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INTERANNUAL ABUNDANCE OF NONNATIVE FATHEAD MINNOWS (*PIMEPHALES PROMELAS*) IN UPPER KLAMATH LAKE, OREGON

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ABSTRACT.—Since its introduction about 20 yr ago, fathead minnow (*Pimephales promelas*) has become very abundant in Upper Klamath Lake, Oregon. In 1991 mean beach seine catch per unit effort (CPUE) was 214, compared to 25 for native blue chub (*Gila coerulea*), the next most abundant species. In 45 trap-net samples collected in 1992, fathead minnow constituted 59% of the fishes caught in Agency Lake subbasin, 27% in Upper Klamath Lake, and 17% in tributary inflow habitats. From 1991 to 1995 fathead minnow declined and the abundance of some native fishes increased. Introduction to Klamath Basin was coincident with U.S. Environmental Protection Agency promotion of fathead minnow as bioassay subjects. Upper Klamath Lake fathead minnow have incomplete lateral lines and males have mandibular tubercles diagnostic of the northeastern subspecies. Although the origin, as bait bucket transfer, forage fish, or laboratory release, cannot be determined with certainty, the possibility of laboratory release suggests modification of bioassay protocols to require destruction of test or excess subjects.

Key words: fathead minnow, Oregon, nonnative species, species interactions, baitfish introductions, laboratory release.

Fathead minnow (*Pimephales promelas*) is broadly distributed east of the Rocky Mountains with a native range from Great Slave Lake, Canada, to Chihuahua, Mexico, and eastward to the Appalachians (Vandermeer 1966, Lee and Shute 1980). Hubbs and Black (1947) recognized 2 broadly distributed subspecies: *P. p. promelas*, a midwestern to northeastern form with an incomplete lateral line and nuptial tubercles on the lower jaw of breeding males; and *P. p. confertus*, a southwestern form with a complete lateral line and no nuptial tubercles on the lower jaw.

Fathead minnow was first collected from Oregon in Spencer Creek, a small tributary to Klamath River, 27 km downstream of Upper Klamath Lake on 13 May 1974 (Andreasen 1975). First reported in Upper Klamath Lake in 1979 (Ziller 1991), it was occasionally captured there in 1982 by Oregon Department of Fish and Wildlife (ODFW). By 1983 fathead minnow was captured in each ODFW trap net set (J. Ziller, fisheries biologist, ODFW, personal communication), and by 1993 we had captured the species from Klamath Marsh National Wildlife Refuge (50 km northeast of Upper Klamath Lake) and Gerber Reservoir (50 km southeast of Upper Klamath Lake; unpublished data).

Fathead minnow has been introduced in many western states as a bait and forage fish. State-sanctioned propagation and distribution began in adjacent states of Idaho about 1945 (Simpson and Wallace 1978) and California in 1953 (Shapovalov et al. 1959). Published information suggests early introductions of fathead minnow as bait and forage fish were *P. p. confertus*, the southwestern form (Evans and Douglas 1950, Miller 1952, Minckley 1973). The northeastern form of fathead minnow, *P. p. promelas*, was promoted as a bioassay subject by the U.S. Environmental Protection Agency (EPA) beginning in the late 1960s (EPA 1972, Brauhn and Schoettger 1975).

In this paper we document relative abundance of fathead minnow in Upper Klamath Lake from 1991 to 1995, discuss possible impacts on native fish, and compare the fish fauna before and after its introduction. We also comment on diagnostic morphological characters of Upper Klamath Lake fathead minnow and suggest possible origin(s).

