALS (Class Crustacea)



Decapoda



Isopoda



Amphipoda

SHREDDERS
Can also function as facultative Gathering Collectors

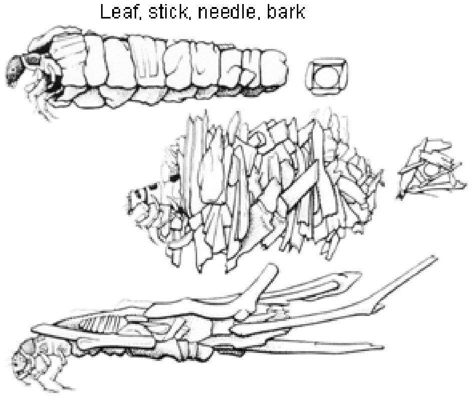
3. LARVAE IN PORTABLE CASE OR "HOUSE".	Go to KEY 2
4. LARVAE IN FIXED RETREAT WITH CAPTURE NET. *Note:* Care must be taken when collecting to observe nets	Go to KEY 3
5. WITHOUT CASE OR FIXED RETREAT.	
a. WORM-LIKE LARVAE, WITHOUT JOINTED LEGS.	Go to KEY 4
b. NYMPHS OR ADULTS WITH JOINTED LEGS.	Go to KEY 5
6. DOES NOT FIT KEY 5 EXACTLY.	Go to KEY 6 or KEY 7

KEY 2

FIRST LEVEL OF RESOLUTION

LARVAE IN PORTABLE CASE
Caddisflies (Order Trichoptera)

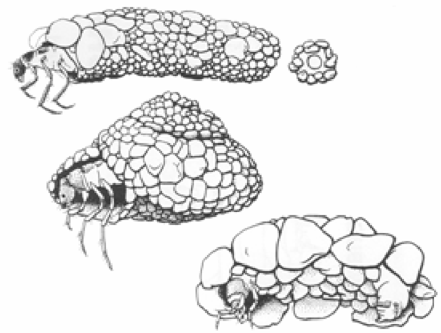
CASES, ORGANIC
Leaf, stick, needle, bark



Families Limnephilidae (in part)
Lepidostomatideae (in part) Phyrganeidae,
Leptoceridae (in part)

SHREDDERS

CASES MINERAL
Sand, fine gravel



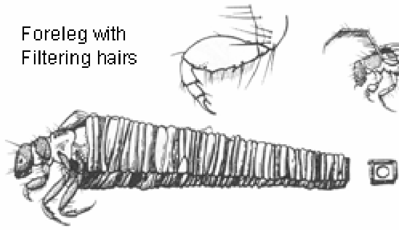
Families Glossosomatidae,
Limnephilidae (in part), Helicopsychidae

SCRAPERS

SECOND LEVEL OF RESOLUTION considers a few fairly common caddisflies that would be misclassified above on the basis of case composition alone.

CASES ORGANIC

Cases square in cross section and tapered, with no bark or flat leaf pieces included. Front attached to substrate. Larvae extend legs and filter the current



Family Brachycentridae(in part)

FILTERING COLLECTORS

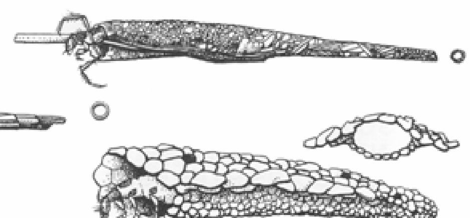
Cases long, slender and tapered, made of plant material

Family Leptoceridae (in part)

GATHERING COLLECTORS

CASES MINERAL

Cases long, slender and tapered (mostly fine sand) or cases ovoid and very flat in cross section



Family Leptoceridae (in part)

GATHERING COLLECTORS

KEY 3

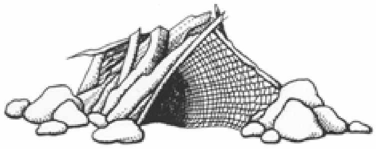
FIRST LEVEL OF RESOLUTION

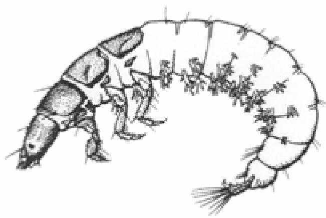
LARVAE WITH FIXED RETREAT AND CAPTURE NET
Note: Care must be taken when collecting to observe nets.

Caddisflies (Order Trichoptera)

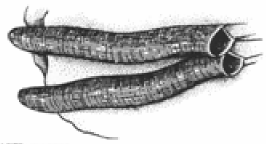
True Flies (Order Diptera)

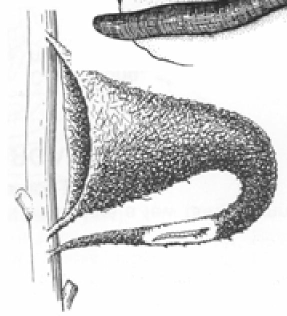
COURSE NET IN "SCAFFOLDING"



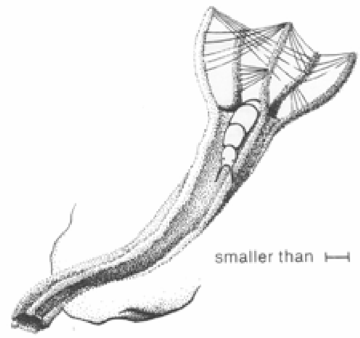


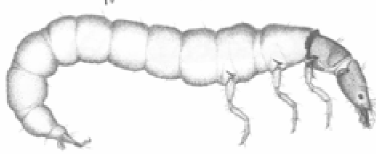
FLATTENED SOCK-LIKE OR TRUMPET-SHAPED NET OF FINE MESH





TUBE WITH SILK STRANDS STRUNG BETWEEN TERMINAL PRONGS





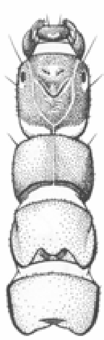
True Midges (Family Chironomidae)

Families Hydropsychidae, Philopotamidae, Polycentropodidae

FILTERING COLLECTORS

SECOND LEVEL OF RESOLUTION separates from free living larvae those net spinning caddisflies that may have been inadvertently collected without being associated with their nets.

