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Habitat Use of Twenty-five Common Species of Oregon Freshwater Fishes

Abstract

This study had two objectives. The first was to determine the use of the physical habitat by the 25 most common native freshwater fishes of Oregon, and the second was to evaluate the use of a large computer database of museum records in the determination. The database encompasses 2021 collections made by various field workers from 1880 to 1984. Statistically distinct habitat use patterns appear for 17 of the species for temperature, 17 for substrate, 19 for stream width, and 22 for current velocity. Habitat use identified from this statistical evaluation is generally consistent with the subjective evaluations of field ichthyologists, and the study revealed additional information for some species. A large computer database compiled from field notes of many collectors allowed useful generalizations concerning species habitats, even though methods of collecting and recording differed greatly. Such databases also permit greater quantification than is typical of species accounts and more robust habitat descriptions than those gleaned from a small number of site specific studies.

Introduction

The objective of this paper is to examine, through statistical analysis of a large computer database, the use of certain aspects of the physical habitat by common freshwater fish species of Oregon. Evaluations of habitat use of many of these species plus others are provided in several standard reference works (Morrow 1980, Moyle 1976, Scott and Crossman 1973, Simpson and Wallace 1978, Wydoski and Whitney 1979). These habitat descriptions are drawn largely from decades of field experience by professional ichthyologists, from intensive research by students examining particular species in particular drainages (e.g., Finger 1979, Ikusemiju 1967, Mathews 1962), and from laboratory studies of particular species (e.g., Ferguson 1958).

We believe that statistical analyses of extensive historical data on habitats of species and their occurrences provide valuable supplements to published material. Such analyses are generally more defensible than qualitative evaluations of field notes and offer greater geographic and temporal coverage than studies of given sites or drainages.

Methods

We compiled a database of more than 9000 collections of freshwater and euryhaline fishes in Oregon. These data were collected during the past century and obtained from the ichthyological collections of the Department of Fisheries and Wildlife, Oregon State University; the University of Michigan Museum of Zoology (UMMZ); and the California Academy of Sciences (CAS) (Rexstad 1987). Eighty-six percent of the collections were made since 1950.

The field collections from which the database is constructed were made by many persons for many different purposes. There was no standard method of collecting or of assessing environmental conditions, and there were obvious biases for season and locality. In the database, observations of habitat-species relationships ranged from detailed measurements of habitat for each collected individual to broad characterizations of the entire collection site generalized to individual species. Although the database is more useful for studying species distributions and communities (Hughes *et al.* 1987) than for examining habitat use patterns, we believe that the included data on habitat provides useful information for the most common species.

The database contained information on up to 50 variables for each collection, including aspects of geography, associated fauna, and descriptions of physical and biological habitat. These data were checked rigorously before being entered into the database and subsequently scrutinized by automated error-detection software. Variables subjected to analysis and the numbers of collections for which each is recorded are the following: water temperature (1792); substrate composition (2021); stream width (1577) and current velocity (1876).

Because we were concerned with evaluating use of particular habitat variables by particular species, and did not wish to determine the portion of a general environmental gradient along which several species are distributed, we chose chi-square analysis over principal components analysis (PCA). Although PCA is an effective tool for evaluating multivariate gradients (Felly 1984, Matthews 1985, Grossman and Freeman 1987), we considered chi-square more appropriate to our data, in that it allows greater opportunity than PCA to assess the importance of individual variables for particular species. Only four habitat variables in the database represented a sufficient number and quality of collections, precluding the need to distill mathematically a small number of variables from the database. Also, spurious correlations among species and habitat variables that are masked by PCA (Beals 1973) are more clearly revealed by examination of the separate variables in chi-square analysis. Finally, chi-square analysis provides a useful tool for examining habitat use of individual species rather than guilds.

Chi-square was used to determine whether the frequency with which a species occurred under particular conditions differed substantially from the hypothetical population frequency. The distribution of observations over all species for each habitat category served as an expected distribution of habitat. To test for departure from expected distributions, chi-square tests for multinomial data (Ostle and Mensing 1975) were performed for each species and habitat category.