DESCRIPTION OF AREA

Upper Klamath Lake, the headwaters of the Klamath River, is in south central Oregon east

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of the Cascades (Fig. 1) at 1262 m; it drains 9415 km^2 of mixed forest, grass-shrub flatland, and marshes (Johnson et al. 1985). The Williamson River is the major tributary, providing about half the inflow, while its northern subbasin, Agency Lake, is fed by the Wood River (Johnson et al. 1985). It is the largest lake in Oregon with a mean summer surface area of 27,811 ha, 141 km of shoreline, and a mean depth of 2.4 m (U.S. Army Corps of Engineers 1978, Johnson et al. 1985). The lake is hypereutrophic, highly turbid, and caustic (pH typically >9.0), with wide diel fluctuations in dissolved oxygen from near depletion to supersaturation (Bortleson and Fretwell 1993). High pH and anoxia are thought to be partially responsible for the declining populations of 2 endangered catostomids, Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris;* Scoppettone and Vinyard 1991). A 3rd catostomid in the Klamath Basin, Klamath largescale sucker (*Catostomus snyderi*), was formerly a U.S. Fish and Wildlife Service category 2 candidate species.

Subspecies Identification

We identified the subspecies of fathead minnow in Upper Klamath Lake using criteria of Hubbs and Black (1947): a complete lateral line and absence of mandibular nuptial tubercles on breeding males to diagnose *P. p. confertus*, and an incomplete lateral line and presence of mandibular nuptial tubercles on breeding males to diagnose *P. p. promelas*.

The following museum specimens were examined: Oregon, Klamath Drainage, Oregon State University (OS) 4944, OS 7953, OS 7955, OS 12506, OS 14116, OS 14326, OS 14327; Minnesota, Great Lakes Drainage, OS 14274 (from stocks maintained by EPA Environmental Research Laboratory–Duluth); and New Mexico, Rio Grande Drainage, Museum of Southwestern Biology, University of New Mexico (MSB) MSB 735.

Average lateral line completeness (pored/total lateral line scales) was 41% (range 6–83%, standard deviation [s] = 0.18) in Klamath, 41% (7–98%, s = 0.29) in Great Lakes and 95% (81–100%, s = 0.07) in Rio Grande fathead minnows. Breeding males from Upper Klamath Lake had an average of 4.3 (2–7, s = 1.45) tubercles on the chin, Great Lakes specimens had an average of 3.3 (1–5, s = 1.41) tubercles, and Rio Grande specimens had no chin tubercles.

Vandermeer (1966) showed a sharp break in lateral line completeness, with populations north and east of Kansas being 2.2–49.9% complete and those to the southwest 63.0–95.0% complete. He considered this northeast vs. southwest pattern to "present a classical pattern of subspecific variation." He also showed that mandibular nuptial tubercles on breeding males were virtually absent south of Kansas and high to the east, with 2 populations around Lake Michigan having mean chin tubercle counts of 4.3 and 11.4 (Vandermeer 1966). Upper Klamath Lake fathead minnows appear to be the northeastern subspecies, *P. p. promelas,* rather than the southwestern form, *P. p. confertus,* but this identification should be considered tentative until the systematics of fathead minnow is better resolved.

Methods

Beach Seine

Beach seine sampling was conducted in 1991, 1993, and 1995 as part of a long-term sampling program of sucker year class strength. Ten sites in Upper Klamath Lake and 5 in Agency Lake (Fig. 1) were sampled with a 6.1-m-long seine with 4.8-mm bar mesh and a 2 × 2 × 2-m bag. A sampling unit was a 1/4 circle arc that sampled 30 m^2. Sites were sampled weekly from 25 July to 26 September 1991, though the full complement of sites was typically not sampled as we implemented other aspects of our catostomid research. Sites were sampled monthly in July and August 1993, and biweekly in July and August 1995.

Analysis of variance (ANOVA) was used to test for differences in relative abundance among years for fathead minnow, blue chub (*Gila coerulea*), tui chub (*Gila bicolor*), and age-0 sucker (both species) catch per unit effort (CPUE). Because catch data frequency distributions were highly positively skewed, data were $\log_e$-transformed (CPUE+1) to better meet assumptions of normality required for ANOVA. Least significant difference (LSD) test was used on mean $\log_e$ (CPUE+1) values to identify interannual differences in abundance for significant ANOVA models. All analyses were performed using Statgraphics Version 7 (Manuguistics 1993).