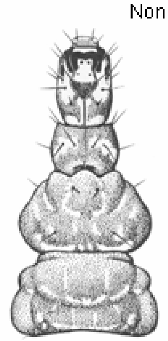
NET SPINNING CADDISFLIES
Frequently separated from their nets



HEAD AS WIDE AS THORAX
Especially Philopotamidae (bright yellow) and Hydropsychidae (bright green or brown)

FILTERING COLLECTORS

FREE LIVING CADDISFLIES
Non net spinning



HEAD LONG, SMALL, AND NARROWER THAN THORAX
Rhyacophilidae (often bright green)

PREDATORS

KEY 4

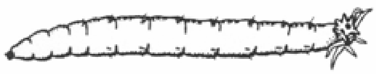
FIRST LEVEL OF RESOLUTION

WORM-LIKE LARVAE WITHOUT JOINTED LEGS

LARGE

Larger than

Head retractile and poorly developed
Caudal lobes with eye-like spiracles



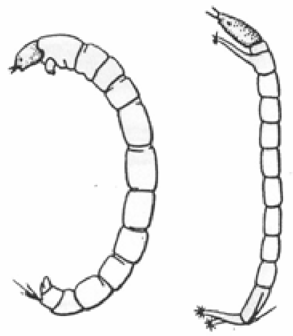
Craneflies (Family Tipulidae (in part)

SHREDDERS

SMALL

smaller than

LONG AND SLENDER



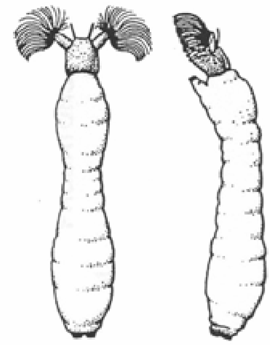
True Midges (Family Chironomidae)

Note: Subtract 10% of count for Predators

GATHERING COLLECTORS

BOWLING PIN SHAPE

Bulbous base usually fastened tightly to substrate



Blackflies (Family Simuliidae)

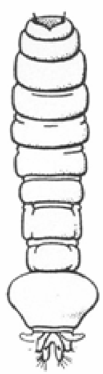
FILTERING COLLECTORS

SECOND LEVEL OF RESOLUTION considers some worm-like Predators that would be misclassified in the above key.

WORM-LIKE LARVAE WITHOUT JOINTED LEGS

LARGE

Posterior segment swollen
Head retractile



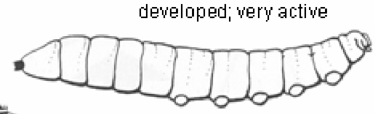
Family Tipulidae (*Eriocera* type)

