DISTRIBUTION AND BIOLOGY OF SUCKERS IN LOWER KLAMATH RESERVOIRS

1999
FINAL REPORT

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PacifiCorp
825 NE Multnomah Blvd., Ste. 1500
Portland, OR 97232

By
Marc Desjardins & Douglas F. Markle
104 Nash Hall
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon 97331-3803

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Abstract

The objectives of this two-year study (1998-1999) were to document distribution, abundance, age class structure, recruitment success, and habitat use by all life history stages of shortnose and Lost River suckers in three lower Klamath River hydroelectric reservoirs (J. C. Boyle, Copco, and Iron Gate). Lost River sucker catches were sporadic (only 3 adult individuals total) and the focus of our analyses, therefore, shifted to shortnose suckers.

Adult and larval suckers were found in all reservoirs both years. All life history stages (larvae, juveniles and adults) were found in J. C. Boyle during both years and in Copco in 1999. Juvenile suckers were not found in Copco in 1998. The number of adult shortnose suckers was highest in Copco reservoir (n=165), followed by J.C. Boyle (n=50) and Iron Gate (n=22). Larger and older individuals dominated Copco and Iron Gate reservoirs and little size structure was detected. J. C. Boyle tended to have smaller adult shortnose suckers and many size classes were present. Unidentifiable larval suckers were most abundant in Copco reservoir where historic spawning of shortnose suckers has been documented. Larval suckers in Copco and Iron Gate reservoirs were most abundant in mid to late June before quickly disappearing from catches. J. C. Boyle larval suckers peaked in mid July, attained larger sizes, and were caught later in the season. It appeared that recruitment of young-of-the-year suckers only occurred in J. C. Boyle with downstream reservoirs recruiting older individuals, perhaps those that had earlier recruited to J. C. Boyle. Tagging studies could clarify adult recruitment dynamics and an additional study of juvenile recruitment would be needed to confirm these patterns.

Predation pressure may be somewhat reduced in J. C. Boyle in comparison to the other reservoirs as its fish community was dominated by native fishes while communities in Copco and Iron Gate reservoirs were dominated by exotic predators. J. C. Boyle also possessed

proportionally more littoral habitat, which suggests it may provide a more stable environment for young fishes. However, our sampling was inadequate to demonstrate such relationships due to high variance in larval and juvenile catches and potentially confounding habitat variables. One such variable was water level fluctuations, which could interact with habitat and resource availability in complex ways. For example, water level fluctuations, presumed to have a negative impact, were greatest in J. C. Boyle. Extrapolation from the literature suggests it should have had the poorest habitat for larval and juvenile suckers, but our results indicated J. C. Boyle had the most young suckers. Additional study of the relationships between water level fluctuations, habitat availability, the exotic fish community, and juvenile sucker recruitment would be needed to better understand early life history ecology of endangered lake suckers in these systems.

Introduction

Among western North American Catostomids, the genera *Deltistes* and *Chasmistes* are obligate lake dwellers. Their maximum distribution and abundance came during pluvial periods between the Pliocene and Pleistocene epochs. Since then, their habitats have been greatly reduced by desiccation and populations have become fragmented and isolated. The Lost River sucker (*Deltistes luxatus* Cope, 1879) and the shortnose sucker (*Chasmistes brevirostris* Cope, 1879) currently occupy lakes in the Upper Klamath Basin, Oregon, and the Lost River system, Oregon and California (Scoppettone and Vinyard 1991).

Currently, all four species of both genera are federally listed endangered species (U.S. Department of the Interior 1973, U.S. Fish and Wildlife Service [USFWS] 1986, 1988). Research has recently been initiated to understand the basic ecology (habitat utilization, community level interactions, influence of water quality, quantity and timing of water fluctuations) of the lake suckers to help explain declining population abundances (U.S. Fish and Wildlife Service 1993, Simon et al 1997). The USFWS recovery plan attributes the decline of the Upper Klamath Lake suckers to several factors: damming of rivers, dredging and draining of marshes, water diversions, hybridization, competition and predation by exotic species, insularization of habitat, and water quality problems associated with timber harvest, removal of riparian vegetation, livestock grazing, and agricultural practices (U.S. Fish and Wildlife Service 1993, 1988). Other potential factors include over-harvest and chemical contamination (Martin and Saiki 1999). Furthermore, Upper Klamath Lake has shifted toward hypereutrophication (Miller and Tash 1967, Vincent 1968). In summer, massive blooms of cyanobacterium (*Aphanizomenon flos-aquae*) contribute to large fluctuations in pH, dissolved oxygen, and other water quality variables (Martin and Saiki 1999). Following blooms, decaying organic matter can increase concentration of unionized ammonia, which is acutely toxic to sucker larvae (Monda and Saiki 1993). The three Klamath River reservoirs in the Lower Klamath Basin also suffer from natural and cultural eutrophication with blooms of blue-green algae (*Aphanizomenon flos-aque*) each summer. Water quality of inflow tributaries is usually superior to the reservoirs.

It is generally believed that the range of the lake suckers has expanded due to the creation of reservoirs by the three lower Klamath River hydroelectric facilities, (J.C. Boyle, Copco No. 1, and Iron Gate), owned and operated by Pacificorp, a private utility (Moyle 1976, Buettner and Scoppettone 1991). Lake suckers are thought to have dispersed from the Upper Klamath Basin (Upper Klamath Lake and/or Lost River subbasins). In the past, these expatriated individuals might have been lost to the species, but the reservoirs create the potential for residual populations. Residual reservoir populations may or may not be self-sustaining.

Both species of lacustrine suckers were once common in Copco reservoir (Coots 1965). By the 1970's very few Lost River suckers were captured (California Department of Fish and Game 1980). In 1987 Beak Consultants, Inc. captured only one Lost River sucker on Copco reservoir and no Lost River suckers were captured from both Copco and Iron Gate reservoirs during a 1989-1990 survey (Buettner and Scoppettone 1991). During the same survey, shortnose suckers were only taken from Copco reservoir. No lake suckers were found in Iron Gate reservoir during the 1989-1990 survey. Older adults (16-33 years) dominated the shortnose sucker population in Copco and no recent recruitment was documented (Beak Consultants 1987, Buettner and Scoppettone 1991). It has been suggested that degraded water quality from upstream sources, scouring and dewatering of spawning sites resulting from highly variable flow rates following the construction of J.C. Boyle dam (peaking power generating facility), and the abundance of exotic predators may be impacting recruitment of lacustrine suckers in Copco reservoir (Buettner and Scoppettone 1991).

The assessment of the lower Klamath River reservoirs was included in a 1996 USFWS biological opinion. As per Term and Condition 4.1 of it's 1996 Incidental Take Statement (ITS), PacifiCorp was required to document distribution and abundance, age class structure, recruitment success and habitat use by different life stages of shortnose and Lost River suckers in J.C. Boyle (Topsy), Copco, and Iron Gate reservoirs. The results of a two-year study to address these questions are presented here.

Description of Sites

The mainstem Klamath River flows from Upper Klamath Lake through Lake Ewauna (Keno reservoir), J.C. Boyle, Copco No. 1, Copco No. 2 and Iron Gate reservoirs (Figure 1). Free flowing sections of the river are found upstream and downstream from J. C. Boyle reservoir. This study was conducted in three reservoirs downstream from Lake Ewauna (J.C. Boyle, Copco No. 1, and Iron Gate). Copco No. 2 was not studied due to its small size (40 surface acres) and limited fish habitat.

J.C. Boyle Reservoir

Located in south central Oregon at river mile (RM) 225, J.C. Boyle dam is located approximately 8 miles west of the town of Keno, Oregon. The dam, built in 1956, has a fish ladder and a juvenile bypass system. The reservoir created by the dam has a surface area of approximately 420 acres providing 7.5 miles of shoreline. Maximum depth is approximately 53 feet but much of the reservoir is 10-20 feet. Due to its shallowness, J.C. Boyle has proportionally more littoral habitat than the other two reservoirs. Dominant substrates are fines and small particle sizes (a mix of sand, gravel and fines). Spencer Creek, which flows into the upstream portion of the reservoir, is the only sizable tributary entering J.C. Boyle. Water quality in Spencer Creek is usually superior to that of the reservoir. Land use around the reservoir is dominated by timber harvest and to a smaller degree cattle grazing. Portions of the surrounding area are privately owned.

Power is generated at J.C. Boyle using daily peaking operations (A.K.A. load factoring). Load factoring is a technique used to conserve water for use during periods of maximum economic gain. Water is run through the turbines when the price of energy is high (i.e. during the day and during summer months). The resulting water level profile shows drafts during daylight hours and refilling during the night. Due to summer demand for power, fluctuations tend to increase during summer months. Peak operations are usually initiated in May or June. This type of operation causes the water fluctuations in J.C. Boyle to be greater than in other reservoirs. During the 1999 sampling period surface elevation fluctuated between 3788.7 - 3793.5 ft. mean sea level and daily fluctuations ranged from 0.04 – 3.53ft. The average daily water level fluctuation was 1.14ft.

Copco Reservoir

In northern California, twenty–two miles downstream from J.C. Boyle dam is the inflow to Copco reservoir (RM 203). The dam was constructed in 1918 and doesn't have a fish ladder or a juvenile bypass system. The reservoir is approximately 4 miles long, has a maximum depth of approximately 90ft, a surface area of roughly 1000 acres and a shoreline distance of 13.2 miles. When compared to J.C. Boyle (upstream) and Iron Gate (downstream), Copco is intermediate in depth, shoreline length, substrate size (small to intermediate mix / fines to cobble), and proportional littoral area. Three intermittent tributaries enter Copco reservoir. Shovel Creek, the only perennial tributary, flows into the river approximately 3 miles above the reservoir. Inflow to the reservoir is limited to the Klamath River and minor flow from the shoreline. Land use surrounding Copco reservoir consists mainly of residential property and rangeland. Copco is maintained near maximum pool elevation during the summer but is drawn down periodically for flood control and power generation. During the sampling period in 1999 surface elevations fluctuated between 2600.4 - 2607.3ft. mean sea level and daily fluctuations ranged from 0 – 1.9 ft. The average water level fluctuation in 1999 was 0.6 ft. per day.

Iron Gate Reservoir

Iron Gate is the most downstream reservoir extending from RM 199 to RM 190 approximately two miles downstream from Copco Dam. The dam constructed in 1962 does not have a fish ladder or a juvenile bypass system. The largest of the reservoirs, Iron Gate has a surface area of 944 acres with a shoreline distance of about 19 miles. Maximum depth is roughly 160 feet but much of the reservoir is more than 35 feet deep with steeply sloped banks. Proportionally, Iron Gate contains the least amount of littoral habitat and larger substrate types (boulders and rock fragments) characterize most of the shoreline. Tributaries entering Iron Gate include two perennial tributaries (Fall Creek and Jenny Creek) along with two intermittent streams (Dutch Creek and Camp Creek).   Most of the surrounding area is used for rangeland. During the 1999 sampling period, water elevation fluctuated from 2324.8 - 2329.7 ft. mean sea level and the daily fluctuations ranged from 0 – 1.7 ft. The average fluctuation was 0.3 ft. per day. Daily fluctuations tended to be less severe in the lower reservoirs (Copco and Iron Gate) because of their large size. In addition, Iron Gate is a re-regulating facility and flows from Iron Gate are maintained for the management of downstream anadromous fishes.

With the possible exception of J. C. Boyle, both Iron Gate and Copco dams effectively block upstream fish movement but do not prevent downstream movement of fish. Fish can be washed down over the spillway or passed through the turbines. The ability of suckers to make the journey between reservoirs is likely dependant on the life stage being transported and the distance to the next reservoir. Consequently, transport between Copco and Iron Gate reservoirs (2-mile distance) is more likely to be successful than the transport between J.C. Boyle and Copco reservoirs (22-mile distance).

Methods

PacifiCorp conducted a pilot trammel net survey in the reservoirs once a month from June through October, 1997. In 1998, we increased effort by trying to sample more available habitat and multiple life history stages. In 1999, knowledge gained from the previous two years was used to modify sampling strategies to better target larval, juvenile, and adult suckers. The targeting of multiple life history stages required many gear types used differently through the season to capture life stages, as they became vulnerable to the gears. Only the most successful techniques and gears were utilized in 1999. Sampling locations within the reservoirs were adjusted seasonally to target different life history stages. For example, adults would be sampled early in the year in deeper habitats with trammel nets while juveniles were sampled late in the year in shallow habitats with seine nets. During 1998, sampling trips were scheduled every three weeks and each reservoir was sampled during a given week (Table 1). In an effort to more efficiently sample larval sucker peaks in abundance, the schedule was altered in 1999 and reservoirs were intensively sampled weekly from mid May to mid June (Table 1). Locations of adult, juvenile and larval sampling sites for each reservoir are presented in the Appendix figures A1-A12.

Adult sampling

Adult sampling commenced the last week of March 1998 and the second week of April 1999 (Table 1). Three 300-ft trammel nets were set non-randomly to sample depths less than approximately 20 feet. Nets were deployed in an attempt to maximize sucker catches and sample a wide variety of habitats. Areas that held suckers on previous sampling trips were often sampled more than once. Trammel nets were deployed both during day and night in 1998. Nets were set only during the night in 1999 as they proved to be more successful. Fish species, size and condition were recorded for all individuals. In addition, spawning condition and weight data were collected for endangered suckers. Endangered suckers were also PIT-tagged to determine recapture rate. Adult suckers that were difficult to identify were recorded as sucker species and were not included in the analyses.

Juvenile sampling

Beach seines, cast nets, trap nets, backpack electrofishing, and otter trawls were used to sample the three reservoirs for juvenile suckers in 1998 (Table 1). Only beach seines and trap nets were used in 1999 because the other techniques were unsuccessful in 1998. Sampling sites were non-randomly chosen with an attempt to maximize sucker catches and sample all available accessible habitats.   Areas that held suckers on previous sampling trips were often sampled more than once. A 6.1 m beach seine (2x2x2m bag and a 4.8mm bar mesh) was used to sample all possible depths and substrates in vegetated and non-vegetated areas. Seine hauls averaged about 15 m in water up to 2 m deep. Fish species and lengths were recorded for all individuals captured.

Two trap nets (5x1.0m (4.8mm mesh) trap and a 25 m lead) were deployed at various depths (1-7m) during day and night in 1998. However, traps were only used late in the 1998 field season. In 1999, night trap nets were used extensively to target juvenile suckers and effort was continuous throughout the sample period (Table 1). Fish species, size and condition were recorded for all individuals. In addition, spawning condition (for adult suckers taken in trap nets) and weight data were collected for endangered suckers. Adult endangered suckers were PIT-tagged to determine recapture rate. An arbitrary length of 30mm was used to separate larval suckers from juvenile suckers. Due to taxonomic difficulties, juvenile suckers could not be identified to species.

Larval sampling

Drift nets, larval trawls, and dip nets were used to sample larval suckers. Drift nets were set for variable periods in 1998 and because night sets were more successful, only night sets were used in 1999. Half-meter diameter (1000-micron mesh) drift nets were set in areas of visible flow, usually at the inflow to the reservoirs. Due to high flow rates, the lack of a place to secure drift nets, and poor drift net accessibility at the inflow to J.C. Boyle, drift nets were deployed from the Highway 66 and Spencer Creek bridges.

The larval trawl consisted of a 2.5 m (1000 micron mesh) net with a 0.8x1.5m opening. It was mounted on an aluminum frame with runners, similar to that described by Labolle et al. (1985). Sites were selected based on accessibility, coverage with the gear type, depth, substrate, slope, and vegetation density. Both vegetated and non-vegetated sites were sampled. Larval trawls were set 3-15 m from shore in water 0.5 to 1.5 m deep. Trawls were allowed to sit for about twelve minutes to allow the site to recover from the disturbance of setting the trawl and then pulled to shore with ropes.

Dip net sites were selected based on suitable habitat (around macrophytes in shallow embayments) for larvae and were used to supplement trawl data and to sample areas not easily sampled with the larval trawl. For example, dip net sampling was very useful in Iron Gate reservoir where steep shorelines made trawl sampling difficult. Dip net sampling used a five-minute search-and-capture technique and was conducted only during daylight hours. All larval samples were preserved in formalin and ethanol and were identified to the lowest possible taxonomic level. Larval suckers could not be identified to species.

Habitat data

Habitat attributes of adult catches (trammel nets) were difficult to quantify due to depth and poor visibility. The following habitat data were collected at all larval and juvenile sampling locations: substrate type, vegetation cover, vegetation type, depth, and distance to shoreline. Substrates were qualitatively separated into fines, sand, gravel, small mix (a mix of the previous three categories), cobble, boulder, large mix (a mix of the previous two categories), and intermediate mix (a mix of both small and large substrates). Sites containing more than approximately 80% of any one substrate were scored as being dominated by that substrate (100%). For a description of the substrate classifications used see Appendix Table A.1. Vegetation was qualitatively categorized as present – absent, submerged or emergent, and vegetation cover or density categorized as low (1%-33.3%), medium (33.3%-66.6%), or high (66.6%-100%).

A Hydrolab ® was used to collect water quality data. In 1998 water quality data were collected during reservoir profiling and from surface waters at each sample site. Comparisons of the 1998 water quality data between variables taken at sampled sites and at fixed reservoir profiling showed no statistical difference. As a result, water quality data were only collected at fixed sites during reservoir profiling in 1999. Only the 1998 water quality data was used to compare sucker catch rates and water quality. Reservoir level fluctuation data were collected by Pacificorp for each reservoir.

Analyses

Catch per unit effort (CPUE) for each gear type was compared across reservoirs to quantify abundance and distribution of sucker life history stages and to examine reservoir community structure (1998 and 1999 only). To reduce the effect of large single catches, we used a ranking system weighted to more diverse catches. For example, the most abundant species in a sample with five species captured was ranked 5 whereas the most abundant species in a sample with three species captured was ranked 3. The least abundant species in a sample was ranked 1. Ranks were summed for each gear and the five most dominant species given grand ranks in the intuitively more obvious notation of 1 for most dominant. Species from larval drift were not ranked. Length frequency distributions were generated for each life history stage to examine recruitment potential for each reservoir. Differences in methods made interannual comparisons problematic and only trends could be described.

Habitat variables (substrate type, vegetation type, and vegetation presence / absence) were compared to catch data to examine larval habitat preferences. Larval trawl data was used for most comparisons because the effort was consistent and multiple habitats were efficiently sampled. Due to the non – normallity of the catch data, non parametric tests were ulilized to quantify variations in catches across habitat types. The Kruskal – Wallis test was used to compare multiple classifications (substrate comparisons) while the Mann – Whitney test was used for two sample comparisons (presence vs absence of vegetation). All tests used a 95% level of significance.

The highly variable larval catches, qualitatively defined habitats, and the presence of many confounding variables made statistical comparisons difficult. As a result, the timing of peaks and declines in larval sucker catches were compared to the timing of critical water quality events and water level fluctuations. Lake wide water quality averages for each reservoir were generated for each sampling date in 1998. Lake wide water quality averages were also obtained from fixed sites on Upper Klamath Lake for comparative purposes. In addition, all water quality variables were compared to 96 – hour LC_{50} values (lethal concentration required to kill half of an experimental population). The LC_{50} values, based on studies of juvenile Lost River suckers, are: 30.51º C , pH 9.55, and 1.41 – 1.86 mg/L dissolved oxygen (Martin and Saiki, 1999). Water level fluctuations were graphically compared to changes in larval sucker abundance to see if changes in water levels were corresponding to declines or peaks in larval sucker catches.

Results

Distribution and Abundance of Suckers

Adults

Total number and species of suckers caught differed between years (Table 2). In part this is due to differences in effort. The total trammel net effort (soak time) was 40.01 hr in 1997, 201.4 hr in 1998 and 120.31 hr in 1999. In 1997 most trammel net sampling in Copco and J.C. Boyle was during September and October, while most sampling in Iron Gate was during June. In 1998 and 1999 trammel net sampling was most intensive during spring and early summer and effort comparable between reservoirs (Table 1). In 1998 and 1999, Copco had the most lake suckers followed by J.C. Boyle and Iron Gate reservoirs (Table 2). CPUE for *C. brevirostris* tended to be 4- 5 times greater in Copco than the other reservoirs in 1998 and 1999 (Figure 2). No PIT tagged lake suckers were recaptured during this study. The highest catches of *Ca. rimiculus* were in J.C. Boyle reservoir in 1998 and 1999 (Table 2) and tended to be an order of magnitude greater in abundance than in Copco and Iron Gate reservoirs. Catches of *D. luxatus* and *C. snyderi* were sporadic during all sampling (Table 2). A total of 9 fish (6-J.C. Boyle and 3-Copco) with questionable identifications were collected. These fish were excluded from the analyses.