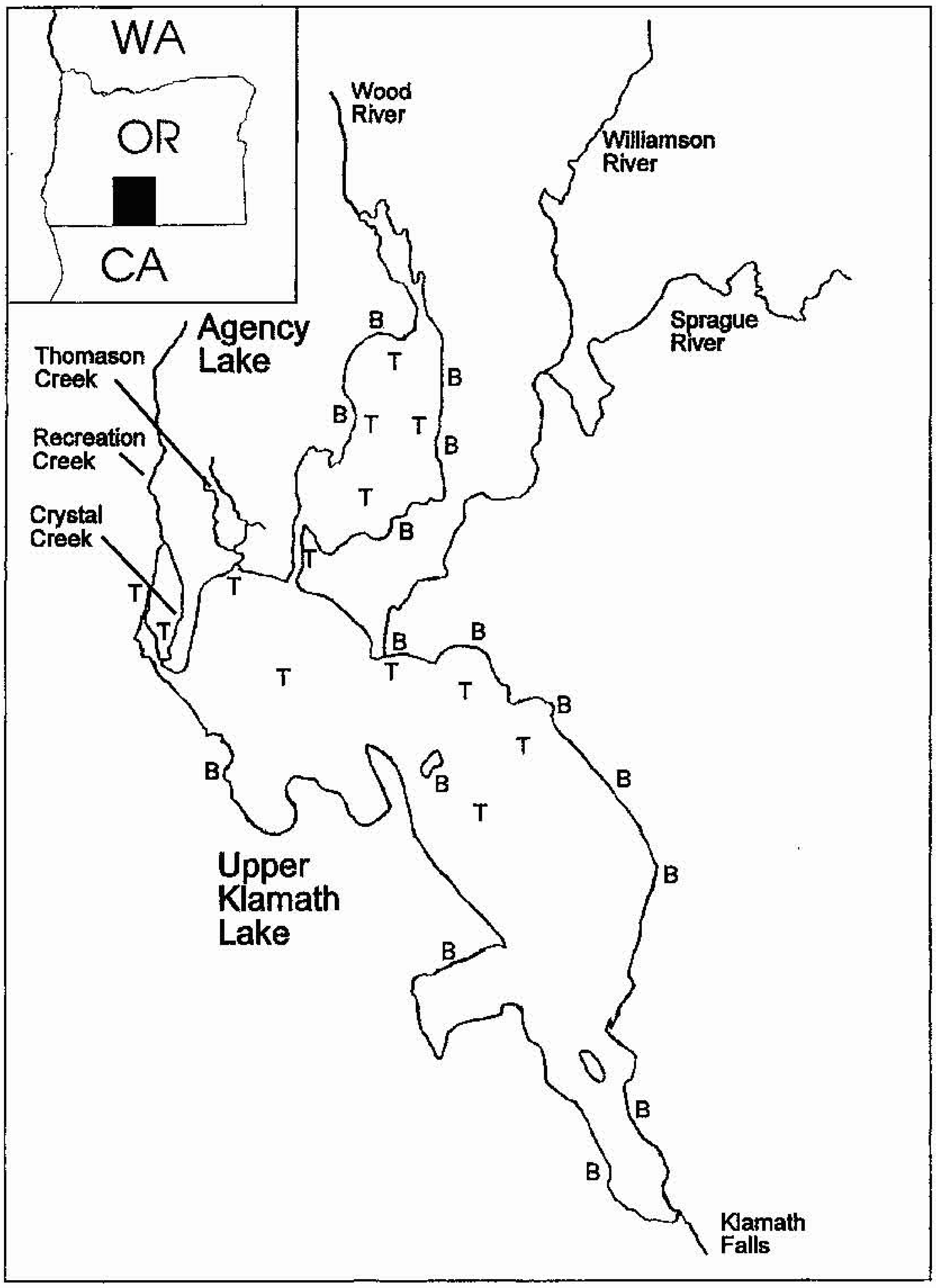

Fig. 1. Map showing Upper Klamath Lake and Agency Lake, Oregon. Shoreline beach seine sites are indicated by a B, and trap-net sites are indicated by a T.