SMALL

Prolegs along entire length
Head visible

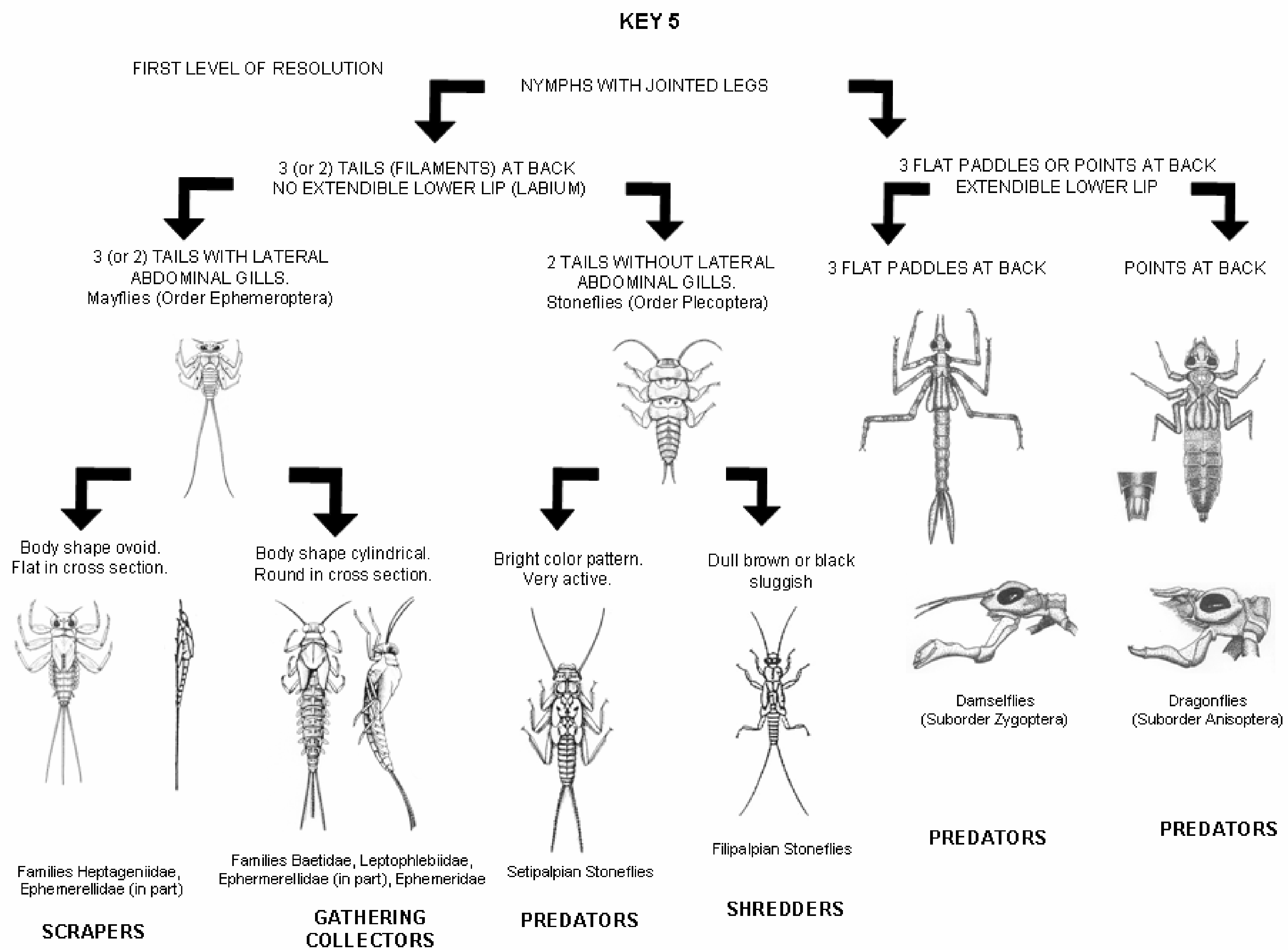
Family Athericidae

Prolegs poorly developed or absent; jaws well developed; very active



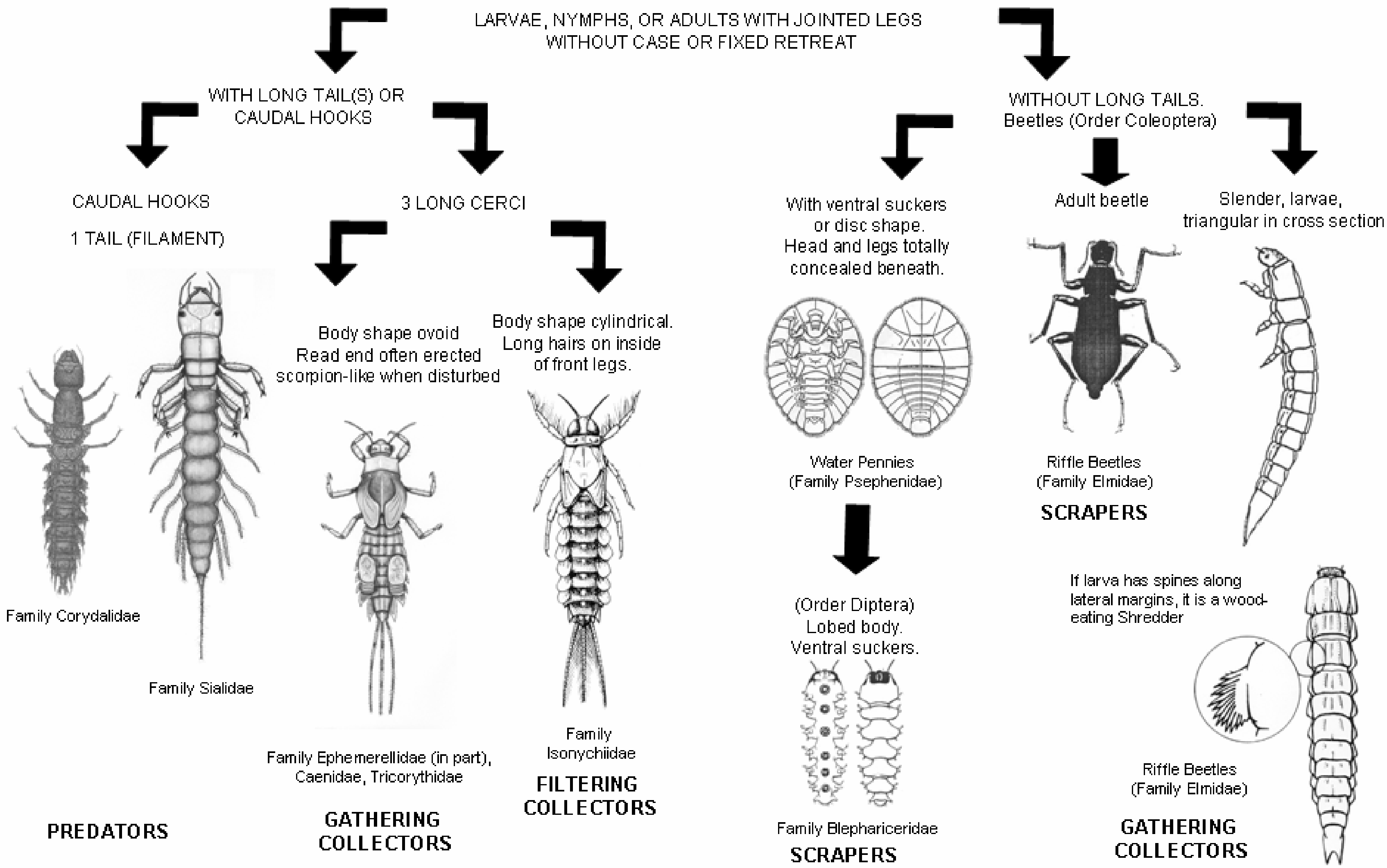
Family Tipulidae (*Dicranota* type)

PREDATORS


KEY 5
FIRST LEVEL OF RESOLUTION
NYMPHS WITH JOINTED LEGS
3 (or 2) TAILS (FILAMENTS) AT BACK
NO EXTENDIBLE LOWER LIP (LABIUM)
3 FLAT PADDLES OR POINTS AT BACK
EXTENDIBLE LOWER LIP
3 (or 2) TAILS WITH LATERAL
ABDOMINAL GILLS.
Mayflies (Order Ephemeroptera)
2 TAILS WITHOUT LATERAL
ABDOMINAL GILLS.
Stoneflies (Order Plecoptera)
3 FLAT PADDLES AT BACK
POINTS AT BACK
Body shape ovoid.
Flat in cross section.
Body shape cylindrical.
Round in cross section.
Bright color pattern.
Very active.
Dull brown or black
sluggish
Damselflies
(Suborder Zygoptera)
Dragonflies
(Suborder Anisoptera)
PREDATORS
PREDATORS
Families Heptageniidae,
Ephemerellidae (in part)
SCRAPERS
Families Baetidae, Leptophlebiidae,
Ephermerellidae (in part), Ephemeridae
GATHERING
COLLECTORS
Setipalpian Stoneflies
PREDATORS
Filipalpian Stoneflies
SHREDDERS

KEY 6

SECOND LEVEL OF RESOLUTION considers some fairly common insects that do not fit in the above key or would be misclassified on the basis of body shape alone.

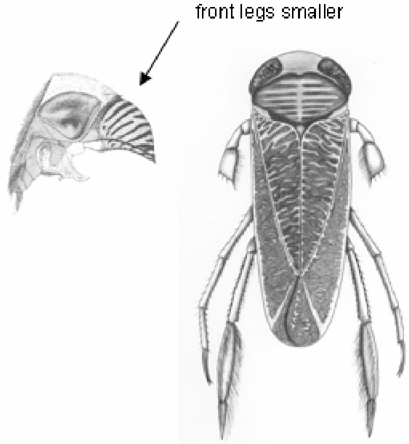


KEY 7

SECOND LEVEL OF RESOLUTION considers some fairly common insects that do not fit in the above key or would be misclassified on the basis of body shape alone.

NYMPHS AND ADULTS
WITH BEAK AND HEMELYTRA

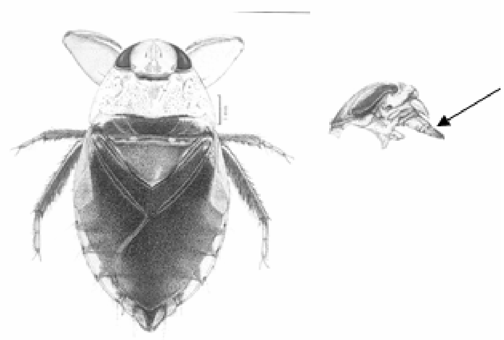
Beak triangular
front legs smaller



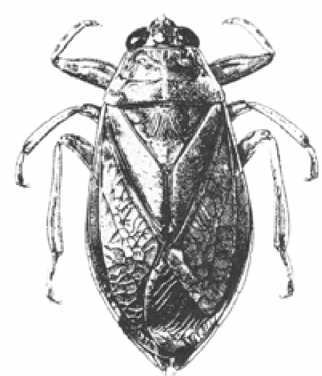
Family Corixidae

SCRAPERS

Sharp beak,
front legs large



Family Naucoridae



Family Belastomatidae

PREDATORS

Appendix II
Example Field Data Sheet

The Institute for River Ecosystems

Invertebrate Functional Group Assessment ~ Field Form

Stream: Cloney Gulch Reach: AFRAMP 2 IRE 204 Drainage: Freshwater Date: 8-2-04

Crew: John Matousek + April Shackelford H_2O Temp: 16°C @ Time: 2:42 PM

Habitat Unit No.: 021 Habitat Type: SP Flagged for stomach sampling? (Yes)/No

Sample Type (*circle one*): (Cobble) Wood Leaf Litter Fine Sediments Composite **SAMPLE #:** C1-___-___