Results and Interpretation

Frequency of Occurrence

The frequency with which species appear in the database reflects their ubiquity, the extent of their distribution in Oregon and collecting effort (Table 1). Most species in Table 1 probably appear in relation to their availability to collectors. The 784 collections of speckled dace, *Rhinichthys osculus,* document its ecological versatility and presence in nearly all drainages in the state. The reticulate sculpin, *Cottus perplexus,* the second most frequently collected species, is ubiquitous in western Oregon, where 62 percent of the collections were made. The rainbow trout, *Salmo*[1] *mykiss,* although somewhat restricted ecologically, is found in nearly all drainages, so its appearance as the third most frequently collected species is not surprising. Two Klamath Basin species (marbled sculpin, *Cottus klamathensis,* and blue chub, *Gila coerulea*) represent an

TABLE 1. The most frequently occurring freshwater fish species in the Oregon database.

Rank	Species	Number of Collections
1	*Rhinichthys osculus*	784
2	*Cottus perplexus*	660
3	*Salmo mykiss*	612
4	*Richardsonius balteatus*	531
5	*Salmo clarki*	416
6	*Cottus rhotheus*	366
7	*Oncorhynchus kisutch*	348
8	*Gila bicolor*	332
9	*Catostomus macrocheilus*	306
10	*Ptychocheilus oregonensis*	286
11	*Oncorhynchus tshawytscha*	251
12	*Lampetra tridentata*	240
13	*Rhinichthys cataractae*	229
14	*Cottus asper*	218
15	*Cottus aleuticus*	192
16	*Cottus gulosus*	163
17	*Cottus beldingi*	149
18	*Acrocheilus alutaceus*	146
19	*Salmo* sp. (redband trout)	143
20	*Cottus klamathensis*	133
21	*Gasterosteus aculeatus*	126
22	*Catostomus columbianus*	125
23	*Gila coerulea*	122
24	*Micropterus salmoides*[1]	121
25	*Ictalurus nebulosus*[1]	101
26	*Cottus confusus*	97
27	*Lampetra richardsoni*[2]	91

[1]Introduced species

[2]Includes *Lampetra pacifica*

[1]Because the generic status of the native trouts of the Pacific drainage is currently under debate, but not yet agreed upon by systematic ichthyologists, we are conservatively using *Salmo* instead of the recently used *Parasalmo,* which appears to be a junior synonym of *Rhabdofario,* or *Oncorhynchus,* to which these trouts may eventually be referred. We accept the priority of *mykiss* over *gairdneri.*

unexpected proportion because of an extended project that resulted in 986 collections (11 percent of the database) from the basin.

Native fishes dominate Table 1. In fact, of the 36 introduced species in Oregon, only six appear among the 40 most-frequently collected. Most of the introduced fishes such as the centrarchids, percids and ictalurids are panfishes or sportfishes that have become established and sometimes dominate in warm, lentic waters. The common carp, *Cyprinus carpio,* is abundant or dominant in some sloughs, lakes and reservoirs. Brown trout, *Salmo trutta,* and brook trout, *Salvelinus fontinalis,* are successful in some spring-fed and high altitude habitats. In a 1984 survey of 99 relatively undisturbed small streams characteristic of the eight Oregon landscape regions, introduced species were found at 19 sites and represented greater than 10 percent of the individuals at 13 sites (R. M. Hughes pers. comm., Whittier *et al.* 1988). In most undisturbed lotic habitats in the state, native fishes are apparently competing well with introduced species.

Temperature

Most collections recorded in the database were made during summer, the primary field season for research; 90 percent of the records were from April through September. August collections accounted for 23 percent of the total temperature records. The expected distribution of species by water temperatures (n = 1792) was as follows: less than 9.9C, 16.2 percent; 10-14.9C, 23.3 percent; 15-19.9C, 37.2 percent; and 20C or greater 23.4 percent. Of the 25 species included in the study, eight showed insignificant ($P > 0.05$) deviations from the observed distribution of water temperature (Tables 2 and 3). The following discussion pertains only to those species showing significant differences from random

TABLE 2. Chi-square values for distribution of the four habitat variables for each species. Asterisks indicate significance level (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