Trap Net

Trap-net sampling was conducted from 21 April to 22 October 1992. Sites were in Agency Lake, the northern half of Upper Klamath Lake, and tributary inflows (lower Williamson River, Thomason Creek, Crystal Creek, and Recreation Creek; Fig. 1). Trap nets were 6.5-mm bar mesh, had a single 2.4 × 23-m lead, two 2.4 × 10.7-m wings, and a 1.2 × 1.2-m square frame with two 10-cm throats. Lake trap nets were set offshore in open water. River mouth trap nets were set in mid-channel. Trap nets were usually set overnight and fished for approximately 24 h, but set times ranged from 15.5 to 99.0 h. We found no significant ($P > 0.05$, $r = 0.037$) relationship between number of hours fished and $\log_e$-transformed number of fish caught, so we calculated trap-net CPUE as number per net.

The only available data for evaluating historical change are 1964 and 1965 surveys in Upper Klamath Lake by Vincent (1968). Vincent's data and analyses are difficult to interpret because he reported pooled results from a gang of 3 gill nets and a single hoop net. His gill nets had stretched mesh sizes 32, 45, 57, and 152 mm, but he gave no mesh size for the hoop net. With 1 exception, he reported results as percent composition rather than in terms of effort. We make comparisons of our trap-net data to Vincent's data, but caution that our data are not directly comparable to his, and only crude comparisons are useful.

RESULTS

Beach Seine

Fathead minnow was the most common species in Upper Klamath Lake beach seines during 1991 (CPUE = 214.4, coefficient of variation [CV] = 270), followed by blue chub (CPUE = 24.9, CV = 190) and tui chub (CPUE = 9.6, CV = 266). Fathead minnow density declined significantly ($P < 0.05$) each year from 1991 to 1995, while blue chub and age-0 sucker increased significantly ($P < 0.05$) from 1991 to 1995 (Fig. 2). Tui chub CPUE trended upward each year but was not significant ($P > 0.05$). Except for yellow perch (*Perca flavescens*) in 1993, other species never exceeded 2% of the total catch in any year. Yellow perch was 7% of the 1993 catch, all of which were age-0. Other native species included marbled sculpin (*Cottus klamathensis*), slender sculpin (*Cottus tenuis*), and Klamath Lake sculpin (*Cottus princeps*); nonnative species included yellow perch, bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*).

In Agency Lake beach seine samples, fathead minnow CPUE also decreased significantly ($P < 0.05$) from 1991 (CPUE = 219.6, CV = 179) to 1995 (CPUE = 108.5, CV = 346), with 1993 intermediate (CPUE = 185.8, CV = 161). Changes in abundance of native species were unclear, with no significant ($P > 0.05$) differences among years for blue chub, tui chub, or age-0 sucker CPUE in Agency Lake.

Trap Net

Fish were captured during 45 trap-net samples: 11 from Upper Klamath Lake, 13 from Agency Lake, and 21 from tributary inflow areas. Fathead minnow was the most abundant species captured in Agency Lake, 2nd in abundance in Upper Klamath Lake, and 4th in abundance in tributaries (Table 1). Agency Lake trap nets caught fewer species (10) than Upper Klamath Lake (13) or tributaries (14), but total catch rates were higher. Variation in