Functional Group	Tally	Total	Identifiable Taxa
Shredders		0	
Scrapers	4,4,8,1,2,2,1	22	Glossosomatidae, Psephenidae, Heptageniidae Gastropoda, Elmidae (adult)
Filtering Collectors		0	
Gathering Collectors	2, 3	5	Tympanoga, Elmidae (larvae)
Predators	1	1	Hydracarina

Sample Type (*circle one*): Cobble Wood Leaf Litter (Fine Sediments) Composite **SAMPLE #:** FS1-___-___

Functional Group	Tally	Total	Identifiable Taxa
Shredders	1,1,3,1,2,3	11	Limnephilidae (organic case)
Scrapers	3,2,1,1	7	Limnephilidae (sand case)
Filtering Collectors		0	
Gathering Collectors	1,3,1,2,1,3,1,1 1,1,1,2,1,1,1	21	Leptophlebiidae, Ceratopogonidae Elmidae (larvae), Dixidae
Predators	1,1,4,1,1,1,2,1 1,1,1	15	Hydracarina, Haliplidae (adult)

Sample Type (*circle one*): Cobble Wood (Leaf Litter) Fine Sediments Composite **SAMPLE #:** LL1-___-___

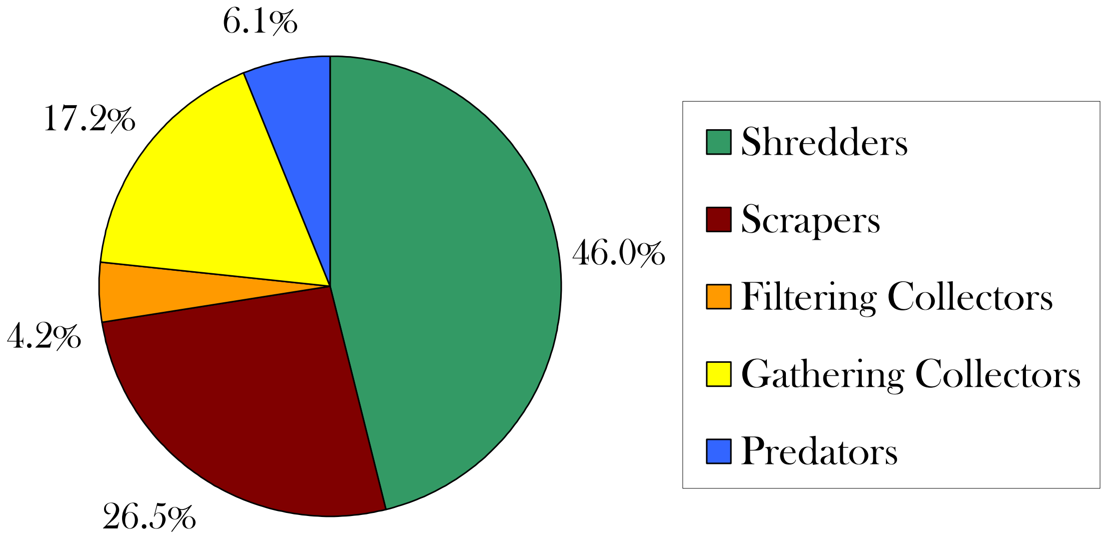
Functional Group	Tally	Total	Identifiable Taxa
Shredders	20,45,3,2, 1	71	Limnephilidae (organic case), Heteroplectron, Lepidostomatidae (≈68)
Scrapers	3,1,1	5	Elmidae (adult), Gastropoda
Filtering Collectors		0	
Gathering Collectors	1,2,1	4	Leptophlebiidae, Dixidae, Orthocladiinae
Predators	2, 1	3	Anisoptera, Hydracarina

Appendix III

FFG Percent Composition invertebrate functional feeding groups in Freshwater Creek Middle Mainstem and tributaries (Graham Gulch, Little Freshwater, South Fork, and Falls Gulch)

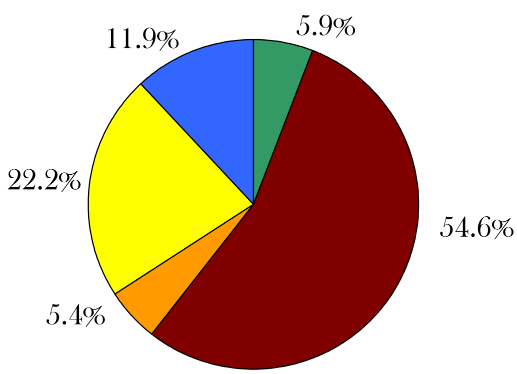
Invertebrate (FFG) Percent Composition,
Middle Freshwater Creek, Freshwater Basin (Summer 2004)