Juveniles

Juvenile suckers were captured from lake habitats in J.C. Boyle in 1998 and J.C. Boyle and Copco in 1999 (Table 2). The highest numbers were taken in J. C. Boyle both years (Table 2). Only 3 juveniles were found from lake habitats in Copco reservoir in 1999. An additional 9 were captured from the Klamath River above the inflow to Copco reservoir. These potentially represent riverine catostomids rather than the endangered lake suckers. To avoid misclassification, these fish were not included in the analysis. Juveniles were captured with a mixture of gears. In 1998 all juveniles in J. C. Boyle were captured with seine nets. In 1999, J. C. Boyle juveniles were taken with dip nets, larval trawls and seine nets. Larval trawls and mostly seine nets were successfully utilized to capture juvenile suckers in Copco reservoir in 1999.

Larvae

Most larval suckers were captured in 1999, possibly reflecting increased effort (Table 2) or a good year class since high larval abundance was also seen in Upper Klamath Lake in 1999 (D. Simon, O.S.U, personal communication, 2000). Catches were highest in Copco and lowest in J. C. Boyle (Table 2). Shortnose sucker staging, migration, and spawning behaviors have been documented in Copco (Beak Consultants, 1987, Buettner and Scoppettone 1991) and suggest that these larvae could be shortnose suckers. Evidence of adult lake sucker spawning behavior is lacking from the other two reservoirs.

Community Structure

Due to differences in sampling effort in 1997, only trammel net surveys from 1998 and 1999 were compared. Adult CPUE from trammel nets differed between reservoirs (Figure 3). Shortnose suckers made the largest percent contribution to the adult fish community in Copco during both years (Figure3). The percent of exotics increased downstream from 40 % in J.C. Boyle to 78% in Iron Gate in 1999. A similar trend was seen in 1998 (Figure 3). Native species were four of the five most dominant species in trammel nets in J. C. Boyle and were only two of the five most dominant species in Copco and Iron Gate reservoirs in 1999 (Table 3). A large percentage of exotic species were potential predators (*Perca flavescens*, *Ameirus sp*., *Pomoxis sp*., *Micropterus salmoides, Archoplites interruptus,* Table 3). In 1999, the percent of exotic predators increased from 37% in J. C. Boyle to 66% Copco and 77% in Iron Gate reservoir.

Trap net catches were more uniformly dominated by exotics with four exotics in the top five species in J. C. Boyle and Copco while all five of the top species in Iron Gate were exotics (Table 3). The *Gila* chubs were the only ranked native taxa contributing to trap net catches in the reservoirs.

Juvenile fish CPUE from beach seines also differed between reservoirs (Figure 4). Juvenile suckers were a numerically important part of the beach seine fish community in J.C. Boyle. Juvenile suckers were important in the dominant rankings in J. C. Boyle and the only native species in the beach seine dominance ranking in Copco in 1999 (Table 3). Again, the proportion of exotic species in the community increased downstream (Figure 4 and Table 3) and the proportion of predators among exotics increased from 14% in J. C. Boyle in 1999 to 99 % in Copco and 87 % in Iron Gate. Similar patterns were also seen in 1998.

Larval fish CPUE from larval trawls was highest in 1999. Larval suckers were the second most abundant category (e.g., exotics, suckers, other natives) in all reservoirs in 1999 (Figure 5) and first or second in the larval trawl catch dominance rankings for all reservoirs in 1999 (Table 3). In 1999, exotic species increased downstream from 15% in J.C. Boyle to 67% in Iron Gate (Figure 5). Native species were four of the five top ranked species in J. C. Boyle, two of the top five in Copco and one of the top five in Iron Gate in 1999 (Table 3). The downstream exotics pattern was not seen in 1998 because of large inter annual differences in relative abundances of larvae. For example, in 1998 large numbers of native *Gila sp*. were captured in Iron Gate and in 1999 large numbers of exotic *Notemigonus crysoleucas* were found throughout the reservoirs.

Size Structure and Recruitment

Adults

The smallest *C. brevirostris* were captured in J.C. Boyle reservoir and the largest in Copco. Within each reservoir, the mean length of adult *C. brevirostris* in trammel nets was similar between years. Mean lengths of J.C. Boyle *C. brevirostris* in trammel nets were 301 +/- 16 mm in 1998 and 327 +/- 27 mm in 1999 (Figure 6). When the 1999 trap net data is combined with the 1999 trammel net data the mean length of *C. brevirostris* drops to 262 +/- 16 mm. There appears to be several size classes of relatively young suckers in J.C. Boyle reservoir (Figure 6). In the 1997 survey only one *C. brevirostris* (405 mm) was captured.

Mean adult lengths were similar to one another in Copco and Iron Gate and about 100mm greater than those in J. C. Boyle. Mean lengths of *C. brevirostris* in Copco reservoir were 498 +/- 30mm in 1997, 456 +/- 10 mm in 1998 and 499 +/- 8 mm in 1999 (Figure 7). Mean lengths of *C. brevirostris* captured in Iron Gate reservoir were 453 +/- 37mm in 1997, 493 +/- 32 mm in 1998 and 481 +/- 24 mm in 1999 (Figure 8) but only two fish were collected in 1998.

Juveniles

J.C. Boyle and Copco were the only reservoirs in which juvenile suckers were collected. Juvenile suckers were occasionally captured with larval trawls and dip nets but the most effective gear was the beach seine. The average length of juveniles taken in J. C. Boyle was 33 mm in 1998 and 35 mm in 1999 (Figures 9 and 10). In Copco, the average size of juveniles taken in 1999 was 34mm (Figure 10). Juveniles were not taken from lake habitats in Copco reservoir during 1998.

Larvae

Larval suckers were captured with larval drift nets, dip nets, larval trawls, and beach seines. In 1998, the average length of sucker larvae was 25 mm in J.C. Boyle, 14 mm in Copco, and 13 mm in Iron Gate (Figure 9). In 1999, the average length of sucker larvae was 19 mm in J. C. Boyle, 13 mm in Copco and 16 mm in Iron Gate (Figure 10). The timing of peak larval abundance differed between reservoirs, occurring in mid to late June in Copco and Iron Gate but later, in early to mid July, in J.C. Boyle.

<u>Habitat Comparisons</u>

Because habitat attributes of adult trammel nets catches were difficult to quantify, only habitats associated with juvenile and larval catches were analyzed. Non parametric statistical comparisons were made between larval trawl catches and habitat type (substrate type, vegetation type, and the presence / absence of vegetation, Table 4). There were no significant relationships between habitat variables and sucker catch rates in part because sucker catches were highly variable across habitats.

Juveniles

In 1999 all juvenile suckers from J. C. Boyle were captured in areas devoid of vegetation near the inflow, where macrophytes were not abundant. In 1998 by contrast, all juvenile suckers were captured in areas with medium to high vegetation densities. In 1999 85% of juvenile suckers were caught over fine substrates and in 1998 75% were caught over fine substrates. The juvenile suckers in Copco reservoir were occupying flooded terrestrial habitats characterized by grasses and other terrestrial plants with fine and intermediate substrates.

Larvae

In 1999, 58% of larval suckers (excluding the drift net samples) were caught over small substrates (small mix see methods). In 1998, 83% of the larval sucker catch was collected over small substrates. The patterns may have been driven by the relative proportions of substrates sampled. In 1999 69% of all sites sampled had small substrates and in 1998 78% of all sites sampled had small substrates.

Across reservoirs, catches of larval suckers were similar in vegetated (54%) and non-vegetated (46%) areas in 1999, despite collections being skewed toward vegetated sites (71%). This apparently even distribution in vegetated and non vegetated areas is largely driven by the sucker catches in Copco reservoir. High catches from non vegetated areas in Copco reservoir were common. Furthermore, larval sucker catches in Copco far exceed those in the other reservoirs. In Copco reservoir, 38% of the collections were from non-vegetated sites but those sites produced 48% of all sucker larvae caught. In contrast, 88% of larval suckers from J.C. Boyle and 100% from Iron Gate reservoirs were from vegetated areas.

In 1998, 71% of larval suckers were captured in vegetation and 81% of all samples were collected from vegetated areas. Again Copco had more suckers taken from non vegetated sites.

Seventy four percent of the larval catch was collected in non-vegetated sites but these non vegetated sites made up only 33% of samples taken from Copco. All larval catches in J.C. Boyle and Iron Gate reservoirs were from vegetated areas in 1998.

Water Quality Parameters

Average lake-wide water temperature profiles for the three Lower Klamath reservoirs and Upper Klamath Lake were similar (Figure 11). Temperature ranges were 5.0 - 27.1 ºC in J.C. Boyle, 7.1 - 27.0 ºC in Copco, 7.3 - 30.1 ºC in Iron Gate, and 6.4 - 29.6 ºC in Upper Klamath Lake. At no point did temperatures reach LC_{50} levels (30.51ºC).

Lake-wide average pH profiles were similar until August (Figure 12). The range of pH was 7.71 - 9.00 in J.C. Boyle, 7.79 - 9.19 in Copco, 7.71 – 9.63 in Iron Gate, and 6.75 – 10.14 in Upper Klamath Lake. LC_{50} levels were not reached in J. C. Boyle or Copco. In Iron Gate reservoir pH exceeded LC_{50} in 15 % of early August samples and 9% of late August samples. In Upper Klamath Lake LC_{50} values were exceed in 18% of early June, 9 % of late June, 25% of mid July, 6% of early August, and 0.6% of late August samples.

The dissolved oxygen profiles were similar until early August when values dropped in Upper Klamath Lake and J.C. Boyle (Figure 13). The range of dissolved oxygen was 5.31 - 14.12 mg/L in J.C. Boyle, 8.05 - 13.93 mg/L in Copco, 7.71 - 9.63 mg/L in Iron Gate, and 2.60 – 14.52 mg/L in Upper Klamath Lake. Dissolved oxygen values below LC_{50} were only observed in Upper Klamath Lake and were 2% of early June samples, 9% in mid July, 3% in early August, and 0.6% in late August.

Water Level Fluctuations

Water fluctuations in J.C. Boyle tended to be greater than the other reservoirs (Figures 14, 15, and 16). During the 1999 sampling period, mean sea level surface elevations ranged 3788.7 -

3793.5 ft in J. C. Boyle, 2600.4 - 2607.3ft. in Copco, and 2324.8 - 2329.7 ft in Iron Gate. Average daily fluctuations and ranges were 1.14 ft (0.04 – 3.53ft) in J. C. Boyle, 0.6 ft (0 – 1.9 ft) in Copco, and 0.3 ft (0 – 1.7 ft) in Iron Gate reservoir. Daily fluctuations tended to increase in late June but elevations increased in Copco and decreased in the other two reservoirs (Figures 14-16). In all reservoirs, the timing of increased hydroelectric production resulting in larger water level fluctuations coincided with times of high larval abundance (Figures 15-17).

Discussion

<u>Reservoir Summaries</u>

J.C. Boyle

J.C. Boyle reservoir was the only reservoir in which all life stages of suckers were collected during both survey years (Table 2). Higher numbers of adult *Ca. rimiculus* were taken in J.C. Boyle with almost 10 times the numbers of the other two reservoirs (Table 2). Although the CPUE for adult *C. brevirostris* was low (Figure 2), J.C. Boyle appeared to have younger year classes of *C. brevirostris* (Figure 6) than downstream reservoirs and was the only reservoir in which juvenile suckers were captured in any numbers (Figures 10 and 11). Even though larval sucker catches were lowest in this reservoir (Table 2), the average size of the larvae were greater than those from the other two reservoirs (Figure 9 and 10).

J.C. Boyle had the highest CPUE for native species assemblages (Figures 3 –5) and usually the percentage of natives was greater than the percentage of exotics. Despite J. C.Boyle having the most dramatic water level fluctuation, there did not appear to be any relationship between water level fluctuation and larval sucker catch rates although the period of increased water fluctuation coincided with peak larval abundance (Figure 15). Water quality did not exceed known LC_{50} values. Fine substrates and vegetated habitats predominated and J. C. Boyle reservoir appeared to have more littoral habitat than the other two reservoirs. Its water quality more closely followed pH and dissolved oxygen trends in Upper Klamath Lake (Figure 13 and 14) than did the other reservoirs.

Proximity to Upper Klamath Lake may make J. C. Boyle a downstream sink for larvae and juvenile lake suckers dispersed from upstream spawning. The later arrival of larvae and their larger size (Figure 9 and 10) would be consistent with dispersal from upstream. The presence of juveniles and younger adults (Figures 6, 10, and 11) suggests that the habitat is sufficient to support these life history stages.

Copco

The largest numbers of larval suckers and adult shortnose suckers were caught in Copco reservoir both years (Table 2). Adult shortnose suckers were dominated by larger, older individuals (Figure 7) than in J.C. Boyle while larval suckers were smaller (Figures 9 and 10). Larval suckers were absent by early July and few juveniles were collected from the reservoir.

Species assemblages for all life history stages in Copco were dominated by exotics (Figures 3 – 5), and many were potential predators of larval and juvenile suckers. Despite the dominance of exotics, *C. brevirostris* made a significant contribution to both adult and larval catches. Like J.C.Boyle, peak larval catches occured during periods of increased water level manipulation. (Figure 16). Non-vegetated sites were 38% of the larval sampling sites and produced 48% of the larval suckers. Since most Copco sites sampled had small substrates, the majority of larval suckers were collected over this substrate type.

If J. C. Boyle reservoir operates as a downstream sink for Upper Klamath Lake juvenile and young adult suckers, Copco reservoir may operate similarly, receiving young adult shortnose suckers dispersed from J. C. Boyle reservoir. However, the abundance of large adults (Figures 2 and 7), known spawning sites, and large larval production (Table 2) are consistent with the interpretation that a residual spawning group of shortnose suckers uses Copco reservoir.

Iron Gate

Only *C. brevirostris* and *Ca. rimiculus* were collected in Iron Gate reservoir (Table 2). Like Copco, Iron Gate adult suckers were large and larvae were small (Figures 8 – 10). Larvae were not collected after early July. Like Copco reservoir, Iron Gate reservoir also appeared to serve as a sink for a residual population of larger adult shortnose suckers.

Species assemblages were dominated by exotics and many were potential predators on larval and juvenile suckers. Again, the period of increased water level manipulation coincided with peak larval abundance (Figure 17). Critical water quality levels were encountered in mid and late July after larval catches of suckers had declined. Larval sucker habitat reflected habitat available for sampling with 93% associated with vegetation and 92% on fine substrates. The shoreline in Iron Gate reservoir is steep and boulder strewn and the limited accessible sites tended to have small substrates and thick vegetation.

<u>Taxonomic problems</u>

The taxonomic identifications used have an unknown, though we believe small, potenetial for mis-identification. The taxonomic status of the Klamath Basin suckers has been debated for many years. Miller and Smith (1981) concluded than the shortnose suckers in Copco reservoir have introgressed with Klamath small scale suckers. Mills (California Department of Fish and Game 1979) using a discriminant function analysis found no evidence of this hybridization event. Andreasen (1975) and Buettner and Scoppettone (1991) found the Copco shortnose population was similar to those in Upper Klamath Lake. We made no attempt to quantify hybridization in this project, but questionable fish were excluded from the analysis. Potential misclassification is more likely to occur during larval and juvenile identification. For this reason we classified all sucker larvae and juveniles as unidentifed suckers. It is important to note that the larvae and juveniles taken in this study may represent riverine catostomids rather than the endangered lacustrine suckers. Ongoing taxonomic studies will hopefully shed light on this problem. Resolution of species taxonomy is imperative for better understanding the roles of the reservoirs in the life cycles of Klamath Basin suckers.

Important Ecosystem Processes and Future Studies

There were no significant relationships between habitat or environmental variables and larval and juvenile sucker catch rates. Despite these results we believe these variables may be important. The nature of our sampling plus the patchy distribution and high variance of sucker catches (0 - 1030 individuals per sample) may have made it impossible for us to detect differences. A structured sampling regime, stratified on variables of interest, rather than such a broad scale survey would be needed to address these types of relationships.

The presence of several smaller size classes of adults and greater abundance of large larvae and juveniles indicated that recent recruitment of young shortnose suckers only occurred in J.C. Boyle reservoir. We are unable to explain this pattern but because of the biological importance of recruitment, we feel it is instructive to review factors that may be favoring sucker recruitment in J.C. Boyle reservoir.

Predation

J.C. Boyle contains fewer exotic predators than the lower two reservoirs, Copco and Iron Gate. The effects of predation on aquatic organisms can be the result of both direct and indirect interactions of predators and prey. Consumption of prey can directly affect prey abundance, distribution, and age or size structure of prey populations (Brooks and Dodson 1965, Kerfoot and

Sih 1987, Stein et al. 1988). Predators can also affect prey indirectly by altering the behavior or habitat choice of prey (Werner and Gilliam 1984, Milinski 1985, Sih 1987, Fraser and Gilliam 1992). Predation by exotics has been identified as an important factor limiting the recovery of razorback and June suckers (Scoppettone and Vinyard 1991). Predation of larval suckers was not quantified in this study, however, it is a potential factor that could reduce survival and affect habitat selection by suckers. Predation effects would be predicted to be greater in Copco and Iron Gate reservoirs than in J. C. Boyle because exotic predators dominate the downstream reservoirs (Figures 3-5, Table3).

Littoral Zone Habitat

J.C. Boyle possesses proportionally more littoral habitats than the two lower reservoirs, although cross reservoir comparisons have not been quantified. The utilization of aquatic plants as fish habitat has been extensively documented. Janecek (1988) compiled a list of 112 different species representing 19 families that were collected in aquatic macrophytes in the upper Mississippi. Vegetated areas support higher fish densities when compared to unvegetated areas (Borawa et al 1979). Kilgore et al (1989) collected up to seven times more fish from vegetated areas in the Potomac river. This relationship is particularly strong for younger and smaller fishes (Barnett and Schneider 1974, Borawa et al. 1979, Moxley and Langford 1985). In the current study, however, no relationship was found between sucker abundance and vegetation presence / absence or vegetation density. All of the reservoirs might provide some larval or juvenile habitat but use might be mediated by biotic interactions, such as predation and competition (Heck and Crowder 1991).

Fish community structure and stability have been associated with the presence, abundance, species composition and structural heterogeneity of macrophytes (Hinch et al 1991, Benson and

Magnuson 1992, Brazner and Magnuson 1994, Weaver et al 1997). In addition, the effects of predation risk on habitat use in vegetated and nonvegetated areas has been extensively investigated (Savino and Stein 1989, Wahl and Stein 1989, Jordan et al. 1996). Jordan et al. (1996) showed in laboratory experiments that pinfish used seagrass and open sand habitats equally in the absence of predators. However, in the presence of predators, pinfish avoided nonvegetated areas. Vegetated and complex habitats are advantagegous for prey species for they can reduce predator efficiency through increases in handling times and visual constraints. However, increased habitat complexity can also decrease foraging success of prey species (Kieffer and Colgan 1993, Tatrai and Herzig 1995). This can lead to a trade-off between mortality and growth. Dill and Fraser (1984) found that starved juvenile coho were less responsive to the presence of predators and willing to take more risks while foraging. Competition and predation could effect habitat selection of prey species and could be an important ecological process effecting sucker survival and habitat choice in the reservoirs.

The availability of littoral habitats would likely be more important in the lower reservoirs where populations of exotic predators are high. However, these reservoirs have proportionally less littoral habitat. The combination of more littoral habitat and fewer exotic species would again favor J.C. Boyle reservoir for larval and juvenile suckers. The combination of high predator abundance and reduced littoral areas has been suggested as a major factor affecting the decline of the June sucker, *Chasmistes liorus,* (Thomas 1998).

Water Level Fluctuations

Water level fluctuations may further complicate the interactions of predation and habitat availability. Theoretically, fish will distribute themselves within and among lakes and reservoirs according to their physiological and behavioral requirements and the availability of preferred habitat (Werner 1986). Individuals are expected to choose habitats where environmental conditions are optimal. However, habitats are multi-dimensional (Magnuson et al. 1979) and environmental variables are interrelated. A site with optimal physical conditions becomes less optimal habitat when species densities become excessive. Similarly, the magnitude and frequency of water level fluctuations can blur otherwise straightforward habitat relationships. Vegetated sites where suckers were captured during one week may be dry the next week due to water drawdown. Water level fluctuation can act as a disturbance through changes in littoral zone cover and substrate (Gasith and Gafny 1990, Dibble 1993, Beauchamp et al. 1994, Irwin and Noble 1996). However, prior studies of this phenomenon were conducted on flood control reservoirs where fluctuations are less frequent and drawdown periods extend for longer periods than in the lower Klamath reservoirs. The relevance of these studies to the suckers in the lower Klamath reservoirs is speculative, but suggestive that the seasonal and daily dynamics of habitat changes could be important.