Species	Water Temperature	Bottom Type	Stream Width	Current Velocity
Acrocheilus alutaceus	2.7	4.4	63.3***	8.2*
Catostomus columbianus	55.8***	0.7	16.0**	0.7
Catostomus macrocheilus	3.9	1.8	29.5***	9.4**
Cottus aleuticus	12.5**	24.9***	10.3	27.3***
Cottus asper	12.0**	10.7**	12.7*	7.5*
Cottus beldingi	3.0	40.1***	15.6**	18.7***
Cottus confusus	28.6***	18.1***	52.3***	48.8***
Cottus gulosus	43.1***	15.9***	57.6***	17.7***
Cottus klamathensis	7.7	15.9***	160.5***	18.3***
Cottus perplexus	29.9***	0.9	13.0*	3.6
Cottus rhotheus	17.3***	41.1***	21.9***	9.8**
Gasterosteus aculeatus	11.7**	25.1***	8.3	25.1***
Gila bicolor	23.5***	66.3***	0.8	18.9***
Gila coerulea	32.8***	24.8***	98.5***	21.3***
Lampetra richardsoni[1]	103.2***	9.4**	26.5***	7.0**
Lampetra tridentata	15.0***	6.9*	10.0	25.4***
Oncorhynchus kisutch	92.7***	35.0***	14.3*	16.3***
Oncorhynchus tshawytscha	5.8	27.5***	164.3***	70.8***
Ptychocheilus oregonensis	1.4	3.4	20.6***	19.0***
Rhinichthys cataractae	31.3***	1.3	15.9**	27.1***
Rhinichthys osculus	1.8	1.4	4.8	5.6
Richardsonius balteatus	10.4*	6.9*	7.1	8.8*
Salmo clarki	11.0*	0.5	41.1***	7.7*
Salmo mykiss	1.7	6.6*	15.9**	8.3*
Salmo sp. (redband trout)	10.2*	11.3**	78.4***	16.1***

[1]Includes *Lampetra pacifica*

TABLE 3. Percent occurrence of selected Oregon freshwater fishes by water temperature (degrees Centigrade), sorted in order of increasing occurrence in cool water (occurrence in 0-9.9). Asterisks indicate chi-square significance level (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

		Temperature °C			
Species	n	0-9.9	10-14.9	15-19.9	20+
G. bicolor ***	94	4.3	12.2	46.8	36.2
R. balteatus *	103	6.8	19.4	40.8	33.0
R. cataractae ***	50	8.0	6.0	60.0	26.0
G. aculeatus **	30	10.0	16.7	53.3	20.0
A. alutaceus	29	10.3	24.1	41.4	24.1
C. macrocheilus	52	11.5	21.2	46.2	21.2
C. columbianus ***	42	11.9	2.5	33.3	52.3
R. osculus	211	11.9	20.9	37.9	26.5
C. klamathensis	15	13.3	13.3	46.7	26.6
S. mykiss	117	13.7	26.5	40.2	19.7
C. beldingi	35	14.3	17.1	42.9	25.7
P. oregonensis	58	17.3	19.0	41.4	22.4
C. confusus ***	27	18.5	44.4	22.2	14.8
C. rhotheus ***	51	19.2	37.3	33.3	9.8
O. tshawytscha	15	20.0	13.3	40.0	26.6
Salmo sp. (redband trout) *	62	20.0	33.9	32.3	13.9
L. tridentata ***	47	21.3	36.2	29.8	12.8
C. asper **	28	21.5	32.1	35.7	10.7
S. clarki *	36	22.2	30.6	36.1	11.1
G. coerulea ***	21	23.8	9.5	23.8	42.9
C. aleuticus **	33	27.3	27.3	30.3	15.2
C. perplexus ***	132	31.1	31.8	30.3	6.8
C. gulosus ***	27	33.3	37.0	22.2	7.4
L. richardsoni[1] ***	35	45.7	40.0	14.3	0.0
O. kisutch ***	36	50.0	22.2	25.0	2.8
Total collections in database	1792	16.2	23.3	37.2	23.4

[1]Includes *L. pacifica*

distributions, as estimated by our hypothetical distribution calculated from the observations of all species. The western brook lamprey, *Lampetra richardsoni* (includes *L. pacifica*), shows the narrowest range; more than 85 percent of its collections are nearly equally divided between the 5-9.9C and 10-14.9C categories. That distribution probably results from a preponderance of collections (68 percent) during its spawning season (April and May).