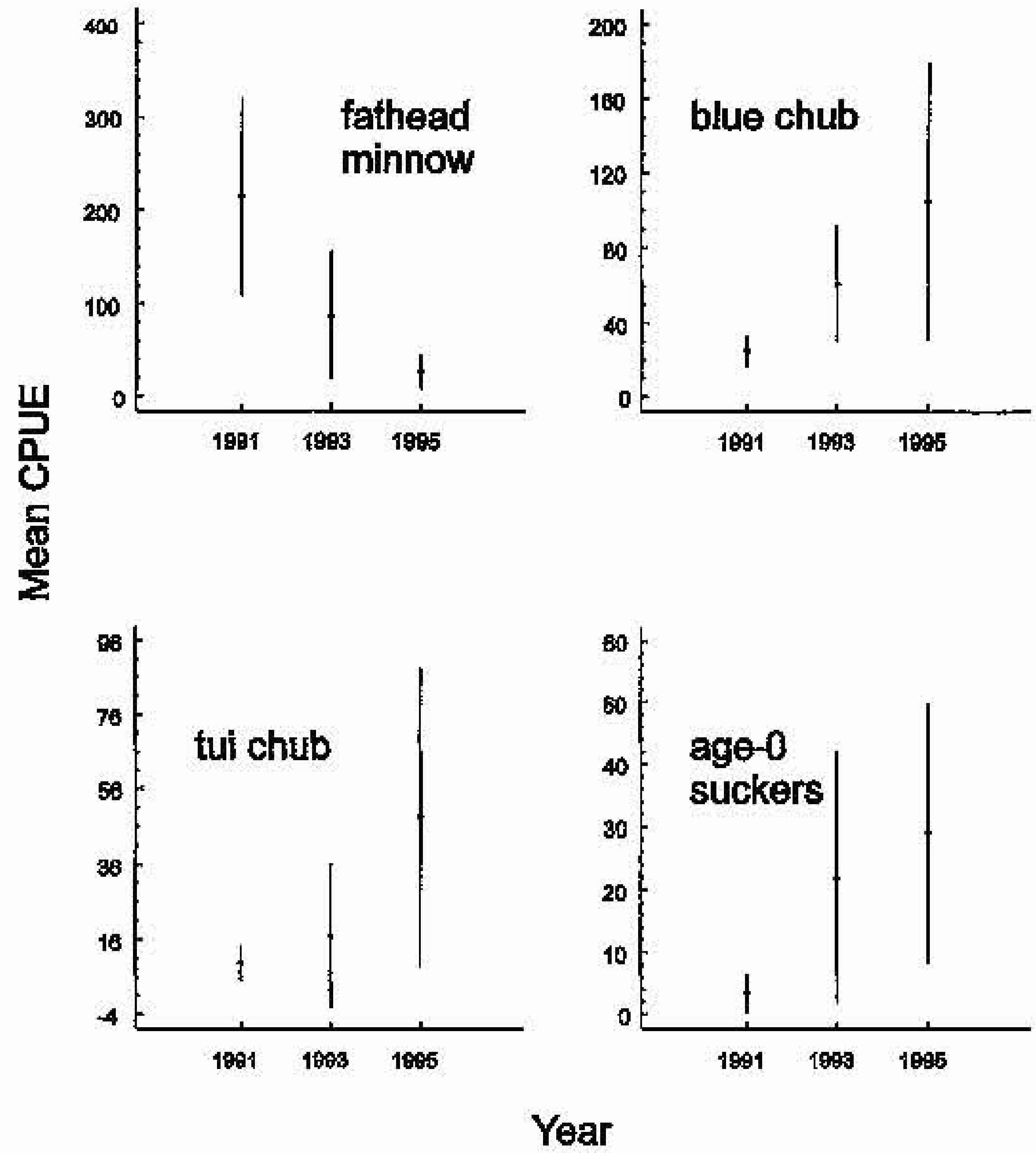

Fig. 2. Mean and 95% confidence intervals of beach seine CPUE for fathead minnow, blue chub, tui chub, and age-0 sucker from Upper Klamath Lake, 1991–1995.

catch rates was much higher in tributaries than in lake samples (Table 1).