Changes in water levels can also alter nutrient concentrations, light, temperature, and grazing pressure and indirectly effect phytoplankton and zooplankton abundance (Lötmarker 1964, Rodhe 1964, Benson 1968, Mitchell 1975). Direct effects on phytoplankton and zooplankton can include physical removal from the system during release of water from reservoirs and dessication from stranding of organisms during drawdown (Benson and Cowell 1967, Clafin 1968, Barman and Barada 1978). Changes in phytoplankton and zooplankton communities can effect higher trophic levels.

Macrophytes can also be adversely effected by dessication and compaction of substrates, erosion of substrates, increased turbidity, and the dessication of the macrophytes themselves (Grimås 1961, Hunt and Jones 1972, Dunst et al. 1974, Wilbur 1983, Burton 1985). Periphyton and inverbetrate recolonization of descicated macrophytes requires 25 days for periphyton and 40 days for insects and can result in significant loss of fish food production from littoral habitats (Cowell and Hudson 1967).

Benthic invertebrates can be indirectly or directly affected by water level fluctuations through export out of the system, exposure and desication, and reduction in community diversity (Grimås 1961, Davis and Hughes 1966, Fillion 1967, Swanson 1967, Cowell and Hudson 1967, Hunt and Jones 1972, Benson 1973, Kaster and Jacobi 1978). Because some macro invertebrates have specific habitat requirements such as soft mud or macrophytes, loss or additions to their habitats greatly alters their species composition and can potentially change fish foraging success (Benson 1973, Wegener et al. 1975).

If water level fluctuations force larval and juvenile fishes to abandon refuge littoral areas, they can be more vulnerable to predators. Increased foraging by predators during or immediately after drawdown has been extensively documented (Heman et al. 1969, Beard and Snow 1970, Johnson and Andrews 1974, Heisey et al. 1980).

The potential impacts documented here would suggest that reservoirs with greater absolute water level changes and more frequent fluctuations would be less desirable habitats. If true, we would predict that Copco would have the best habitat for larvae and juveniles because water levels tended to rise over the season (Figure 15). We would also predict that J. C. Boyle should have the worst habitat because the total change in lake level was greatest (Figure 14) and the frequncy of fluctuations greater than Iron Gate (Figure 16). Our results did not agree with this simplistic pattern (Table 2) and suggest that the dynamics of these reservoirs are more complex.

Inter-Reservoir Fish Movement

J.C. Boyle reservoir is closer geographically to Upper Klamath Lake than the two lower reservoirs (Copco and Iron Gate). The observed recruitment of larvae and juveniles in J.C. Boyle (Figures 6, 10-11, Table 2) could be due to export out of Upper Klamath Lake. Markle and Simon (1993) documented movement of larval suckers out of Upper Klamath Lake in June and early July and Brant Guttermuth (CellTech, pers. comm. 1999) has documented export of juvenile lake suckers from Upper Klamath Lake in August.

One interpretation of the patterns seen in this study is that the lower Klamath River reservoirs act as catch basins for expatriated lake suckers from Upper Klamath Lake. In this scenario, shortnose suckers enter the system at J.C. Boyle as late larvae or juveniles. Juveniles and sub-adults survive and grow in J. C. Boyle but older individuals move downstream to Copco and eventually to Iron Gate. In the two lower reservoirs, they spawn and larvae are produced. Few or no larvae survive in the lower reservoirs, either because adult populations are too small, producing too few larvae to survive normal early mortality rates, or because habitat conditions are not favorable. Tagging studies could clarify adult recruitment dynamics and an additional study of juvenile recruitment would be needed to confirm this scenario.

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Table 1. The number of net sets by gear type and reservoir for 1998 and 1999. Dates reported represent the entire week. Numbers in parenthesis reflect effort. Trammel net, trap net and larvaldrift net data is displayed as hours soaked. Seine data is presented as meters seined and the dip net data as minutes searched. Trawl data is represented as number of trawls only.

Year	Reservoir	Gear	March 30	April 22	May 12	June 3	June 24	July 13	August 5	August 25	September 14	October 8	**Totals**
1998	JCBoyle	Trammel	5(47.25)	3(40.82)	3(46.40)		2(12.33)	2(11.00)				1(15.20)	**173.00**
		Trap Net									8(87.67)	2(30.47)	**118.14**
		Trawl			4	3	3	5	4				**19**
		Dip					3(30)	2(20)	1(10)	1(10)			**70**
		Larvaldrift		2(5.18)	2(16.22)	2(3.75)	1(0.17)						**25.32**
		Seine						6(66)	5(55)	8(88)			**209**
	Copco	Trammel	6(64.58)	3(40.90)	3(46.90)		2(25.83)	2(9.75)				1(16.33)	**204.29**
		Trap Net										2(35.27)	**35.27**
		Trawl			2	3	3	5	5				**18**
		Dip				2(20)	3(30)						**50**
		Larvaldrift		2(7.23)	2(15.32)	2(4.00)	2(3.58)						**30.13**
		Seine						6(75)	6(66)	9(99)			**240**
	Iron Gate	Trammel	4(41.45)	3(36.55)	3(45.08)	2(37.52)		4(17.50)				3(48.80)	**226.90**
		Trap Net										3(56.03)	**56.03**
		Trawl			2	3	4	3	5				**17**
		Dip				2(20)	4(40)						**60**
		Larvaldrift		4(11.90)	2(16.13)	4(12.97)	2(3.35)						**44.35**
		Seine						3(33)	5(55)	5(55)			**143**

Year	Reservoir	Gear	April 12	May 3	May 18	May 26	June 3	June 8	June 16	June 22	July 8	July 28	**Totals**
1999	JCBoyle	Trammel	3(40.35)	3(50.28)		2(28.65)							**119.28**
		Trap Net	1(15.08)	2(29.63)		2(29.58)		2(30.53)	2(24.62)		2(35.55)	2(32.28)	**197.27**
		Trawl			6			5	1	4	1		**17**
		Dip			1(3)				1(5)	6(42)	2(17)		**67**
		Larvaldrift	3(10.62)	3(17.78)	2(10.23)	2(8.97)		2(8.33)	2(8.00)	2(15.50)			**79.43**
		Seine						3(73)	6(82)	4(55)		5(57)	**267**
	Copco	Trammel	3(43.92)	2(28.52)		3(50.93)							**123.37**
		Trap Net	2(31.08)	2(28.57)		2(35.35)		2(28.08)	2(30.70)		2(31.37)	2(33.95)	**219.10**
		Trawl			10		8	6	3	3	2		**32**
		Dip			1(2)		1(5)	2(10)	4(21)	5(30)	1(10)		**78**
		Larvaldrift	2(6.33)	2(12.17)	2(9.90)	2(8.53)	2(10.00)	2(8.33)	2(8.67)	2(9.43)			**73.36**
		Seine						1(20)	5(69)	5(90)	4(70)	6(115)	**364**
	Iron Gate	Trammel	3(45.02)	2(28.77)		3(44.48)						2(32.27)	**118.27**
		Trap Net	2(32.92)	2(27.73)		2(30.08)		2(27.83)	2(25.68)		2(29.28)		**205.79**
		Trawl			7		8	4	3	2	3		**27**
		Dip			1(4)		1(20)	4(25)	8(40)	5(28)	6(30)		**147**
		Larvaldrift	3(11.87)	3(18.07)	2(8.40)	3(11.95)	2(8.33)	3(11.50)	2(8.63)	2(8.03)			**86.78**
		Seine							6(76)	5(61)		2(17)	**154**

Table 2. Numbers of Adult, juvenile, and larval suckers caugth in the respective reservoirs in 1997-1999. Only adult sampling was conducted in 1997

Species	J. C. Boyle				Copco				Iron Gate			
	1997	1998	1999	**Total**	1997	1998	1999	**Total**	1997	1998	1999	**Total**
Chasmistes brevirostris	1	5	44	**50**	6	95	64	**165**	9	2	11	**22**
Deltistes luxatus	0	0	2	**2**	0	1	0	**1**	0	0	0	**0**
Catostomus rimiculus		64	126	**190**		16	1	**17**		12	10	**22**
Catostomus snyderi		1	0	**1**		2	0	**2**		0	0	**0**
sucker larvae		66	209	**275**		222	8507	**8729**		42	1135	**1177**
sucker juveniles		62	61	**123**		0	3	**3**		0	0	**0**

Table 3. Grand rank for five most dominant taxa in trammel net (TR), trap net (TP), beach seine (BS) and larval trawl (LT) in each reservoir in 1999. A rank of one was the most dominant. Native species in boldface print.

<table>
<tr><th>Taxon</th><th colspan="4">J. C. Boyle</th><th colspan="4">Copco</th><th colspan="4">Iron Gate</th></tr>
<tr><th></th><th>TR</th><th>TP</th><th>BS</th><th>LT</th><th>TR</th><th>TP</th><th>BS</th><th>LT</th><th>TR</th><th>TP</th><th>BS</th><th>LT</th></tr>
<tr><td>Chasmistes brevirostris</td><td></td><td></td><td rowspan="4">5</td><td rowspan="4">2</td><td>1</td><td></td><td rowspan="4">2</td><td rowspan="4">1</td><td></td><td></td><td></td><td rowspan="4">2</td></tr>
<tr><td>Deltistes luxatus</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Catostomus rimiculus</td><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>C. snyderi</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Gila bicolor</td><td>1</td><td rowspan="2">1</td><td rowspan="2">2</td><td rowspan="2">1</td><td></td><td>5</td><td></td><td rowspan="2">4</td><td>4</td><td></td><td></td><td></td></tr>
<tr><td>Gila coerulea</td><td>3</td><td>4</td><td></td><td></td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Lampetra sp.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Oncorhynchus mykiss</td><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Rhynichthys osculus</td><td></td><td></td><td></td><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Cottidae</td><td></td><td></td><td>4</td><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Perca flavescens</td><td></td><td></td><td></td><td></td><td>3</td><td>1</td><td>1</td><td>2</td><td>3</td><td>1</td><td>3</td><td>3</td></tr>
<tr><td>Ameirus sp.</td><td>4</td><td>2</td><td></td><td></td><td>5</td><td>2</td><td></td><td></td><td>1</td><td>3</td><td></td><td></td></tr>
<tr><td>Pomoxis sp.</td><td></td><td></td><td></td><td></td><td>2</td><td>4</td><td>5</td><td></td><td>5</td><td>4</td><td></td><td></td></tr>
<tr><td>Archoplites interruptus</td><td></td><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Micropterus salmoides</td><td></td><td></td><td></td><td></td><td></td><td></td><td>4</td><td></td><td></td><td></td><td>2</td><td></td></tr>
<tr><td>Lepomis gibbosus</td><td></td><td>3</td><td>3</td><td></td><td></td><td>3</td><td></td><td rowspan="2">5</td><td></td><td>2</td><td>1</td><td rowspan="2">4</td></tr>
<tr><td>L. cyanellus</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pimephales promelas</td><td></td><td>4</td><td>1</td><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td>5</td><td>5</td></tr>
<tr><td>Notemigonus crysoleucas</td><td></td><td></td><td></td><td></td><td></td><td></td><td>3</td><td>3</td><td></td><td>5</td><td>4</td><td>1</td></tr>
</table>

Table 4. A comparison of larval sucker catch rates (1999) over different substrates, vegetation types, as well as in the presence vs. absence of vegetation.

Comparison	Sample Size	Average Rank	Test Statistic	P-value
Substrate				
Fines	20	29.95	H = 2.43*	0.77
Sand	2	44.00		
Small Mix	14	32.75		
Cobble	4	25.75		
Intermediate Mix	17	35.26		
Large Mix	6	28.00		
Vegetation				
Absent	15	38.20	W = 282.00**	0.18
Present	49	30.76		
Submerged	23	32.59	H = 3.51	0.17
Emergent	26	28.33		
Absent				

** Denotes the test statistic generated by the Mann – Whitney test

* Denotes the test statistic generated by the Kruskal – wallis test

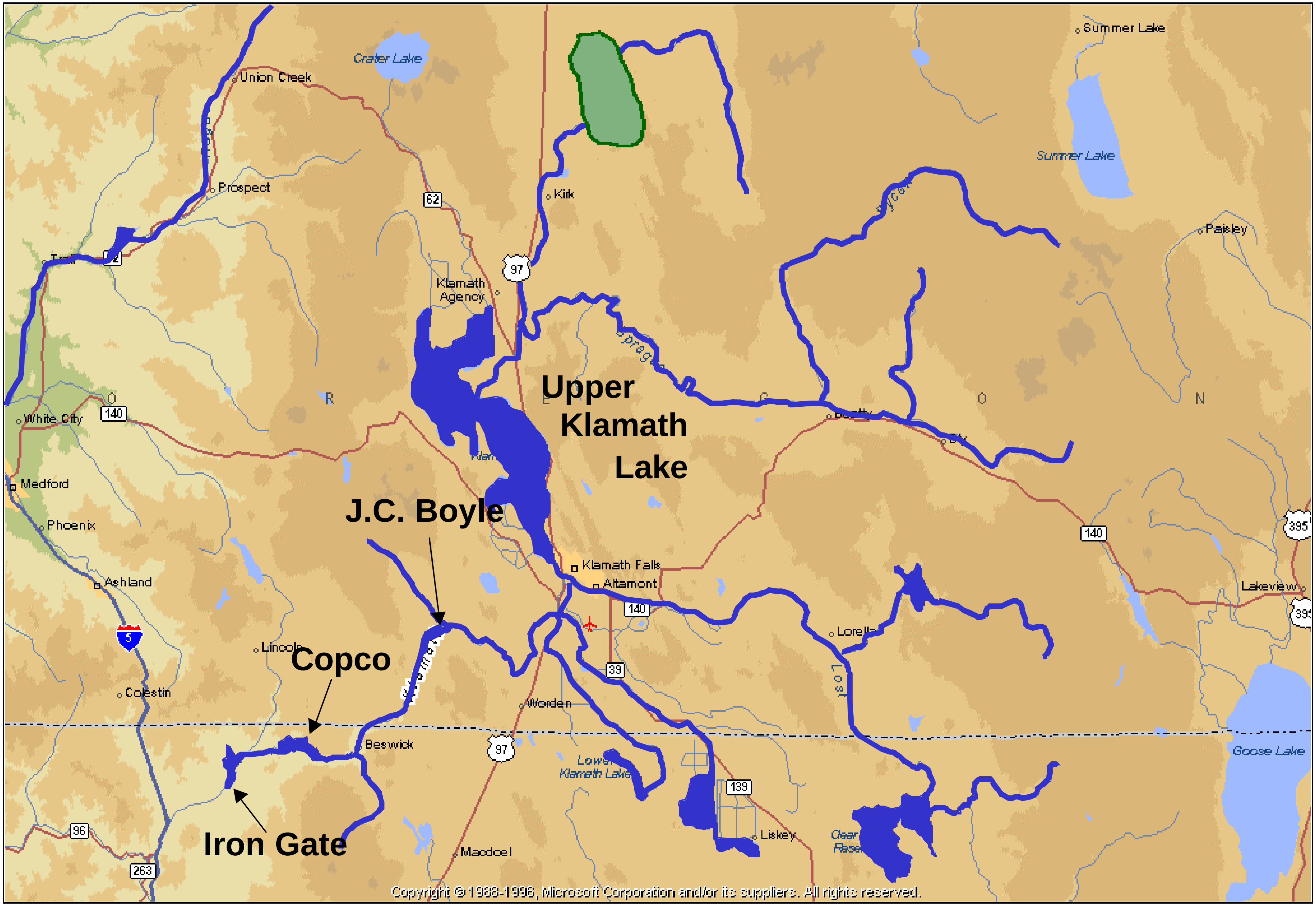

Figure 1. A map of the three lower hydroelectric reservoirs and their proximity to Upper Klamath Lake

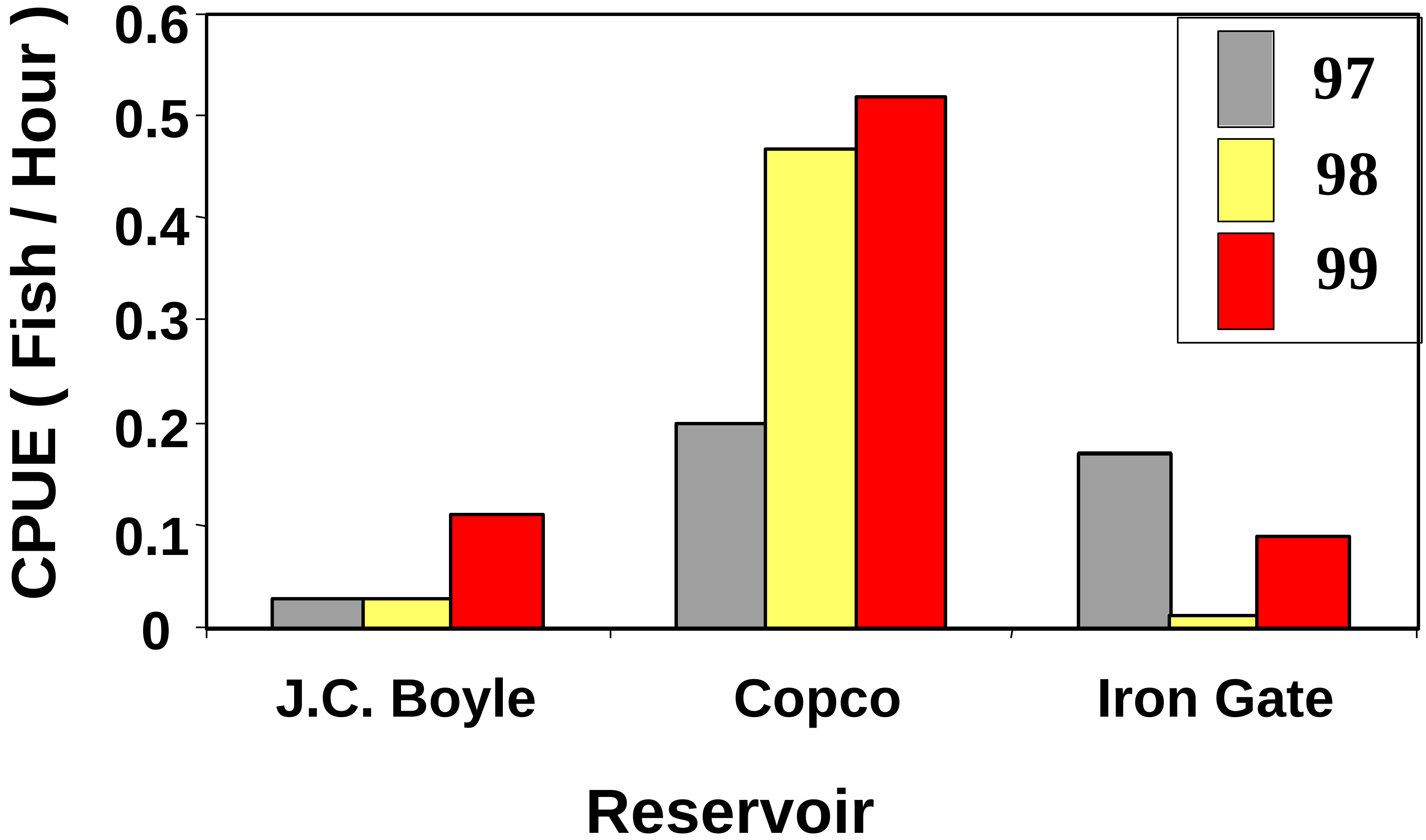

Figure 2. *Chasmistes* CPUE values obtained from trammel net surveys taken in 1997 - 1999 on the three lower Klamath reservoirs.