The distribution of several species is skewed toward cool water. Fifty percent of the collections of coho salmon, *Oncorhynchus kisutch,* are at temperatures between 0 and 9.9C; 90 percent of the collections of *Cottus perplexus* and Aleutian sculpin, *C. aleuticus,* are nearly equally subdivided among the three categories between 0 and 19.9C. The temperature distributions of redband trout, *Salmo* sp., and cutthroat trout, *S. clarki,* are about 20 percent in 5-9.9C and 30 percent to 36 percent in each of the next two higher categories. Pacific lamprey, *Lampetra tridentata,* and prickly sculpin, *C. asper,* also are found in cool water.

The 10-14.9C interval is typical for shorthead sculpin, *Cottus confusus,* torrent sculpin, *C. rhotheus,* and riffle sculpin, *C. gulosus* (44, 37 and 37 percent respectively), but distribution around this interval differs. More than 33 percent of the *C. rhotheus* collections are in the 15-19.9C interval and over 33 percent of *C. gulosus* collections are in the 0-9.9C range. *C. confusus* is taken about 20 percent of the time in each of those two categories. There are a few collections of *C. gulosus* and *C. confusus* in waters warmer than 25C.

Some species tend to be found in warmer water than these cottids. For example, 60 percent of the longnose dace, *Rhinichthys cataractae,* collections are from 15-19.9C water and 26 percent from temperatures greater than 20C. The threespine stickleback, *Gasterosteus aculeatus,* is found about 17 percent of the time in 10-14.9C, about 53 percent in 15-19.9C and 20 percent in water warmer than 20C. The redside shiner, *Richardsonius balteatus,* occurs in waters warmer than 14.9C about 74 percent of the time and in waters cooler than 10C about 7 percent of the time. About 47 percent of the collections of tui chub, *Gila bicolor,* are from the 15-19.9C interval, and about 36 percent from the 20+ interval. *G. coerulea* appears in water warmer than 20C in 43 percent of the collections. The bridgelip sucker, *Catostomus columbianus,* is significantly over-represented in warm water. It is taken 85 percent of the time in water warmer than 15C; more than 52 percent of the collections are from water temperatures greater than 20C (actually, nearly 7 percent from water > 25C).

Bottom type

Data for bottom type (n = 2021) were interpreted and assigned to the following categories (number in parentheses indicates percentage occurrence in the database over all species): "rubble" (24.0%), which included bedrock, boulders and rubble; "pebble" (57.2%), large to small gravel; and "sand" (18.8%), coarse sand to silt. More refined categories are precluded by the qualitative nature of the data and the differing terminologies used by collectors.

Seventeen species show statistically distinct patterns of substrate use (Tables 2 and 4). *Cottus* species, except for *C. asper* and *C. perplexus*

TABLE 4. Percent occurrence of selected Oregon freshwater fishes by bottom type, sorted in order of increasing occurrence over rubble substrate. Asterisks indicate chi-square significance level (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.005$).

		Bottom Type		
Species	n	Rubble	Pebble	Sand
C. rhotheus ***	45	6.7	88.9	4.4
G. bicolor ***	111	11.7	37.8	50.5
L. richardsoni[1] **	34	11.8	70.6	17.6
G. aculeatus ***	29	13.8	48.3	37.9
P. oregonensis	60	18.3	56.7	25.0
L. tridentata *	53	18.9	69.8	11.3
R. balteatus *	131	19.9	51.2	29.0
C. asper ***	38	21.1	47.4	31.6
C. macrocheilus	71	21.1	54.9	23.9
C. columbianus	49	22.4	61.2	16.3
C. confusus ***	31	22.6	74.2	3.2
C. aleuticus ***	33	24.2	75.8	0.0
C. perplexus	152	24.3	60.5	15.1
R. cataractae	56	25.0	60.7	14.3
S. mykiss *	135	25.2	65.9	8.9
S. clarki	43	25.6	58.1	16.3
R. osculus	238	26.1	59.7	14.3
C. gulosus ***	31	29.0	67.7	3.2
Salmo sp. (redband trout)***	65	29.8	66.2	6.2
A. alutaceus	32	31.3	56.3	12.5
G. coerulea ***	27	33.3	33.3	33.3
C. klamathensis ***	20	40.0	40.0	20.0
O. tshawytscha ***	18	44.4	50.0	5.6
C. beldingi ***	43	46.5	53.5	0.0
O. kisutch ***	63	49.2	36.5	14.3
Total collections in database	2021	24.0	57.2	18.8