All Samples and Habitats



n=27

Cobble Samples

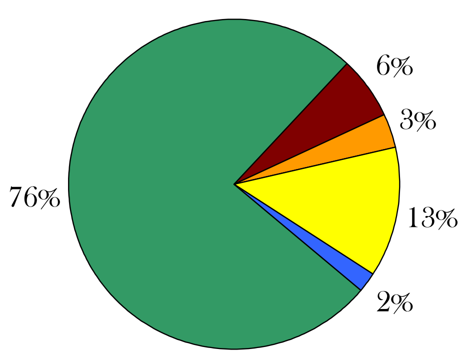


n=17

Fine Sediment Samples

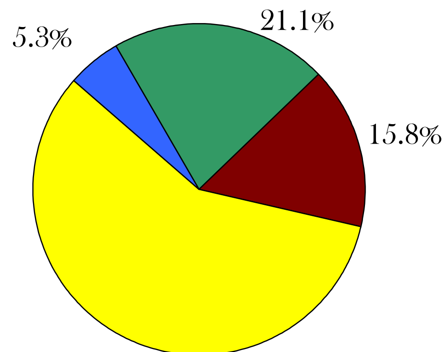
n=0

Leaf Litter Samples



n=9

Wood Samples

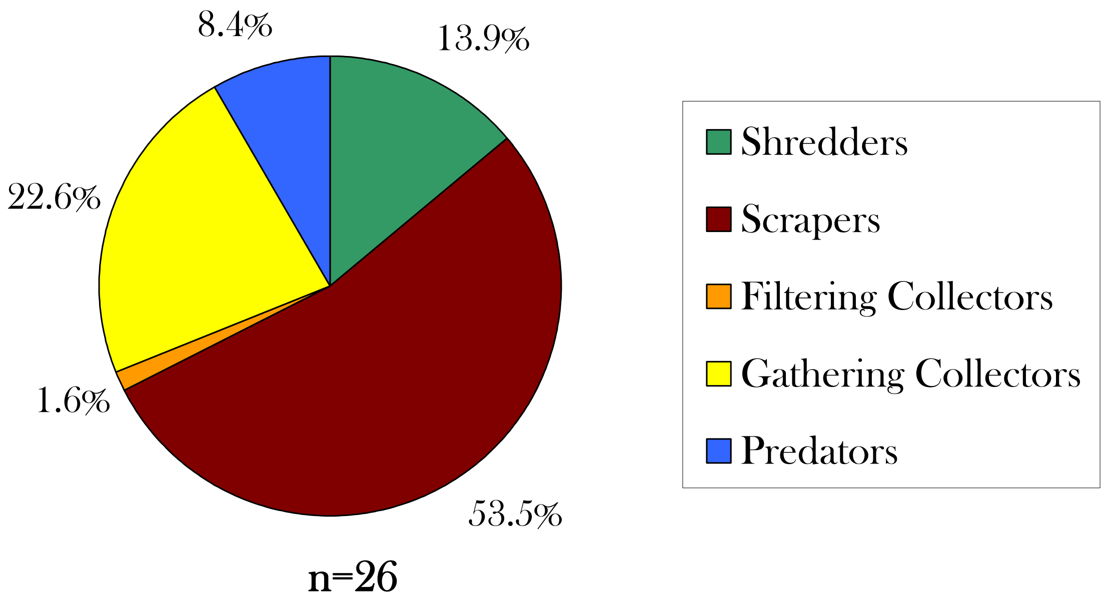


n=1

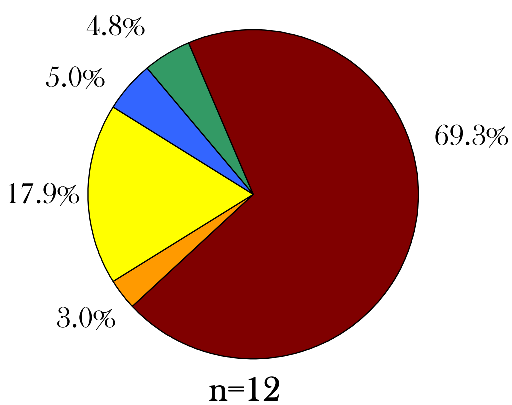
Juvenile Salmonids per Meter: 3.47 Length of Middle Freshwater: 3.91 km

Invertebrate (FFG) Percent Composition
Graham Gulch, Freshwater Basin (Summer 2004)