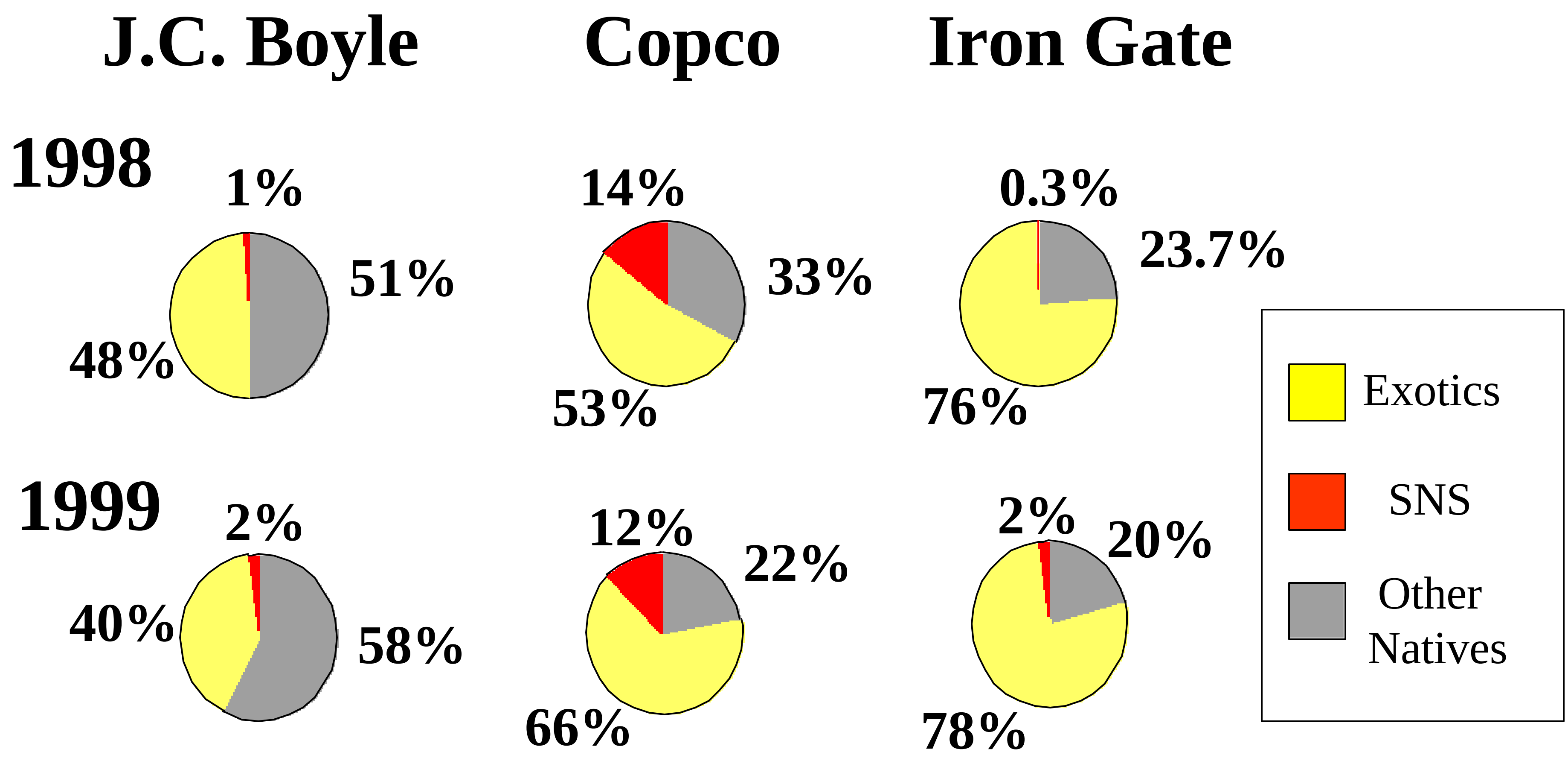

Figure 3. Proportions of the 1998 and 1999 trammel net catch. Sequence of the reservoirs left to right also represent an upstream to downstream continuum. SNS signifies shortnose suckers.

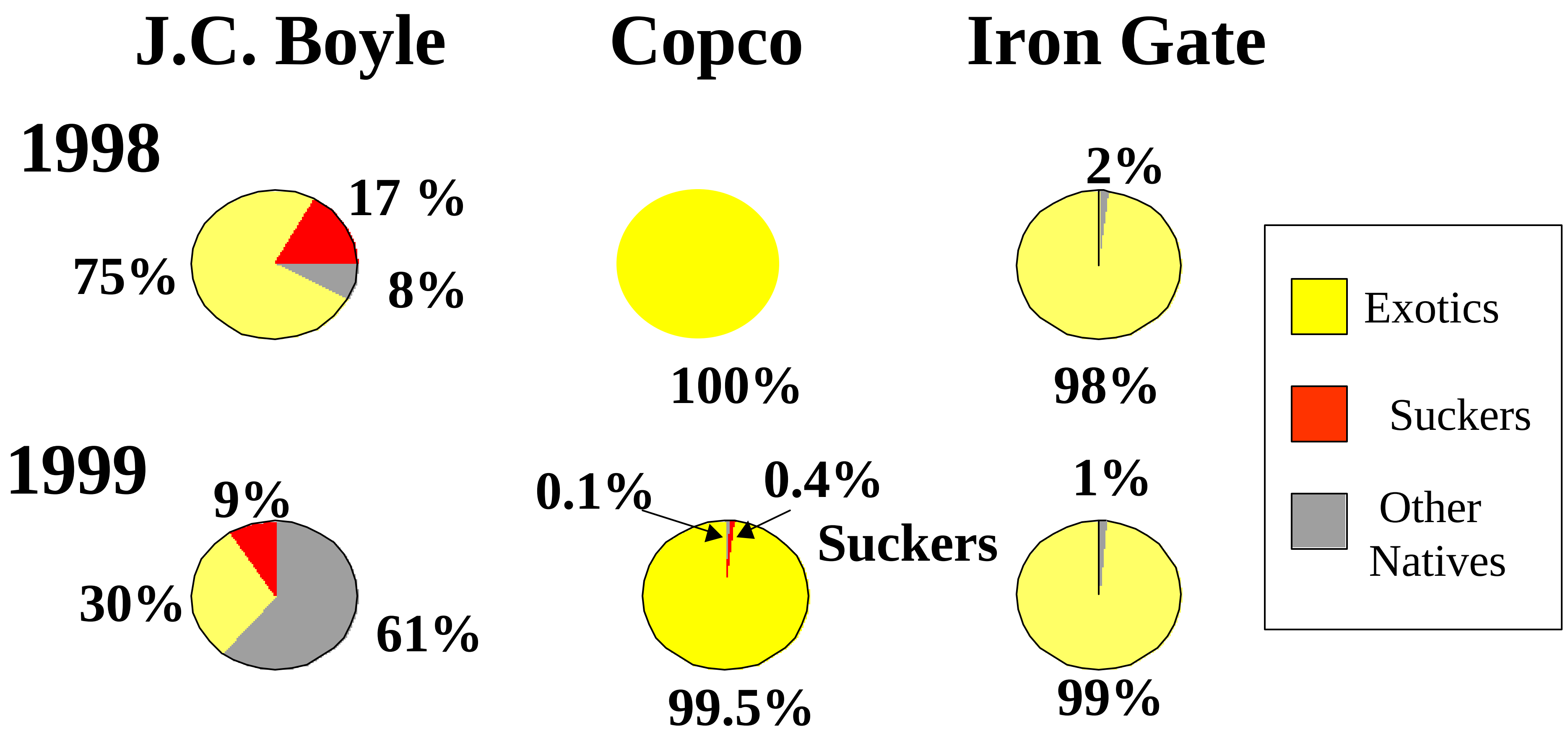

Figure 4. Proportions of the 1998 and 1999 seine net catch. The sequence of the reservoirs left to right also represent an upstream to downstream continuum.

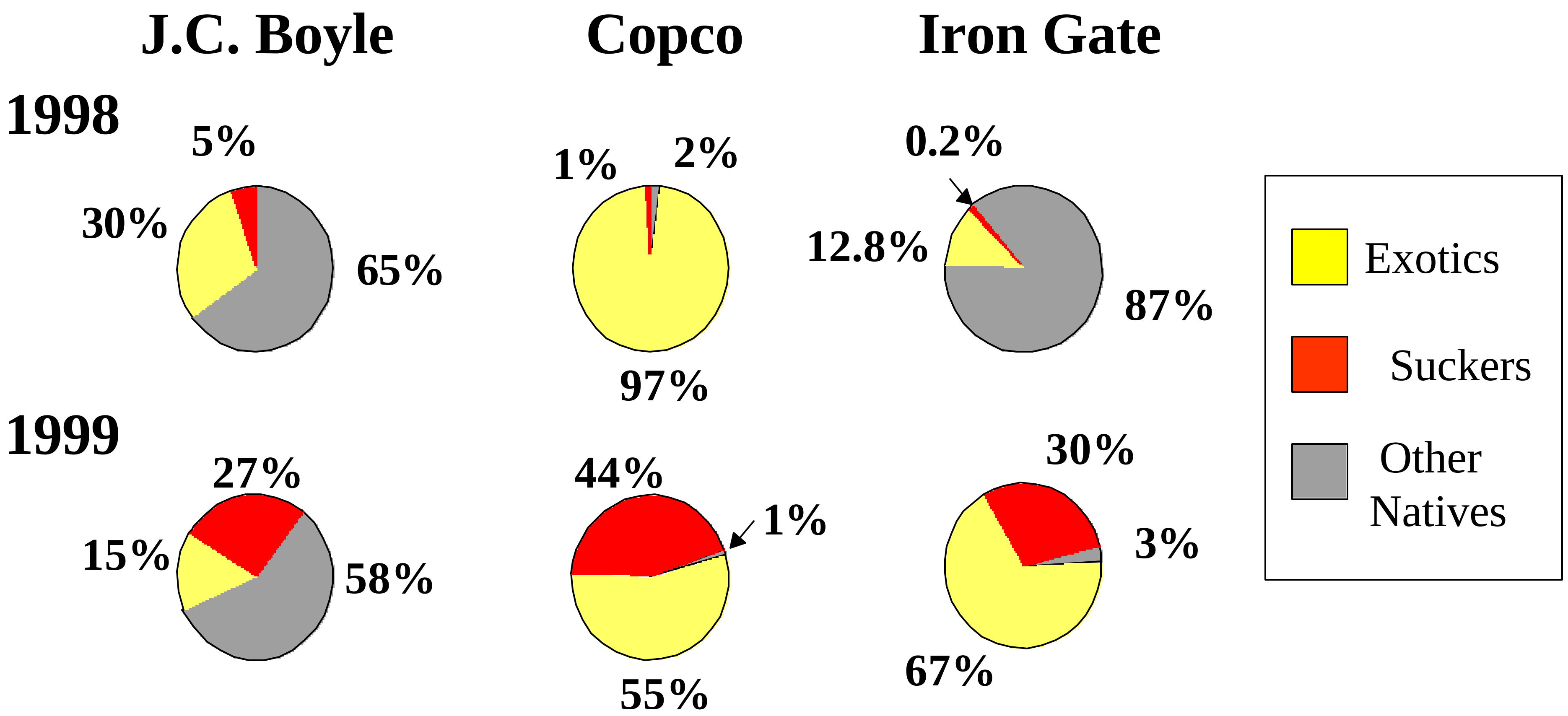

Figure 5. Proportions of the 1998 and 1999 larval trawl catch. The sequence of the reservoirs left to right also represent an upstream to downstream continuum.

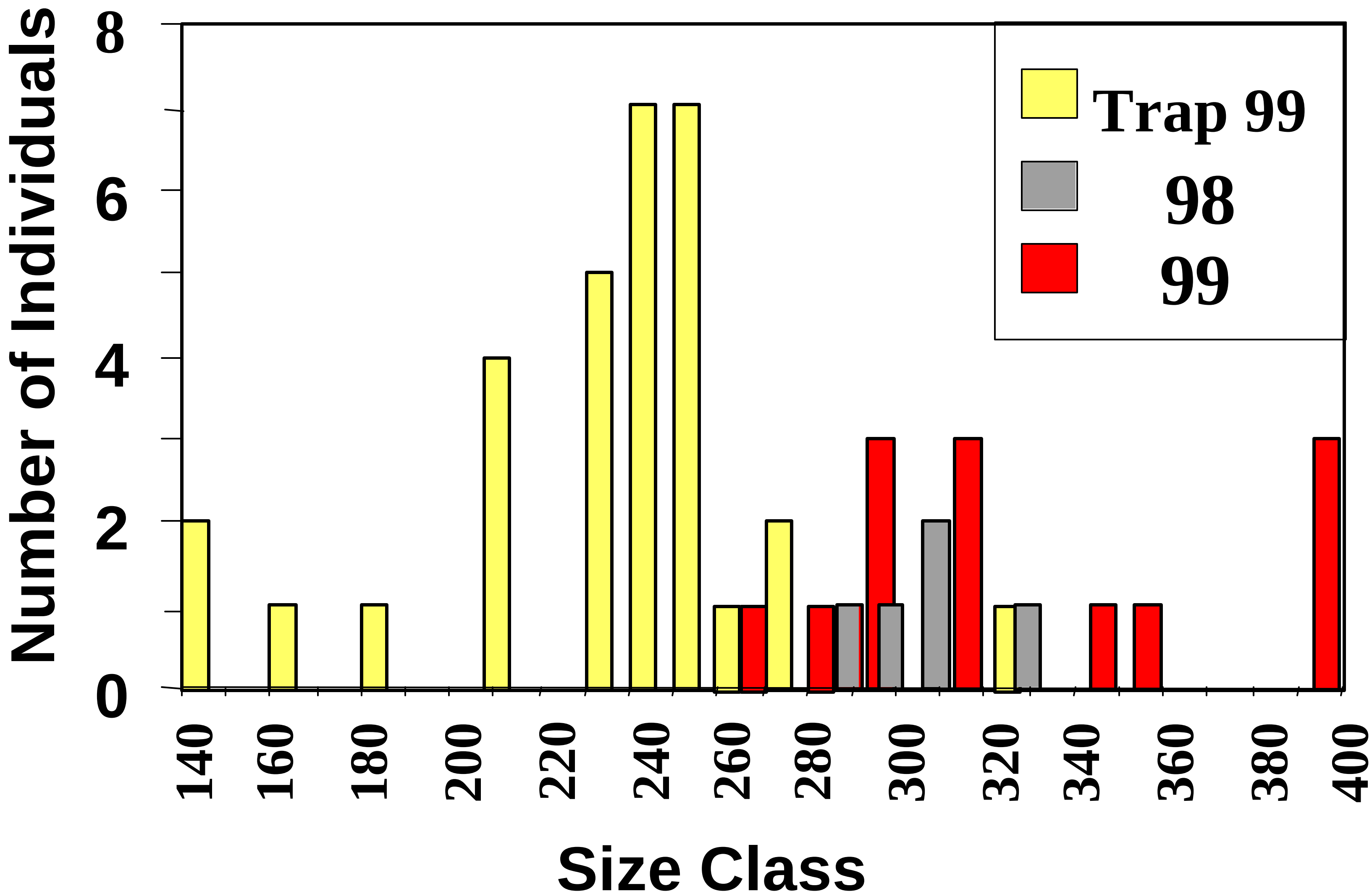

Figure 6. Size distribution of adult *Chasmistes* captured in trammel and trap nets during the 1998 and 1999 field season on J.C. Boyle reservoir.

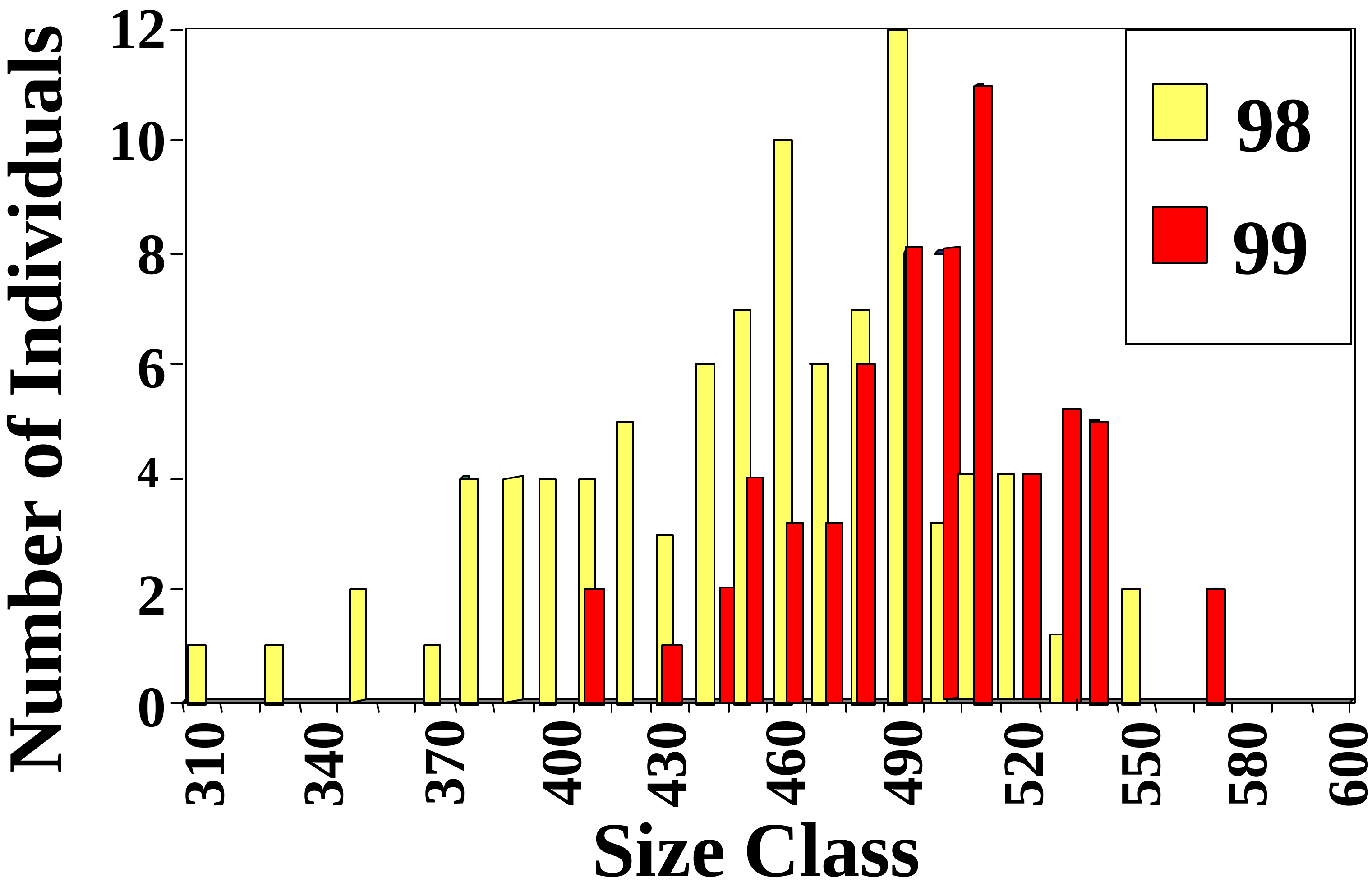

Figure 7. Size distribution of adult *Chasmistes* taken with trammel nets from Copco reservoir during the 1998 and 1999 sampling periods.