[1]Includes *L. pacifica*

usually are found over coarse substrates; *C. asper* is found frequently on sand and *C. perplexus* appears not to discriminate. Pacific salmon, *Oncorhynchus* spp., usually are collected over coarse substrates as is the redband trout and, to a lesser extent, *Salmo mykiss. Lampetra richardsoni* and *L. tridentata* are taken about 70 percent over pebble substrate. *Gasterosteus aculeatus* is collected over fine bottom materials in 38 percent, and *Gila bicolor* in 50 percent of the collections. *Richardsonius balteatus* also tends to be found over fine substrate. *G. coerulea,* which feeds in the water column, appears not to discriminate among the three bottom types. Eight species show insignificant ($P > 0.05$) deviations from the observed distribution of bottom type.

Stream Width

Because stream widths reported in the collections were usually estimates, we categorized the data into broad 10m increments. We felt these categories would offer meaningful estimates of stream sizes for the species examined. The expected distributions (over all species, n = 1577) are 0-9.9 m, 61.1 percent; 10-19.9m, 20 percent; greater than 20m, 18.7 percent (Table 5). Distributions of *Catostomus columbianus; Cottus aleuticus;* Paiute sculpin, *C. beldingi; Gasterosteus aculeatus; Gila bicolor; Rhinichthys cataractae; R. osculus* and *Richardsonius balteatus* are not significantly different from the expected ($P > 0.05$, Tables 2 and 5).

TABLE 5. Percent occurrence of selected Oregon freshwater fishes by stream width (meters), sorted in order of increasing occurrence in streams < 10m wide. Asterisks indicate chi-square significance level (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.005$).

		Width (m)		
Species	n	0-9.9	10-19.9	20+
C. klamathensis ***	16	18.8	18.9	62.6
G. coerulea ***	19	36.8	15.9	47.4
C. confusus ***	29	37.9	37.9	24.1
C. macrocheilus ***	52	38.5	34.6	26.9
A. alutaceus ***	28	39.3	18.0	42.9
P. oregonensis *	45	46.7	28.9	24.5
C. rhotheus ***	51	47.0	33.3	17.7
C. beldingi	33	48.6	24.3	18.2
R. cataractae	50	50.0	28.0	22.0
O. tshawytscha ***	10	50.0	40.0	10.0
L. tridentata *	24	50.0	29.1	20.9
O. kisutch *	52	51.9	30.8	17.3
R. balteatus	88	53.4	21.6	25.0
C. asper *	31	54.8	16.2	29.0
C. columbianus	38	57.9	21.0	21.0
G. aculeatus	28	58.7	17.8	21.4
G. bicolor	73	63.0	19.2	17.8
C. aleuticus	30	63.3	16.7	20.0
R. osculus	191	68.6	17.3	14.1
C. gulosus *	32	71.9	18.8	9.4
S. mykiss **	119	74.8	17.8	7.5
C. perplexus ***	121	76.9	15.7	7.4
L. richardsoni[1] ***	27	85.2	11.1	3.7
S. clarki ***	36	86.1	11.1	2.8
Salmo sp. (redband trout) ***	60	96.7	3.4	0.0
Total collections in database	1577	61.1	20.2	18.7

[1]Includes *L. pacifica*

Except for redband trout, which occur in isolated desert mountain streams, all species are found across the entire range of stream widths. The redband trout is taken almost exclusively in streams less than 10m wide. Also, *Cottus gulosus* is found 72 percent of the time in streams less than 10m wide and *Salmo mykiss, C. perplexus, Lampetra richardsoni,* and *S. clarki* are collected in streams less than 10m wide 75, 78, 85 and 86 percent of the time, respectively.