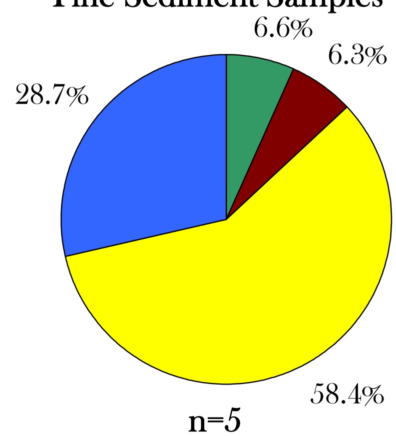
All Samples and Habitats



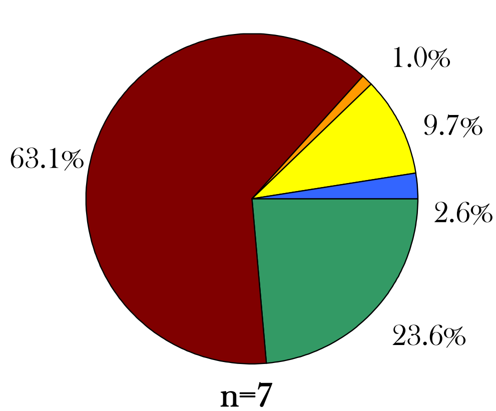
Cobble Samples



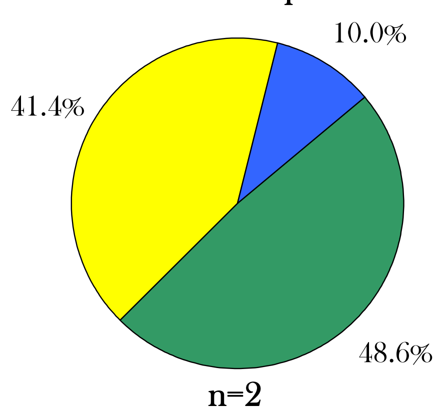
Fine Sediment Samples



Leaf Litter Samples



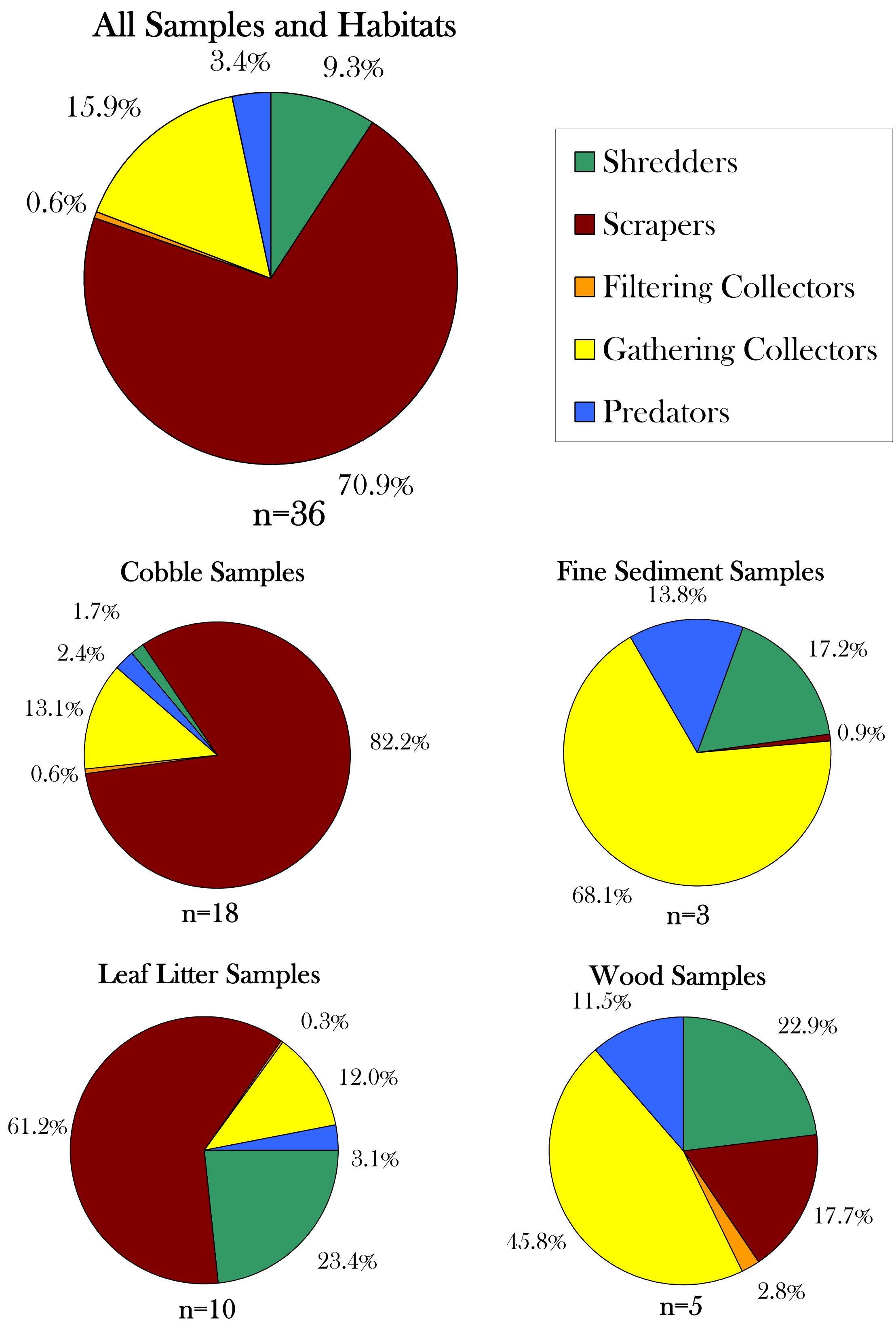
Wood Samples



Juvenile Salmonids per Meter: 2.61

Length of Graham Gulch: 2.04 km

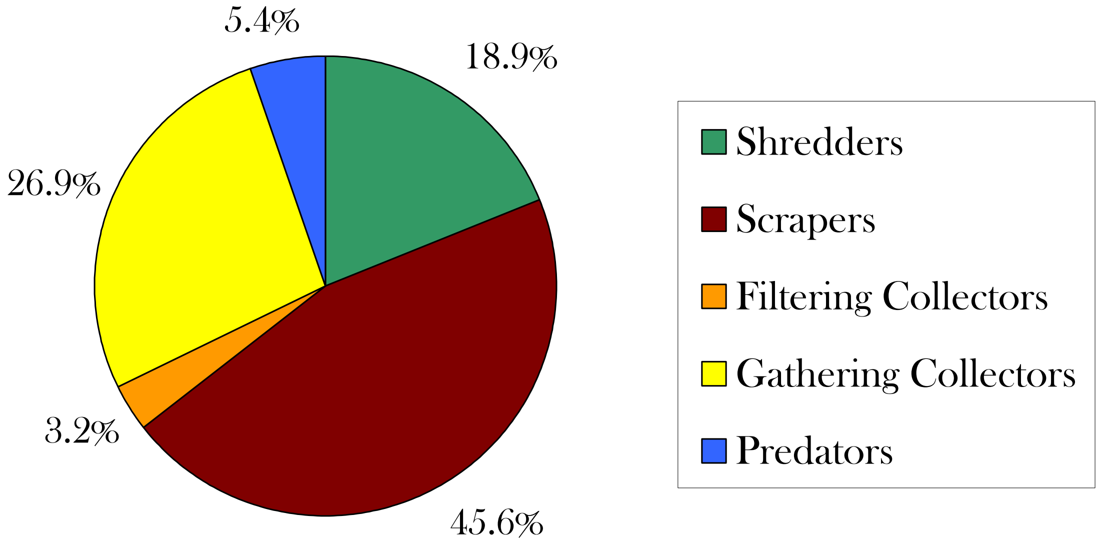
Invertebrate (FFG) Percent Composition
Little Freshwater Creek, Freshwater Basin (Summer 2004)



Juvenile Salmonids per Meter: 1.68   Length of Little Freshwater Creek: 3.31 km

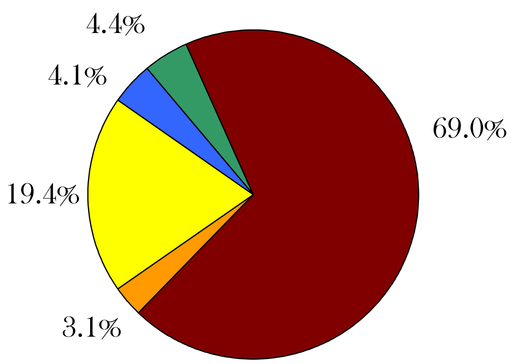
Invertebrate (FFG) Percent Composition
South Fork, Freshwater Basin (Summer 2004)