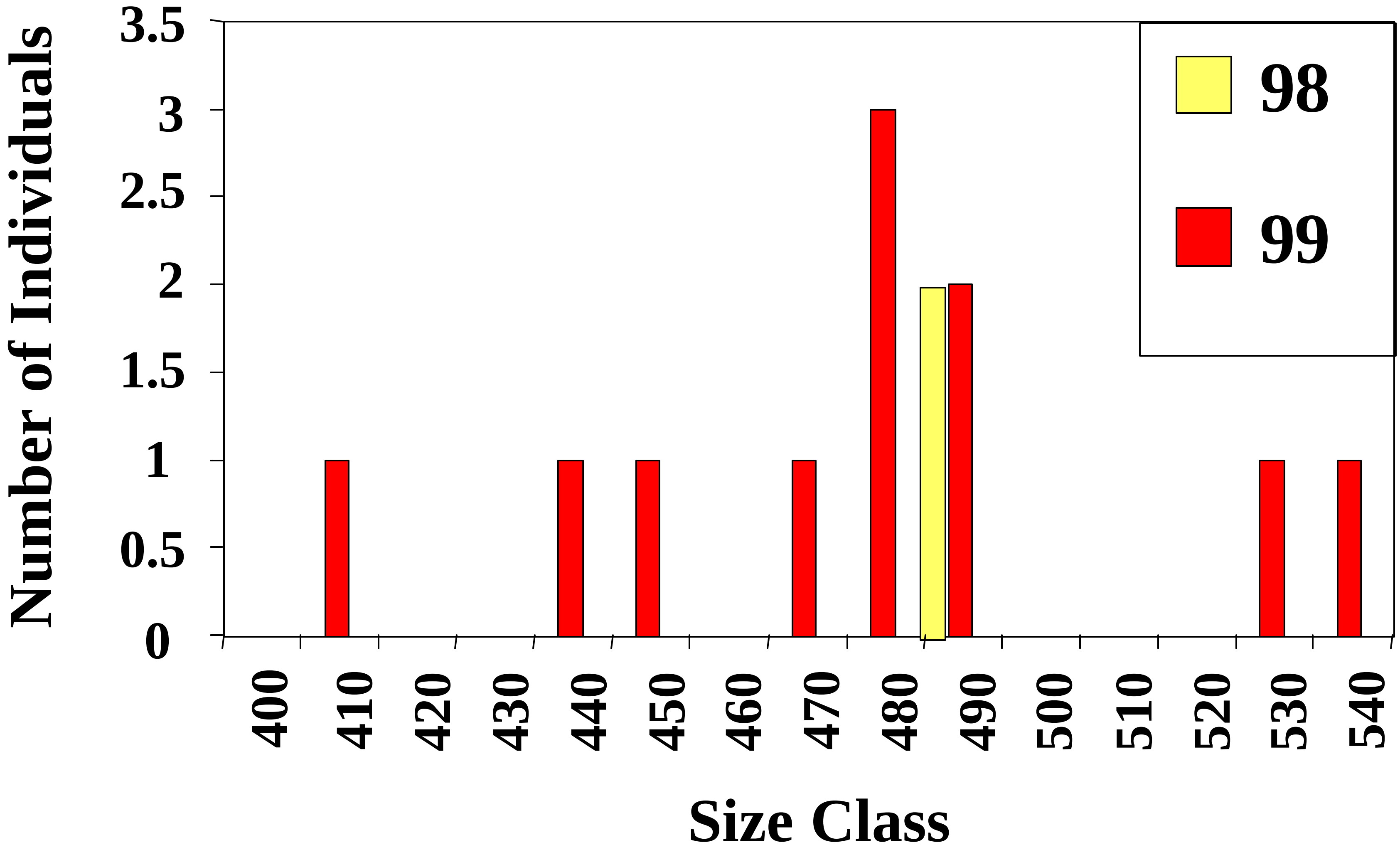

Figure 8. Size distribution of adult *Chasmistes* taken with trammel nets from Iron Gate reservoir during the 1998 and 1999 sampling periods.

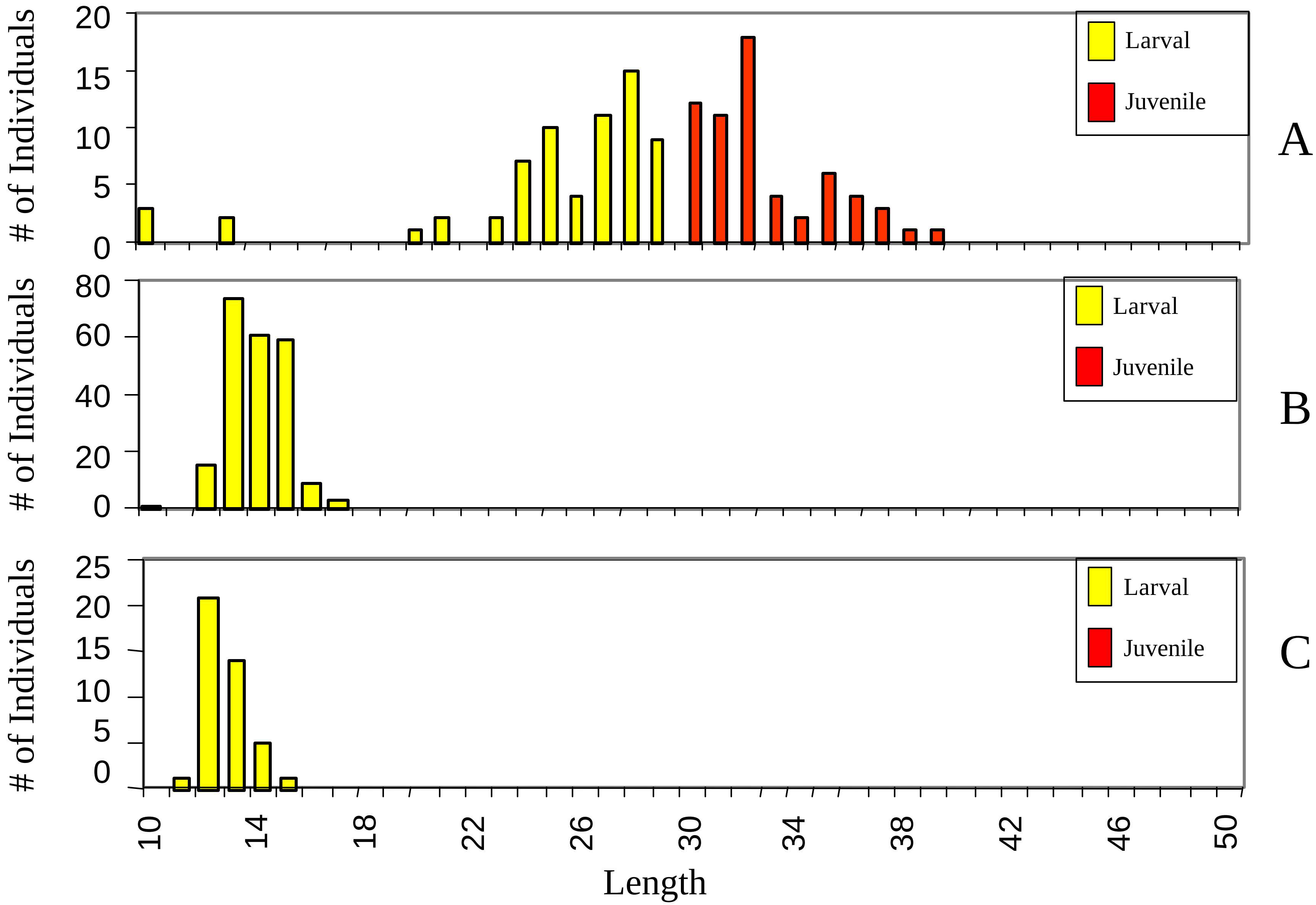

Figure 9. The number of larval and juvenile suckers captured with larval drift nets, larval trawls, dip nets, and seine nets in the three reservoirs during 1998. (A) J.C. Boyle. (B) Copco. And (C) Iron Gate. Fish were classified as juvenile once they reached a length of 30mm.

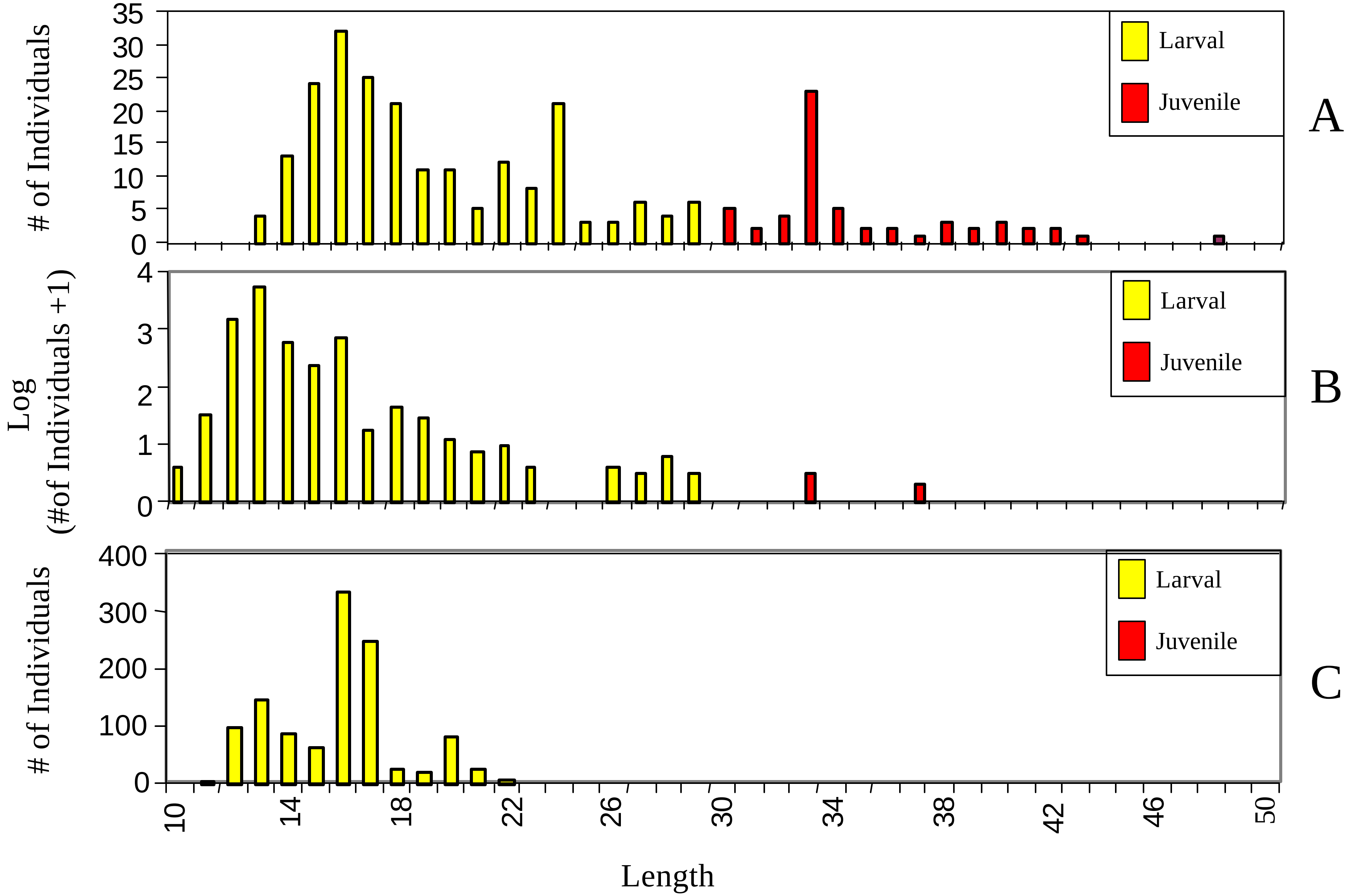

Figure 10. The number of larval and juvenile suckers captured with larval drift nets, larval trawls, dip nets, and seine nets in the three reservoirs during 1999. (A) J.C. Boyle. (B) Copco. And (C) Iron Gate. Fish were classified as juvenile once they reached a length of 30mm.

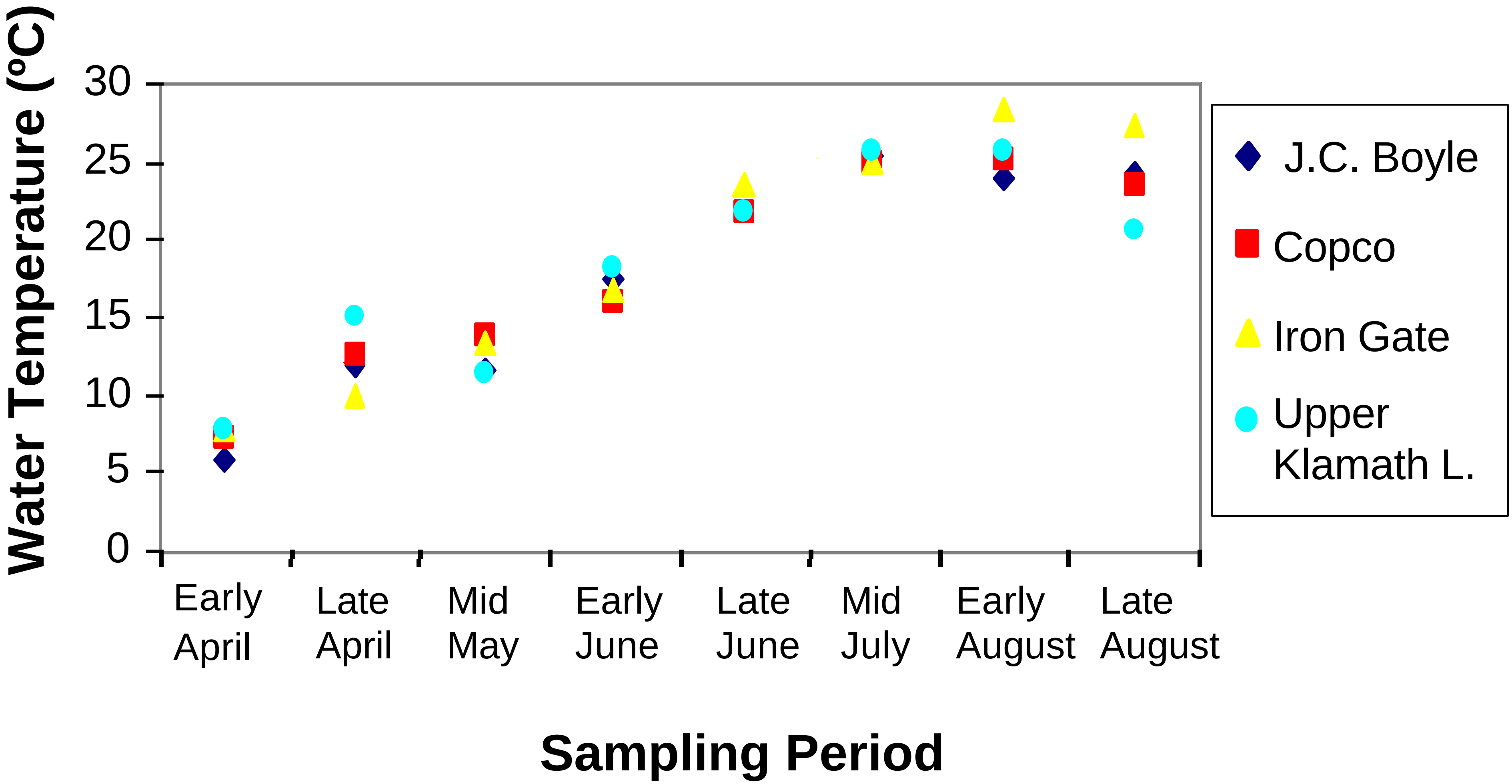

Figure 11. Average water temperature values taken during sampling periods on the three lower Klamath reservoirs and Upper Klamath Lake. Sampling on the lower reservoirs occurred within one week of the sampling on Upper Klamath Lake.

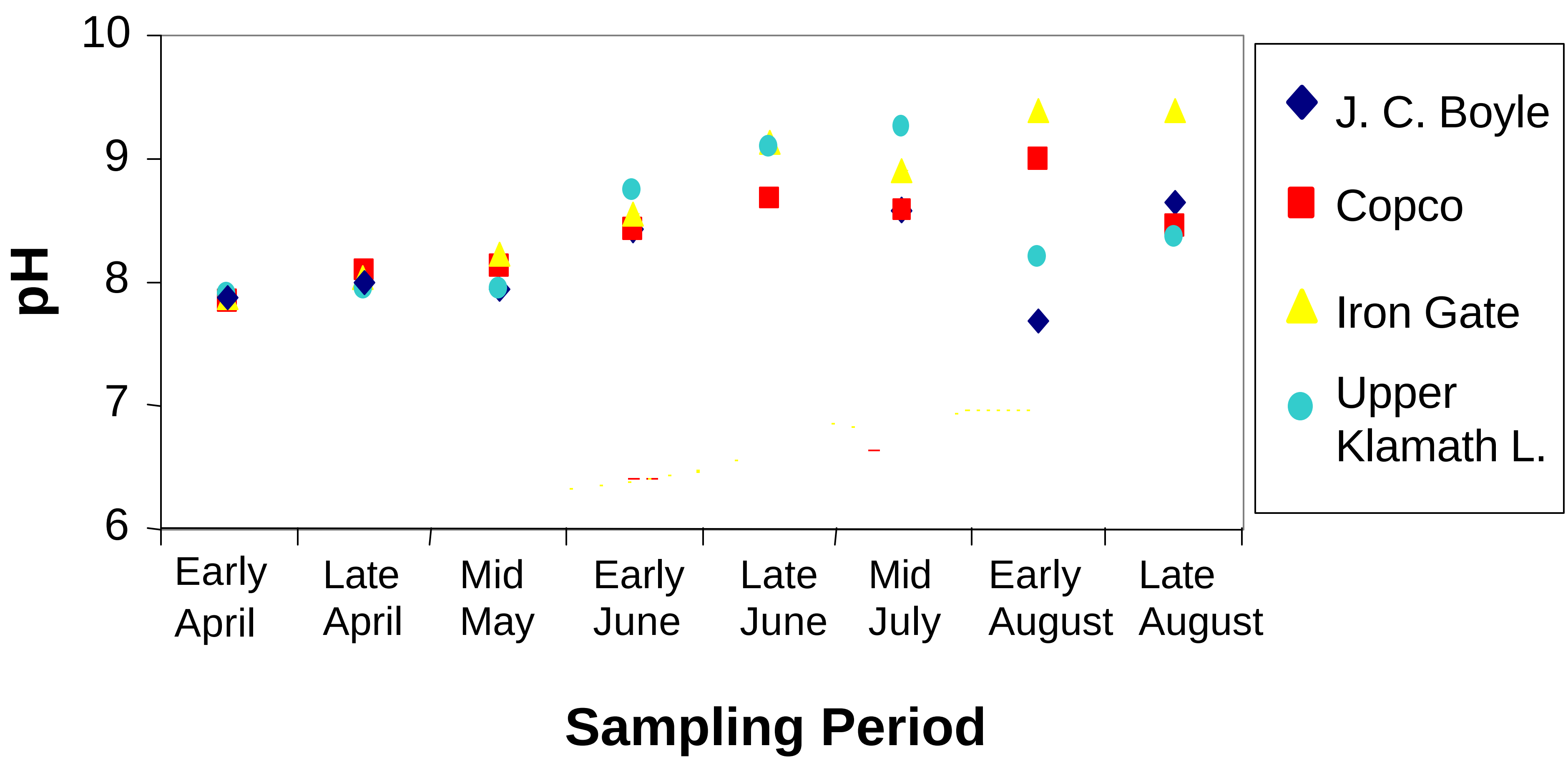

Figure 12. Average water pH values taken during sampling periods on the three Lower Klamath reservoirs and Upper Klamath Lake. Sampling on the lower reservoirs occurred within one week of the sampling on Upper Klamath Lake.

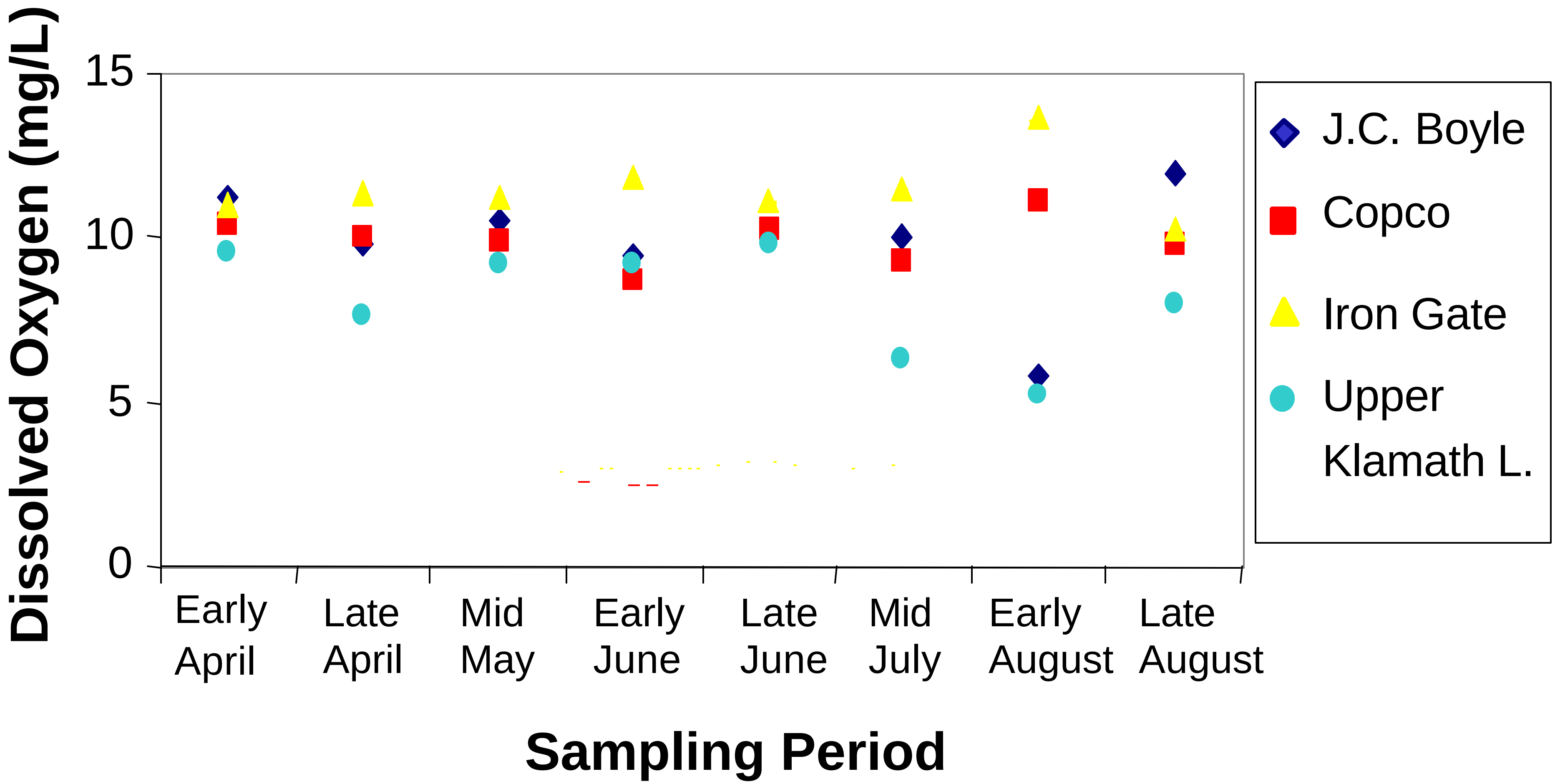

Figure 13. Average dissolved oxygen values taken during sampling periods on the three Lower Klamath reservoirs and Upper Klamath Lake. Sampling on the lower reservoirs occurred within one week of the sampling on Upper Klamath Lake.