Some species are significantly over-represented in large water bodies. Collections of chiselmouth, *Acrocheilus alutaceus, Cottus klamathensis,* and *Gila coerulea* deviate from the expected distribution in that more than 40 percent of the collections come from water bodies wider than 20 m. Northern squawfish, *Ptychocheilus oregonensis, Cottus asper* and largescale sucker, *Catostomus macrocheilus* also are significantly over-represented in larger streams. *Cottus confusus; C. rhotheus;* chinook salmon, *Oncorhynchus tshawytscha; O. kisutch* and *Lampetra tridentata* were collected significantly more often from streams in the middle-width category.

Current velocity

Field collectors usually make subjective estimates of current velocity; only occasionally do they measure it. Because most records are based on subjective estimates, we express the data as "slow," "moderate," or "swift," with the three categories corresponding to 0-0.4 meters per second (mps), 0.5-0.9 mps and over 0.9 mps, respectively. Estimates of actual velocity are derived from measurements discussed by Bond (1963). Estimates of velocity reported in the database (n = 1876) are distributed evenly: 30.7 percent slow, 32.9 percent moderate and 36.4 percent swift (Tables 2 and 6). Collections of *Catostomus columbianus, Cottus perplexus* and *Rhinichthys osculus* do not differ significantly from these percentages.

TABLE 6. Percent occurrence of selected Oregon freshwater fishes by current velocity, sorted in order of increasing occurrence in swift water. Asterisks indicate chi-square significance level (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.005$).

		Velocity		
Species	n	Swift	Moderate	Slow
*G. coerulea****	22	18.2	31.8	50.0
G. aculeatus ***	28	19.9	28.6	53.6
G. bicolor ***	85	20.0	30.6	49.4
S. clarki *	42	23.8	40.5	23.8
C. asper *	36	25.0	33.3	41.7
C. macrocheilus **	70	25.7	30.0	44.3
P. oregonensis ***	61	26.6	23.0	50.8
R. balteatus *	127	26.8	29.1	44.1
A. alutaceus *	32	28.1	28.1	43.8
C. klamathensis ***	20	30.0	20.0	50.0
R. osculus	228	32.9	46.0	31.3
Salmo sp. (redband trout) ***	62	33.3	50.0	16.1
C. gulosus ***	28	35.7	50.0	14.3
L. richardsoni[1] *	30	36.7	43.3	20.0
C. perplexus	143	38.5	39.2	22.4
C. columbianus	48	39.6	33.3	27.1
C. rhotheus **	43	44.2	39.5	16.2
S. mykiss **	126	44.7	38.9	17.9
C. beldingi ***	36	50.0	38.9	11.1
O. kisutch ***	57	54.4	17.5	28.1
L. tridentata ***	47	57.5	31.9	10.6
C. aleuticus ***	31	58.1	32.3	9.7
R. cataractae ***	56	58.9	30.4	10.7
C. confusus ***	31	61.3	38.7	0.0
O. tshawytscha ***	15	73.3	0.0	26.7
Total collections in database	1876	36.4	32.9	30.7

[1]Includes *L. pacifica*

Some species appear to inhabit slow water. More than 53% of the collections of *Gasterosteus aculeatus* are from slow water, and collections of *Cottus klamathensis, Ptychocheilus oregonensis* and *Gila coerulea* are 50 percent from slow current. Species collected 40 percent to 50 percent from slow current are *G. bicolor, Catostomus macrocheilus, Richardsonius balteatus, Acrocheilus alutaceus,* and *Cottus asper.*

Species that tend significantly toward moderate current are *Cottus gulosus* and *Salmo* sp., both taken 50 percent of the time in moderate and less than 40 percent in fast water. *S. clarki* also occurs in moderate current to a significant degree, with occurrence in swift and slow water 23 percent of the time. Three species, *C. rhotheus, Lampetra richardsoni* and *S. mykiss,* show collections about 40 percent in moderate current and 44 percent in fast. *Cottus beldingi, C. aleuticus, L. tridentata* and *Rhinichthys cataractae* are similar; only 10-11 percent of the collections are in slow water with 50 to 60 percent in swift water. *Oncorhynchus kisutch* collections are bimodally distributed: 28 percent in slow water, 18 percent in moderate water and 56 percent in swift water. This may be explained by the occurrence of juveniles in the pools or pocket water of fast streams. There is a similarity to this in the distribution of the 15 collections of *O. tshawytscha,* also mainly juveniles. There are no collections recorded from slow water for *C. confusus,* which is taken 61 percent of the time in fast water.