All Samples and Habitats



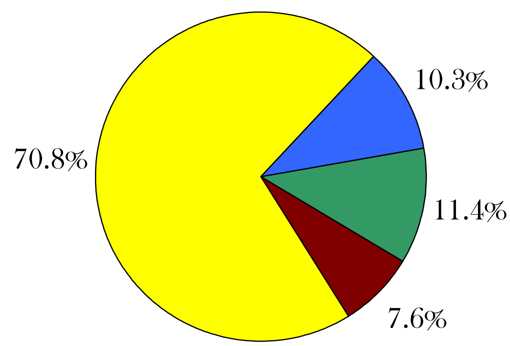
n=42

Cobble Samples



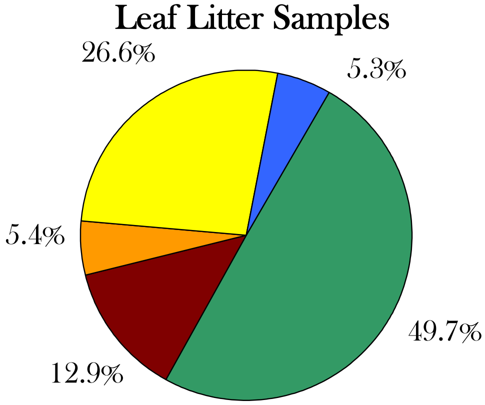
n=24

Fine Sediment Samples



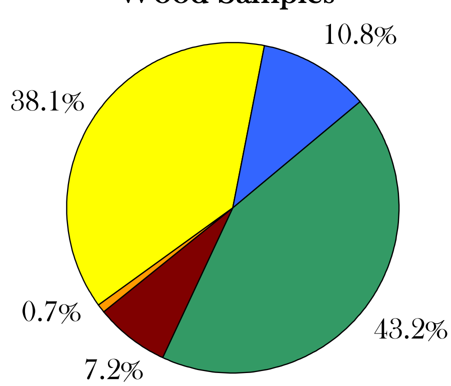
n=3

Leaf Litter Samples



n=11

Wood Samples

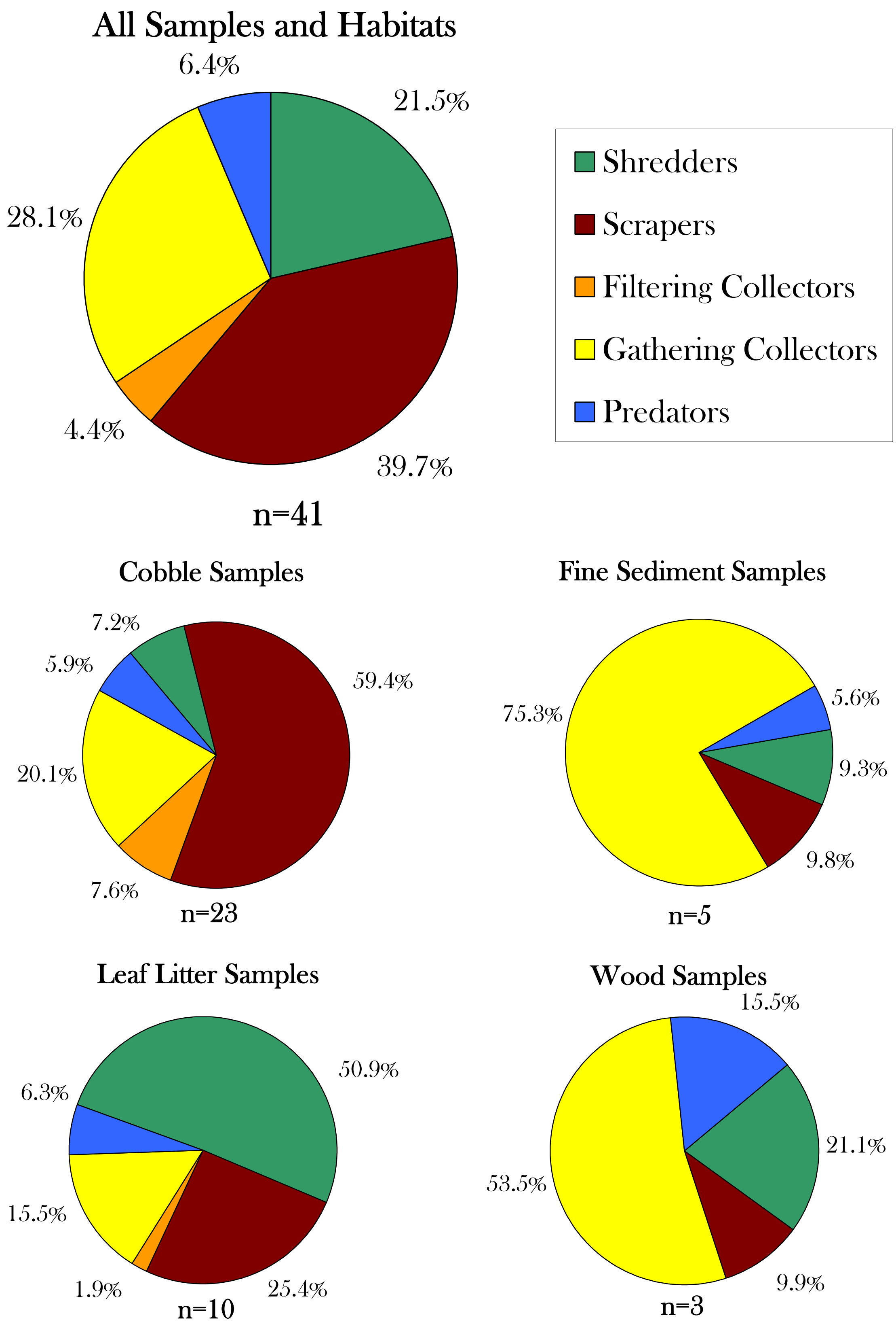


n=4

Juvenile Salmonids per Meter: 1.46

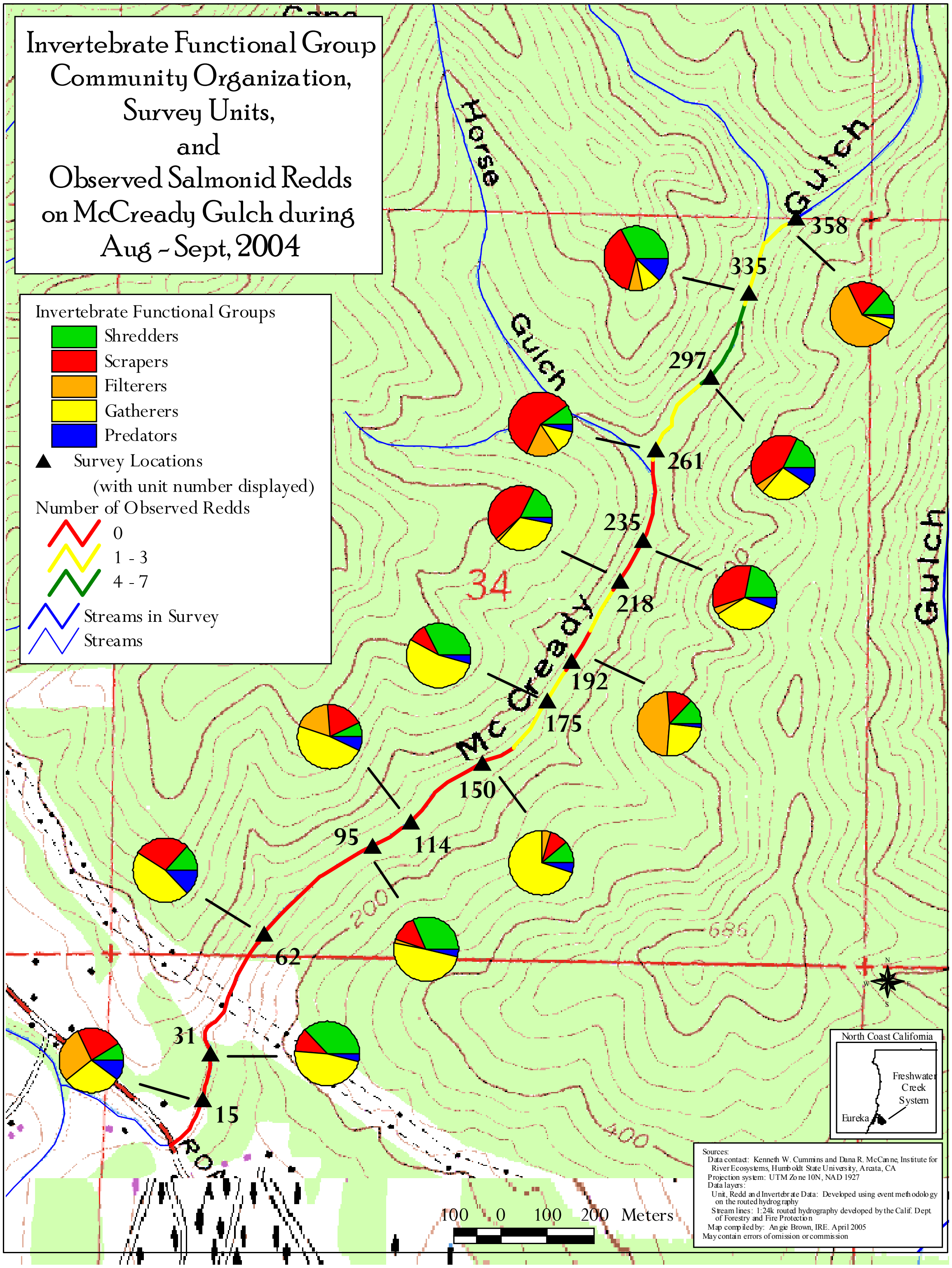
Length of South Fork Freshwater: 3.26 km