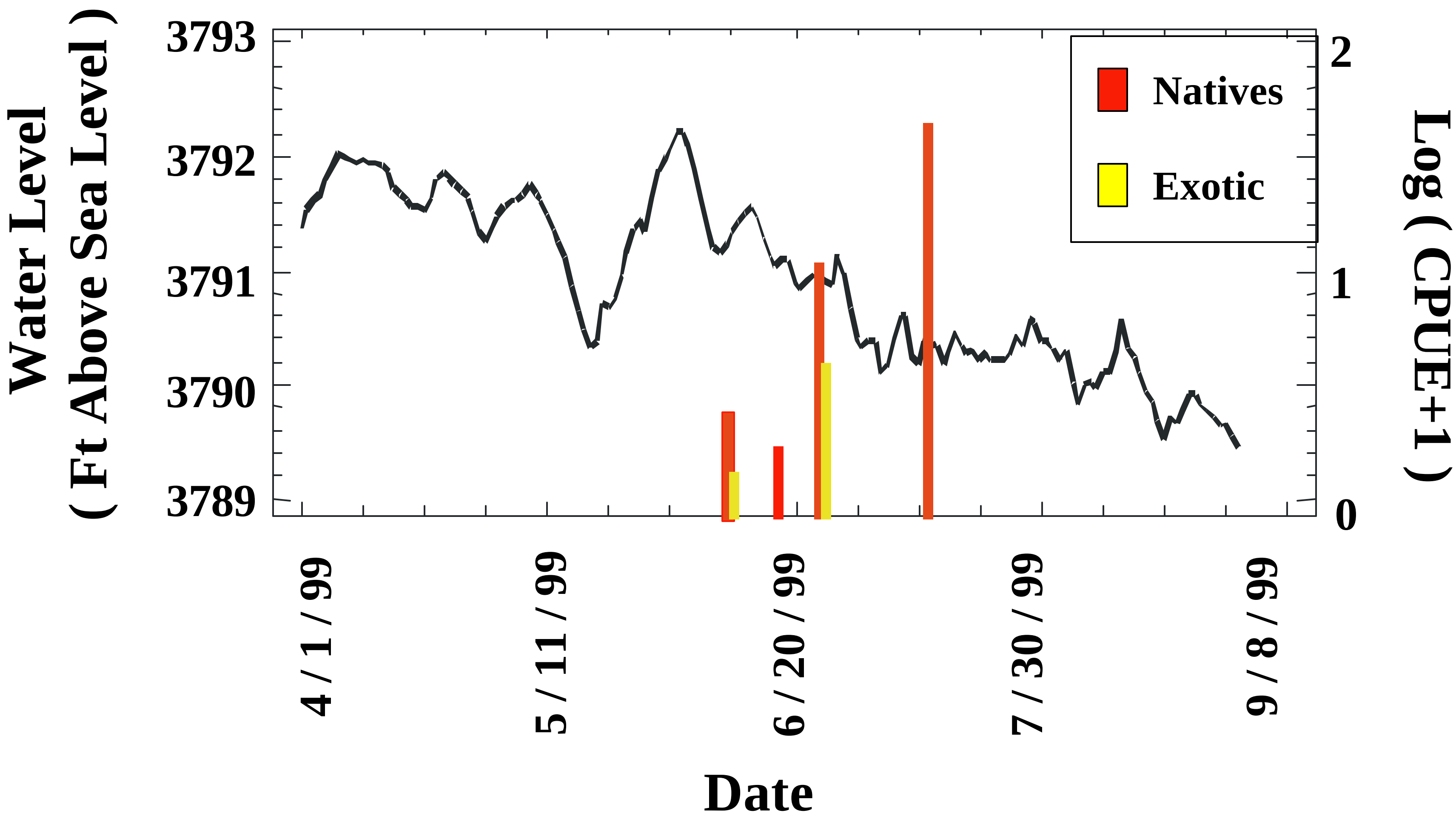

Figure 14. J.C. Boyle minimum water levels against CPUE values of native and exotic species captured with larval trawls during 1999 sampling period. The water level data was transformed using a 5% running mean to remove noise from the graphic.

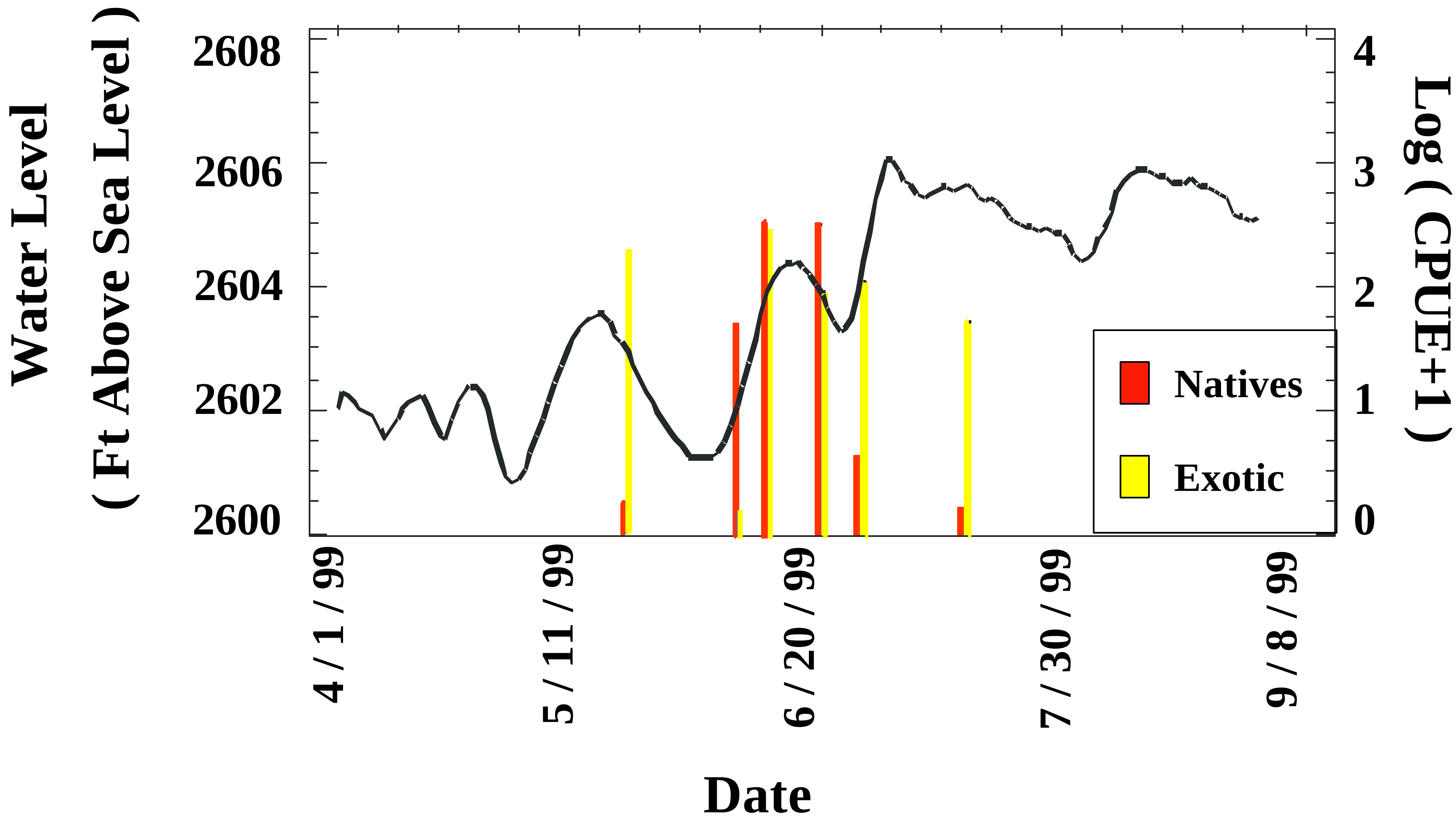

Figure 15. Copco minimum water levels against CPUE values of native and exotic species captured with larval trawls during 1999 sampling period. The water level data was transformed using a 5% running mean to remove noise from the graphic.

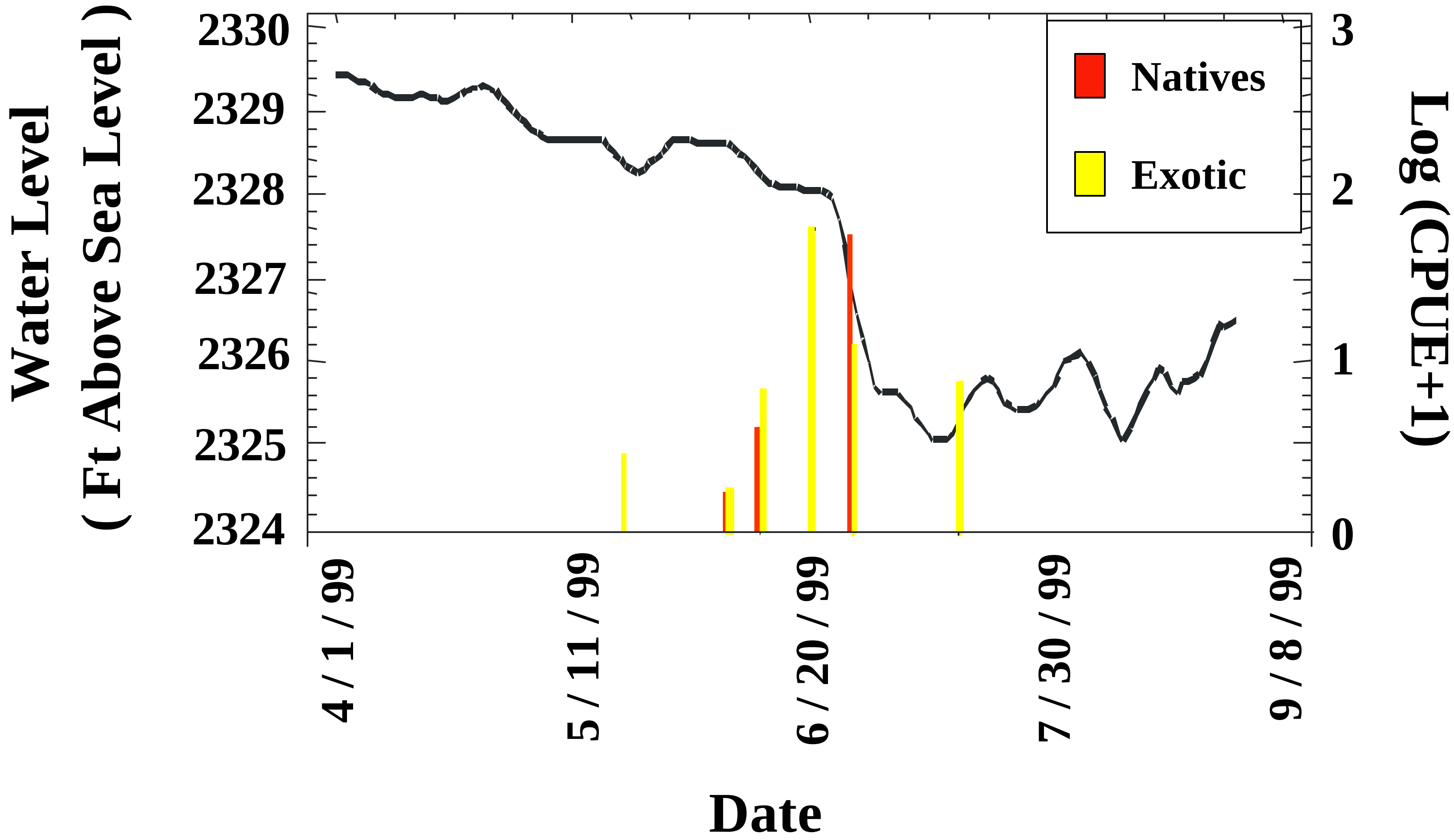

Figure 16. Iron Gate minimum water levels against CPUE values of native and exotic species captured with larval trawls during 1999 sampling period. The water level data was transformed using a 5% running mean to remove noise from the graphic.

Appendix A.

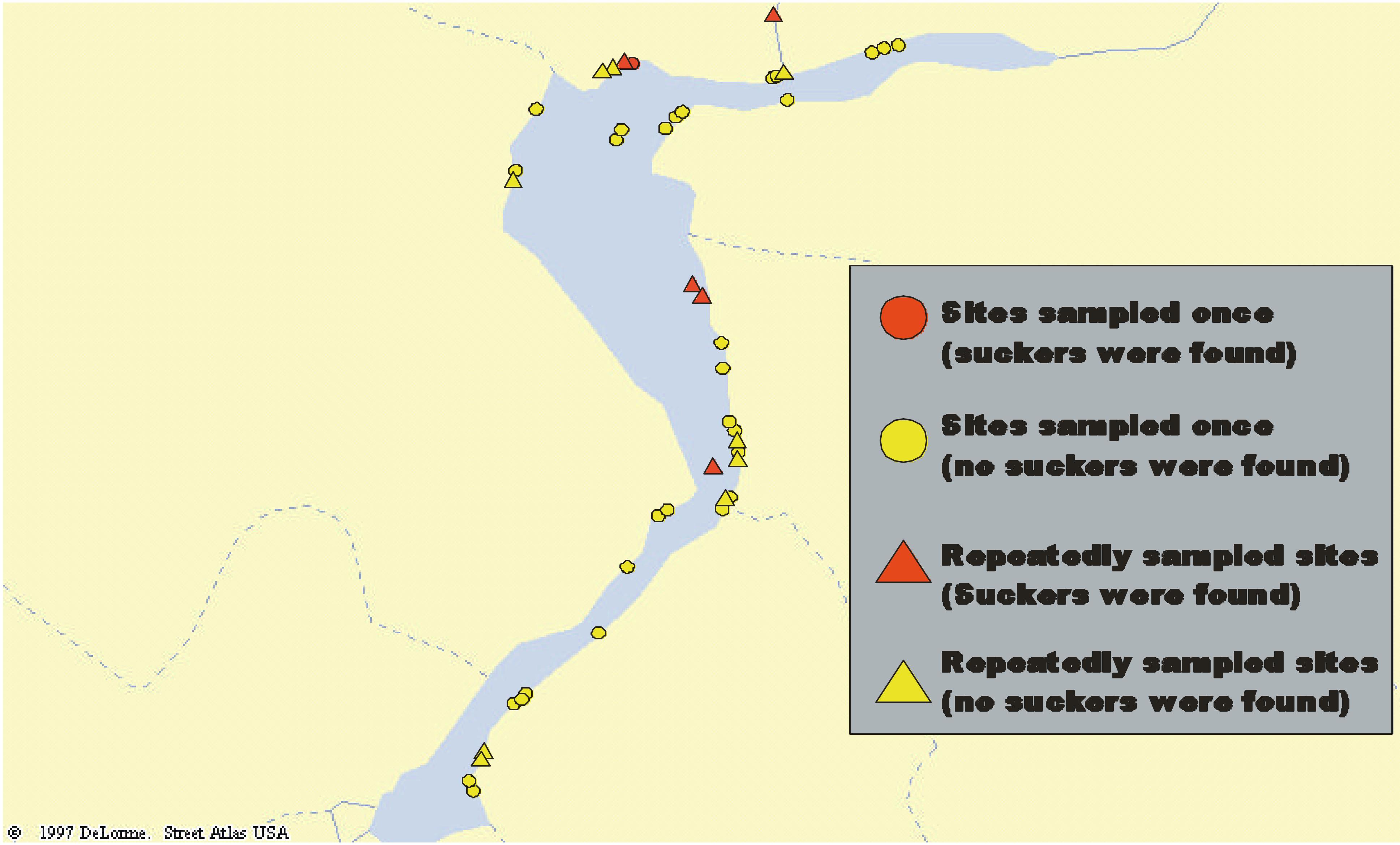

Figure A1. Sampling locations for larval and juvenile suckers on J. C. Boyle reservoir in 1998. The gear types represented here include larval drift nets, dip nets, larval trawls, and beach seines

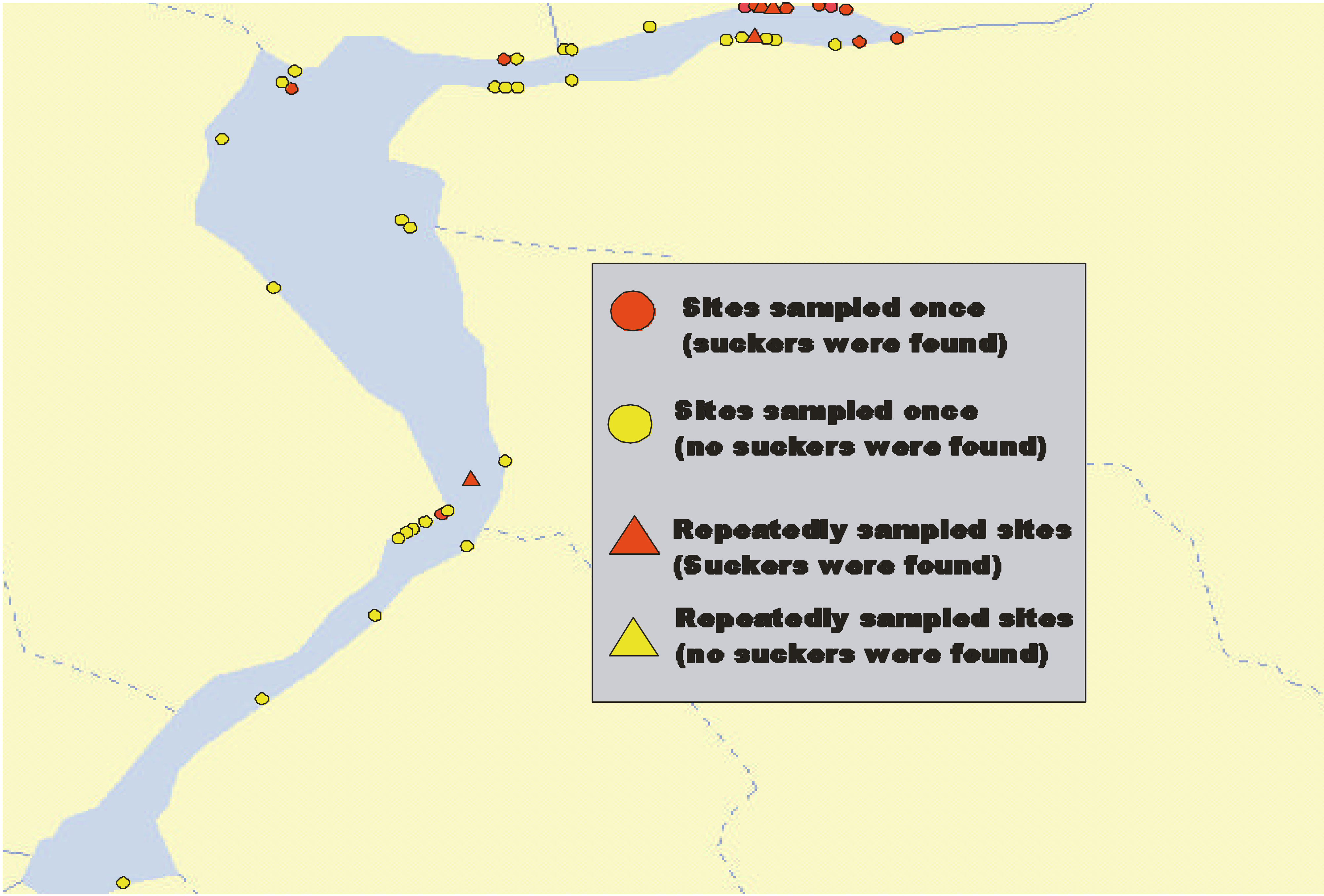

Figure A2. Sampling locations for larval and juvenile suckers on J. C. Boyle reservoir during 1999. The gear types represented here include larval drift nets, dip nets, larval trawls and beach seines.