Compared with Vincent's (1968) data, our trap-net data (Table 2) are noteworthy in the presence of fathead minnow. However, without knowledge of the mesh size of Vincent's trap nets, we cannot determine whether fathead minnow were vulnerable to his gear. In our trap nets fathead minnow constituted 17% of the fish in tributaries, 27% in Upper Klamath Lake, and 59% in Agency Lake. Because fathead minnow now represents a substantial portion of the fish fauna, percentages of other species must decline if densities remain constant. Vincent (1968) mentioned tui chub was caught at a maximum rate of about 5 per hour (h) in July and December. Based on his relative species composition (Table 2), Vincent's maximum rate for blue chub must have been about 8.3/h. Our 1992 Upper Klamath Lake trap-net catch rates were 1.1 tui chub/h and 18.9 blue chub/h, indicating that tui chub may have declined after the introduction of fathead minnow. However, we found up to a 5-fold increase in interannual beach seine abundance for tui chub from 1991 (CPUE = 9.6) to 1995 (CPUE = 48.6) and a 4-fold increase in blue chub from 1991 (CPUE = 24.9) to 1995 (CPUE = 105) in our surveys. Thus, apparent changes in abundance from the 1960s in both chub species could be attributed

TABLE 1. Species, mean catch (number per net), median catch (number per net), and coefficient of variation (CV) of the mean for fish caught in trap nets from Upper Klamath Lake, Agency Lake, and tributary inflow habitats in 1992.

Species	Mean	Median	CV
UPPER KLAMATH LAKE			
blue chub	484.1	417.0	88
fathead minnow	175.2	60.0	125
tui chub	41.0	24.0	133
Klamath Lake sculpin	6.5	1.0	175
marbled sculpin	5.7	4.0	144
slender sculpin	1.4	0	244
Pacific lamprey	0.5	0	228
suckers[a]	0.4	0	185
yellow perch	0.1	0	331
brown bullhead	0.1	0	332
pumpkinseed	0.1	0	332
bluegill	0.1	0	332
	715.0	625.0	82
AGENCY LAKE			
fathead minnow	559.8	356.0	109
blue chub	135.5	88.0	104
tui chub	59.2	70.0	77
yellow perch	21.8	0	249
marbled sculpin	2.3	1.0	146
Klamath Lake sculpin	1.3	0	193
Pacific lamprey	1.1	0	180
brown bullhead	0.3	0	205
suckers[b]	0.1	0	361
slender sculpin	0.1	0	361
pumpkinseed	0	0	—
bluegill	0	0	—
	781.5	793.0	81
TRIBUTARY INFLOW HABITATS			
blue chub	105.8	13.0	237
brown bullhead	39.0	0	309
tui chub	17.4	7.0	203
fathead minnow	9.6	3.0	149
yellow perch	4.6	2.0	128
marbled sculpin	3.8	1.0	154
suckers[c]	2.8	1.0	206
Klamath Lake sculpin	2.5	0	201
pumpkinseed	1.0	0	199
Pacific lamprey	0.7	0	183
slender sculpin	<0.1	0	458
bluegill	<0.1	0	458
	187.3	97.0	168

[a]Lost River and shortnose sucker
[b]Lost River sucker
[c]Lost River, shortnose, and Klamath largescale sucker

to fathead minnow introduction, natural population variation, or susceptibility to poorer water quality (Castleberry and Cech 1993).

DISCUSSION

With the possible exception of native catostomids, the fish community of Upper Klamath Lake appears resilient. Williams (1988) partly attributed the decline of Lost River and shortnose suckers to competition and/or predation by nonnative species. Most nonnative species in Upper Klamath Lake (bluegill, pumpkinseed, yellow perch, and brown bullhead [*Ameirus nebulosus*]) are relatively rare, and density-dependent impacts on suckers might be small. However, fathead minnow is still abundant even after a 5-yr decline. Although the fathead minnow reportedly consumes algae, higher plants, zooplankton, and insects (Becker 1983), Dunsmoor (1993) has experimental evidence that it feeds on sucker larvae in aquaria; additionally, Franzin and Harbicht (1992) found walleye (*Stizostedion vitreum*) larvae in fathead minnow stomachs from a Manitoba irrigation drainage.