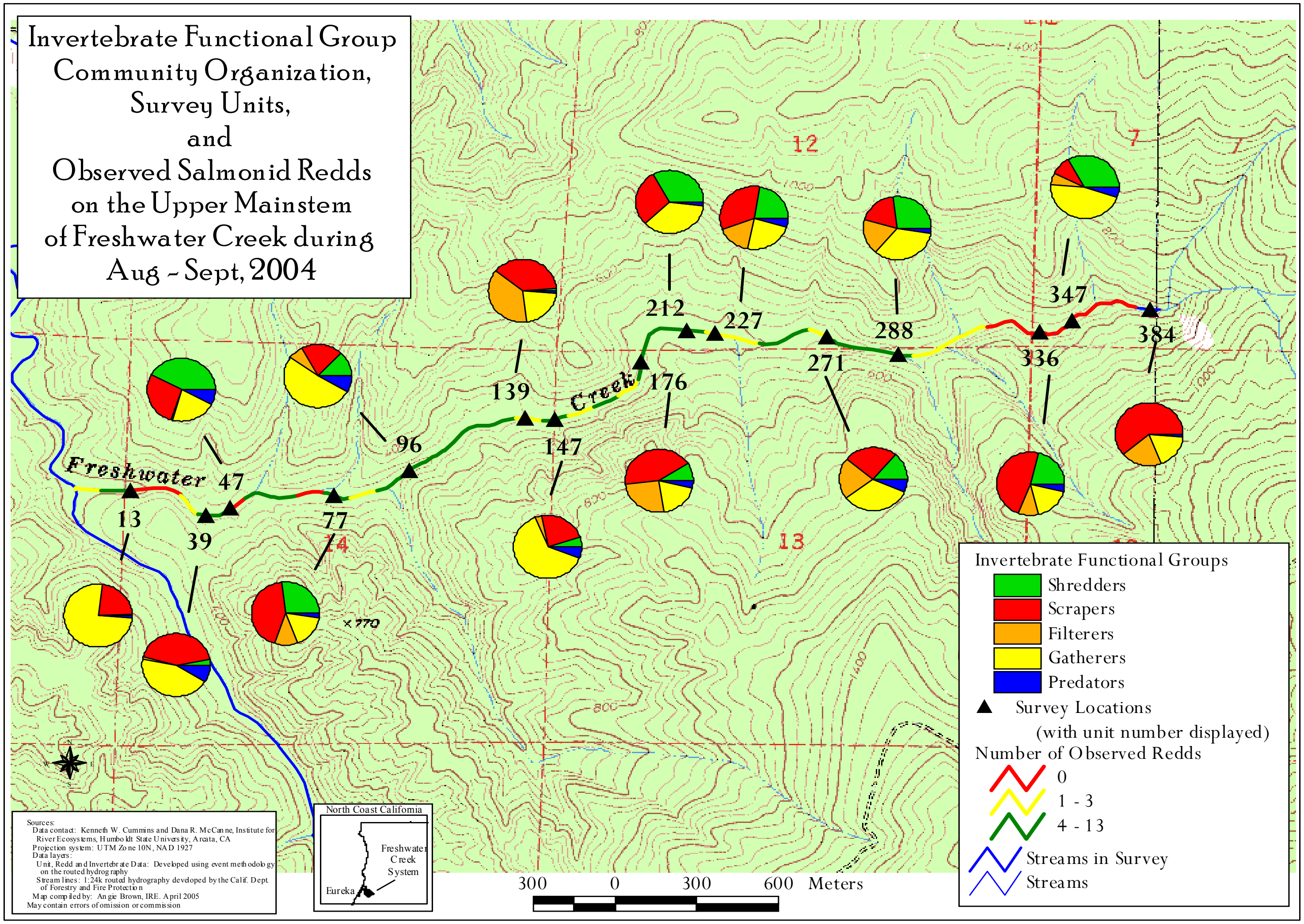
Invertebrate (FFG) Percent Composition
Falls Gulch, Freshwater Basin (Summer 2004)



Juvenile Salmonids per Meter: 1.99

Length of Falls Gulch: 0.50 km


Invertebrate Functional Group
Community Organization,
Survey Units,
and
Observed Salmonid Redds
on McCready Gulch during
Aug - Sept, 2004
Invertebrate Functional Groups
Shredders
Scrapers
Filterers
Gatherers
Predators
Survey Locations
(with unit number displayed)
Number of Observed Redds
0
1 - 3
4 - 7
Streams in Survey
Streams
Horse
Gulch
Gulch
Gulch
Mc Cready
34
358
335
297
261
235
218
192
175
150
114
95
62
31
15
200
686
400
100 0 100 200 Meters
North Coast California
Freshwater
Creek
System
Eureka
Sources:
Data contact: Kenneth W. Cummins and Dana R. McCanne, Institute for River Ecosystems, Humboldt State University, Arcata, CA
Projection system: UTM Zone 10N, NAD 1927
Data layers:
Unit, Redd and Invertebrate Data: Developed using event methodology on the routed hydrography
Stream lines: 1:24k routed hydrography developed by the Calif. Dept of Forestry and Fire Protection
Map compiled by: Angie Brown, IRE. April 2005
May contain errors of omission or commission



Invertebrate Functional Group Community Organization, Survey Units, and Observed Salmonid Redds on the Upper Mainstem of Freshwater Creek during Aug - Sept, 2004
Freshwater
Creek
13
39
47
77
96
139
147
176
212
227
271
288
336
347
384
Invertebrate Functional Groups
Shredders
Scrapers
Filterers
Gatherers
Predators
Survey Locations
(with unit number displayed)
Number of Observed Redds
0
1 - 3
4 - 13
Streams in Survey
Streams
300 0 300 600 Meters
N
S
E
W
North Coast California
Freshwater Creek System
Eureka
Sources:
Data contact: Kenneth W. Cummins and Dana R. McCanne, Institute for River Ecosystems, Humboldt State University, Arcata, CA
Projection system: UTM Zone 10N, NAD 1927
Data layers:
Unit, Redd and Invertebrate Data: Developed using event methodology on the routed hydrography
Stream lines: 1:24k routed hydrography developed by the Calif. Dept of Forestry and Fire Protection
Map compiled by: Angie Brown, IRE. April 2005
May contain errors of omission or commission