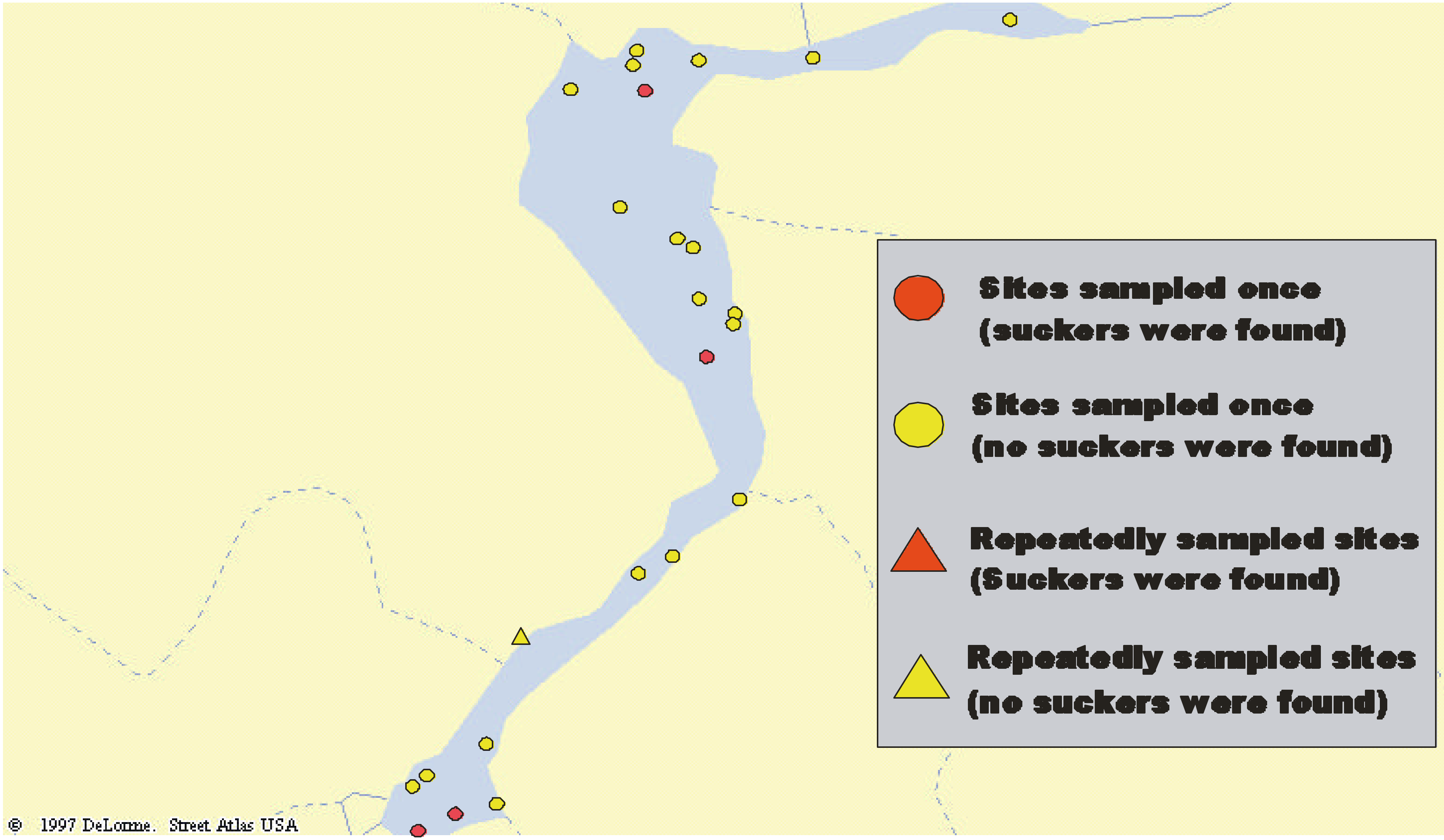

Figure A3. Sampling locations for adult *Chasmistes* on J. C. Boyle reservoir during 1998. The gear types represented here are trammel and trap nets.

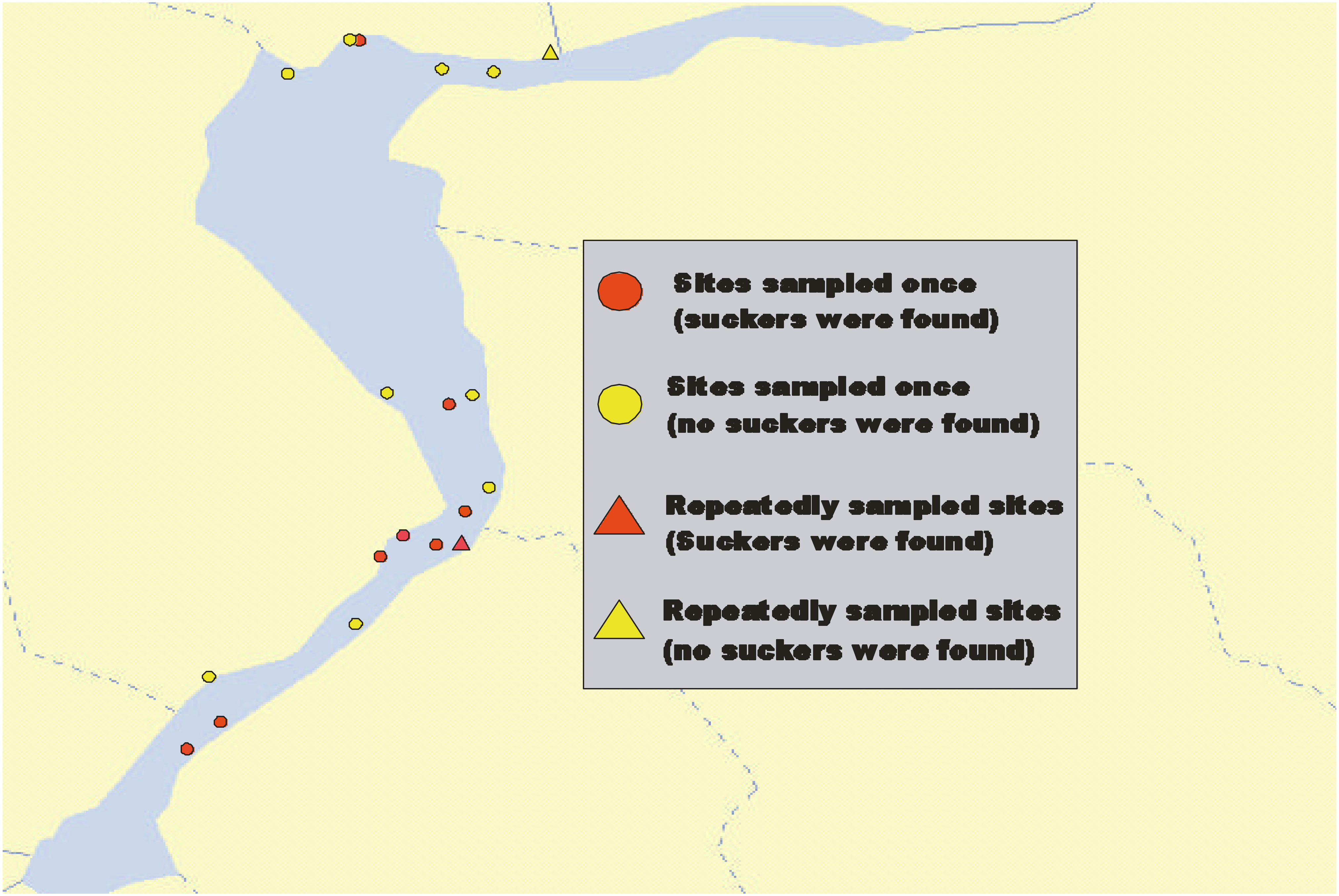

Figure A4. Sampling locations for adult *Chasmistes* on J. C. Boyle reservoir during 1999. The gear types represented here include trammel and trap nets.

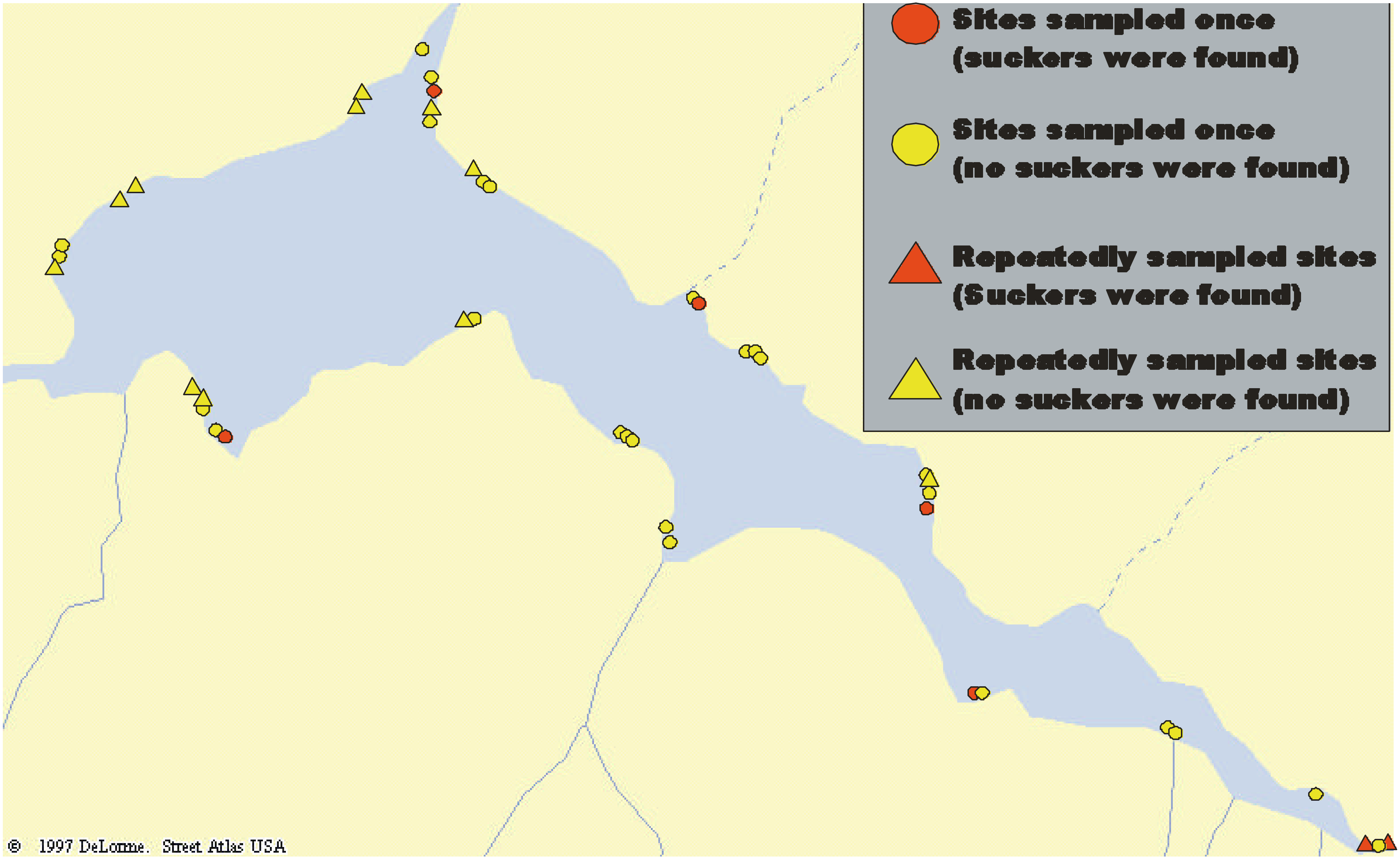

Figure A5. Sampling locations for larval and juvenile suckers on Copco reservoir during 1998. Gear types represented here include larval drift nets, dip nets, larval trawls, and beach seines.

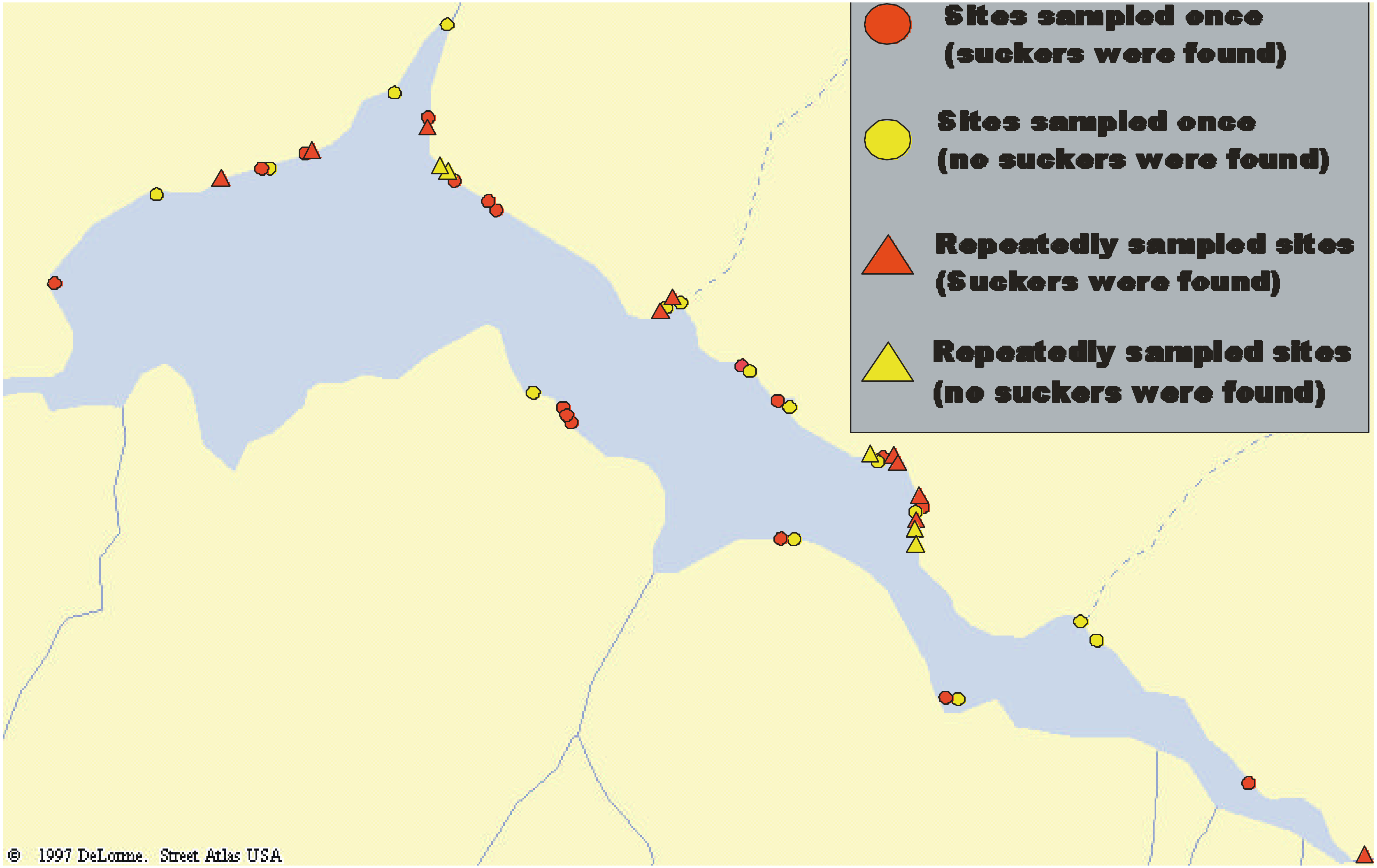

Figure A6. Sampling locations for larval and juvenile suckers on Copco reservoir during 1999. Gear types represented here include larval drift nets, dip nets, larval trawls, and beach seines.

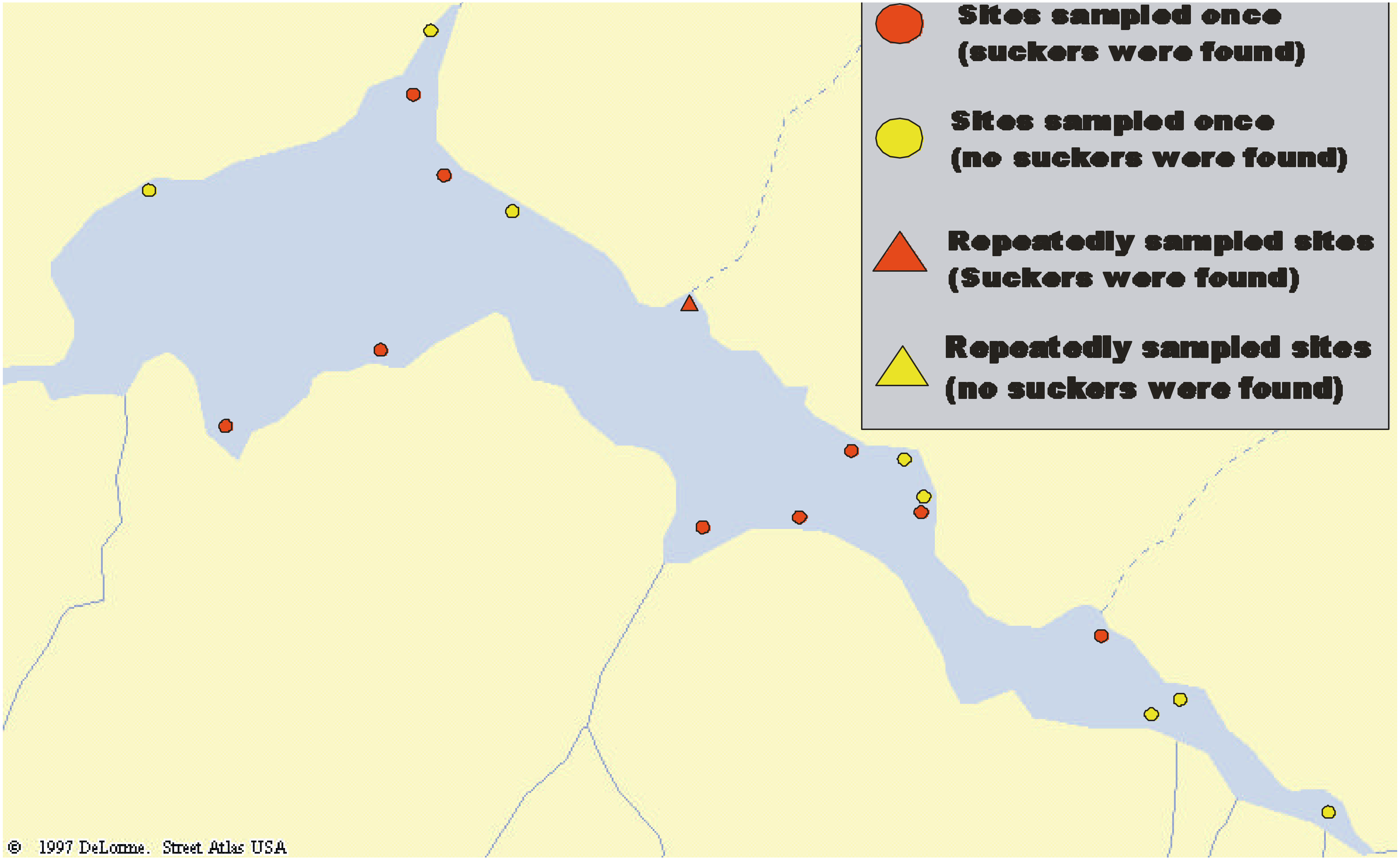

Figure A7. Sampling locations for adult *Chasmistes* on Copco reservoir during 1998. Gear types represented here include trammel and trap nets.