If fathead minnow has a density-dependent impact on suckers or other native fishes, we might expect a compensatory response to the fathead minnow decline we observed from 1991 to 1995. Extraneous mechanisms influencing the direction of change of fish abundances from 1991 to 1995 are unknown. Because Upper Klamath Lake is managed by the U.S. Bureau of Reclamation as an irrigation reservoir, lake levels are regulated. However, there is no active management to reduce fathead minnow abundance. Only 2 active management strategies have been implemented as a consequence of endangered species listing of Lost River and shortnose sucker: (1) closure of a snag fishery on adult sucker, and (2) prolonged elevation of springtime water levels. The 1st strategy would seem to have little impact on fathead minnow abundance. The 2nd inundates sucker spawning gravels and shoreline vegetation and was designed to provide cover to reduce larval sucker

TABLE 2. Comparison of percent species composition for 1992 trap-net samples from this study with data reported from Upper Klamath Lake by Vincent (1968): UKL = Upper Klamath Lake, AL = Agency Lake, and TI = tributary inflow habitats.

Species or species group	TI	AL	UKL	Vincent (1968)
lampreys	2	<1	<1	<1
trouts	—	—	—	<1
brown bullhead	13	<1	<1	5
tui chub	10	9	7	35
blue chub	36	20	62	58
fathead minnow	17	59	27	—
suckers	1	<1	<1	<1
sculpins	13	2	4	<1
yellow perch	8	9	<1	2
sunfish	<1	—	<1	<1

vulnerability to predation. However, prolonged springtime water levels could also promote fathead minnow abundance by providing complex structural spawning habitat, such as undersurfaces of rocks, logs, and vegetation (Scott and Crossman 1973, Becker 1983). Although the trends evident in Figure 2 suggest that elevated springtime water levels had the desired effect by increasing young sucker abundance, they did not increase fathead abundance.

Native fishes have responded positively to declines of nonnatives in other systems, such as the Great Lakes (Jude and Tesar 1985, Eck and Wells 1987), North Carolina streams (Lemly 1985), and Great Smoky Mountains National Park streams (Moore et al. 1984). However, we found no documentation of responses of western U.S. native fishes where spread of nonnatives has seriously compromised many native fish populations (Minckley and Douglas 1991, Rinne and Minckley 1991). We have demonstrated in Upper Klamath Lake that decreasing abundance of nonnative fathead minnow is associated with increasing abundance of some native fishes.

Finally, diagnostic characteristics of Klamath fathead minnows indicate they are of northeast origin, possibly including the Great Lakes region where EPA began use and promotion of fathead minnow as a standard bioassay subject. Governmental and other laboratories using fathead minnow in bioassay work, as well as baitshops, obtain supplies from multiple sources, often the lowest bidder. Thus, it is not known whether there have been laboratory releases of fathead minnow and, if so, whether these could be distinguished from baitfish release. However, their detection in Oregon was coincident with the promotion of fathead minnow by EPA and 21–29 yr after their introduction as baitfish in neighboring Idaho and California (Shapovalov et al. 1959, Simpson and Wallace 1978).

The potential for nonnative bioassay subjects to be released—and the irony that it might happen in the furtherance of environmental protection—suggests a prudent countermeasure. Although the EPA's published protocols specify initial quarantine of incoming fish, they do not specify disposition of excess or test fathead minnow except in some larval assays where specimen fixation in formalin is part of the assay (Brauhn and Schoettger 1975, Norberg and Mount 1985, DeGraeve et al. 1991). It can be argued that states govern access, distribution, and handling of fishes within their borders; but a laboratory's record for following EPA protocols may be a greater incentive than poorly enforced state regulations, and the costs of disastrous introductions far outweigh the minimal costs associated with destruction of test organisms. All protocols for bioassay of exotic organisms should specify destruction of all test and all excess individuals at the end of the bioassay.

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