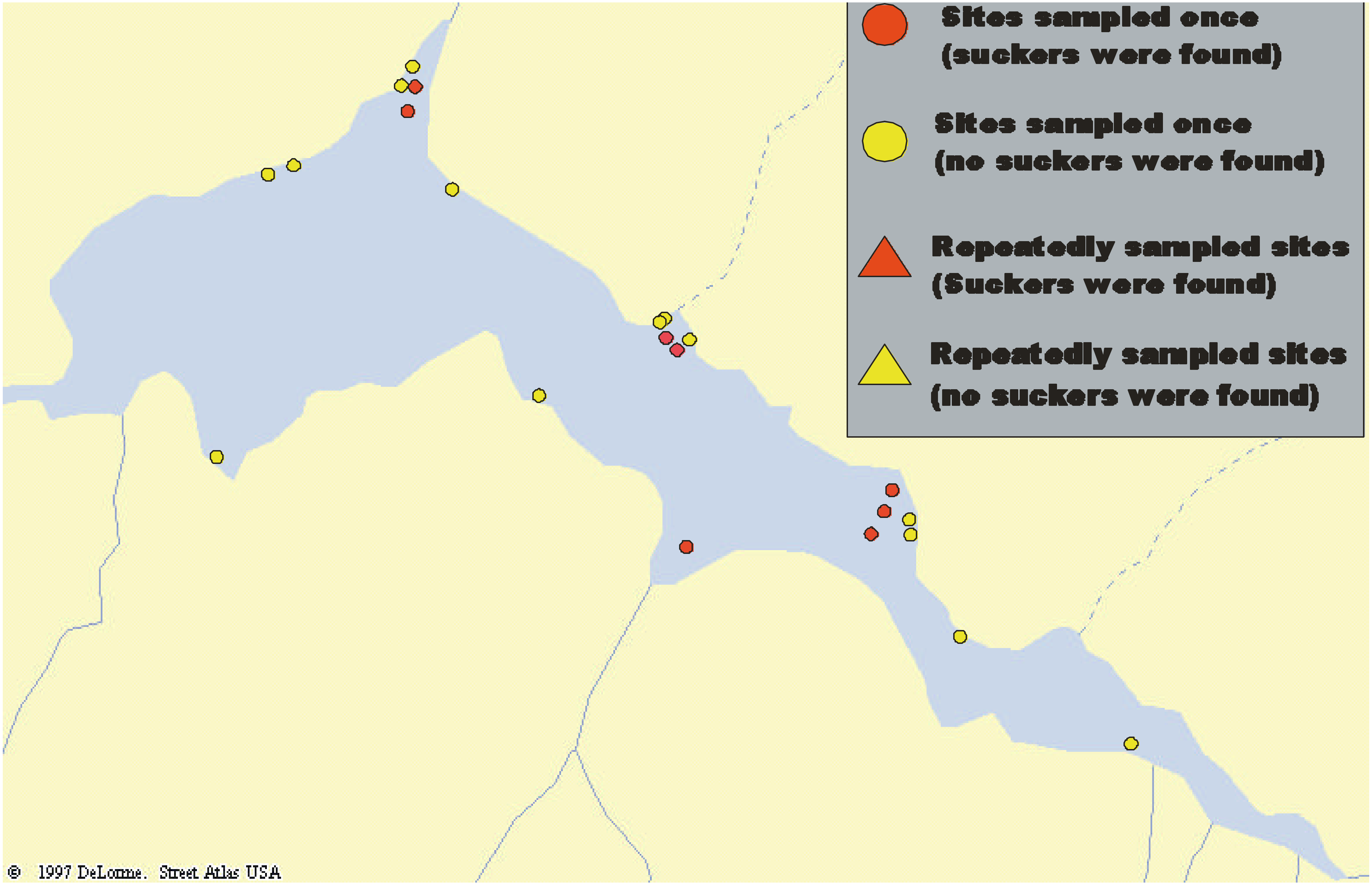

Figure A8. Sampling locations for adult *Chasmistes* on Copco reservoir during 1999. Gear types represented here include trammel and trap nets.

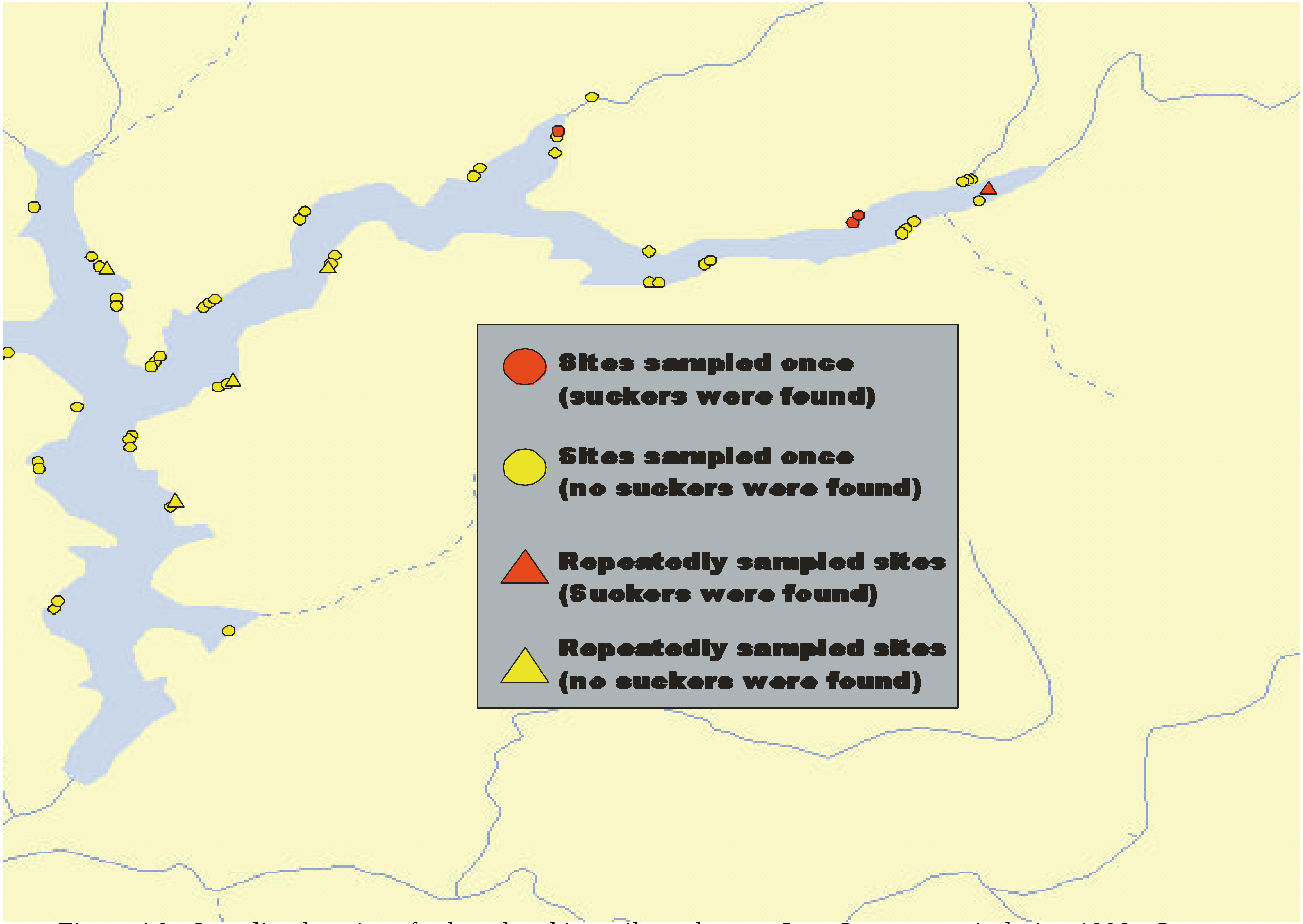

Figure A9. Sampling locations for larval and juvenile suckers on Iron Gate reservoir during 1998. Gear types represented here include larval drift nets, dip nets, larval trawls, and beach seines.

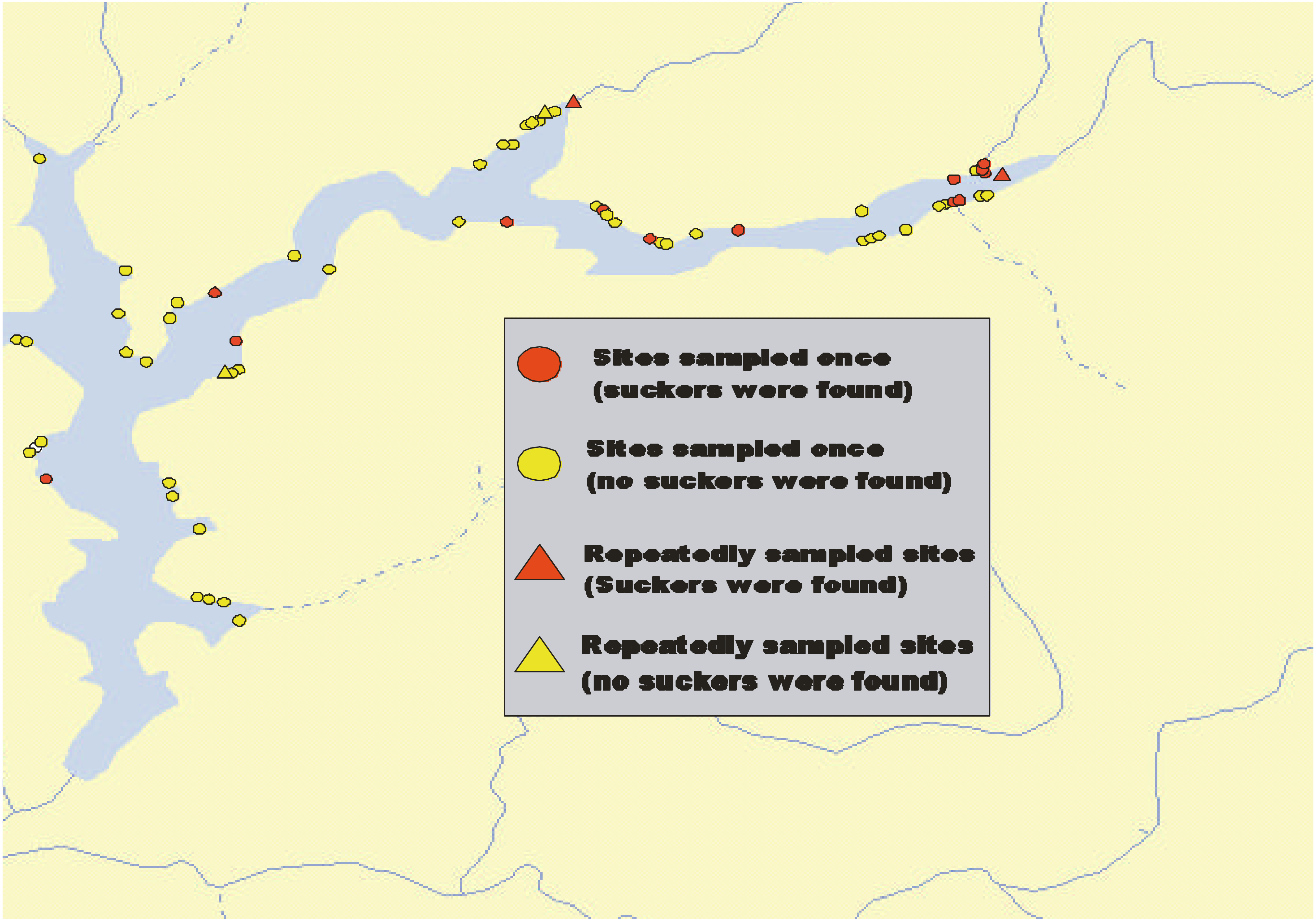

Figure A10. Sampling locations for larval and juvenile suckers on Iron Gate reservoir during 1999. Gear types represented here include larval drift nets, dip nets, larval trawls, and beach seines.

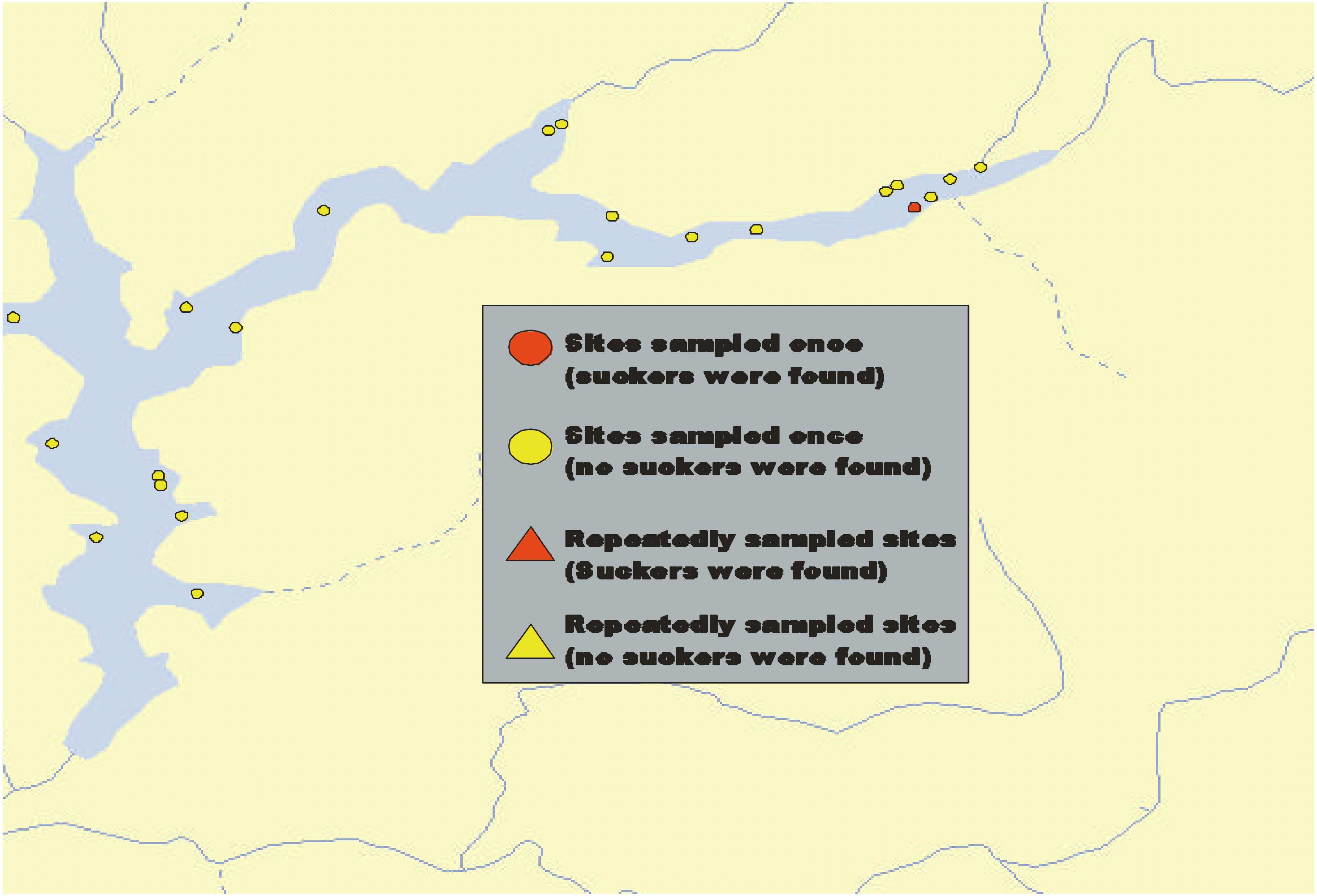

Figure A11. Sampling locations for adult *Chasmistes* on Iron Gate reservoir during 1998. Gear types represented here include trammel and trap nets.

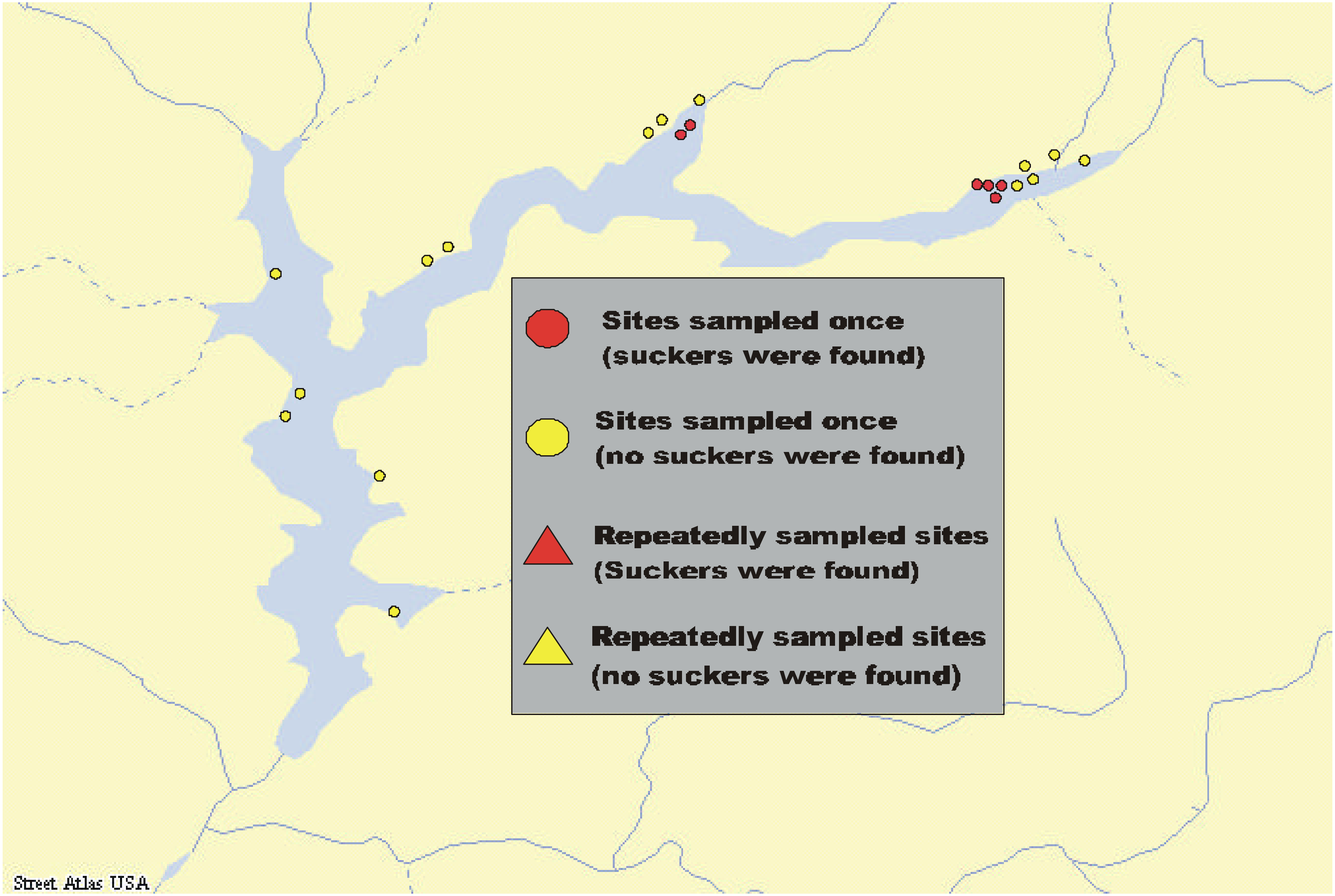

Figure A12. Sampling locations of adult *Chasmistes* from Iron Gate reservoir during 1999. The gear types represented here include trammel and trap nets.

Table A1. Particle size of each substrate type classified.

Substrate	Size (mm)
Fines	,0.06
Sand	0.06-2
Gravel	2-64
Cobble	64-250
Boulder	>250
Small Mix	More than 80% of particles less than 64mm
Inter. Mix	A wide variety of particles ranging from 0.06mm to >250mm
Large Mix	More than 80% of particles greater than 64mm