Discussion

Native species outnumber introduced species in most of the largely natural Oregon water bodies sampled. These findings support the conclusions of Leidy and Fiedler (1985), Minckley (1973), and Moyle and Nichols (1973). Their work showed that introduced species tend to disperse and dominate in highly disturbed habitats. However, a much more quantitative assessment of numbers and biomasses of species is needed before any conclusive statement is possible about the relative success of native and introduced fish in Oregon.

Results of this analysis appear consistent with previous descriptions of several of the species considered (Li *et al.* 1987, Moyle 1976, Wydoski and Whitney 1979). For many other species, additional knowledge is provided because so little was published previously. This approach demonstrates how certain species, such as *Rhinichthys osculus,* can be considered as habitat "generalists." Such species show no significantly distinct patterns for any of the four variables studied; they occur in a wide variety of habitat conditions. *Catostomus columbianus* and *Cottus perplexus* can be considered current/substrate generalists. *Richardsonius balteatus* appears to be a thermal/stream-size generalist. Other species, such as *Cottus confusus* and *C. gulosus,* have very specific habitat requirements.

Two recent papers propose models for species distribution and abundance. Our data, based on common species, could not be used to evaluate Hanski's (1982) satellite species or Matthews' (1985) rare-habitat specialists and rare-habitat generalists hypotheses. Data for the common species, however, reveal common-habitat specialists (*Oncorhynchus kisutch*) and common-habitat generalists (*Rhinichthys osculus*) as defined by Matthews. *R. osculus* cannot be considered a core species as defined by Hanski. Core species are regionally common and locally abundant, but well-separated in niche space, which *R. osculus* is not.

The chi-square analysis is useful for analyzing habitats of individual species. Although we analyzed each habitat variable separately, we did not assume they were independent. The groupings of most species in Tables 3-6 reveal the expected habitat guilds (warm water, fine substrate, large streams, low velocity versus cool water, coarse substrate, small streams, high velocity, versus intermediate conditions). Some species (e.g., *Gila bicolor* and *Cottus confusus*) do not fit these guilds. *G. bicolor* is significantly over-represented in waters of warmer temperature, lower velocity, and sandy substrate, but does not differ significantly from the expected stream-width frequency. *C. confusus* is significantly over-represented in waters of moderate temperature, pebble substrate and moderate width, but in swift, rather than moderate, velocity waters. Such habitat use patterns would not have been revealed by PCA.

The database provided a general, statewide overview of statistically distinct patterns of fish habitat use. This type of analysis provides meaningful insights about the general habitat-use patterns of species. Intensive studies of a species' habitat in particular drainages may not be applicable throughout the species' range. This is

because a species may occupy a wider range of habitats than is evident from a study in a particular drainage. It is useful to compare regional habitat use patterns just as taxonomists and systematists compare morphometric and meristic characteristics of fish collected across large geographic regions. Incipient speciation may be indicated where a regional analysis demonstrates clear differences between distinct populations of a species.

A computer system for storing and retrieving biological field data for the entire nation has been developed by the U.S. Environmental Protection Agency (BIOS, Lamborne 1986). BIOS allows scientists to analyze rapidly species habitat use patterns on a nationwide basis. Detailed analyses of fish habitat data on this scale await data storage. Such analyses could improve the form of habitat suitability curves used in Habitat Evaluation Procedures (HEP, U.S. Fish and Wildlife Service 1980) and could encourage greater consistency among state fish books. Ornithologists have been using nationwide Christmas and breeding bird counts for several years to assess such habitat use patterns. This paper is an example of the habitat generalizations possible using large databases of fish collections.

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Literature Cited

Beals, E. W. 1973. Ordination: mathematical elegance and ecological naivete. J. Ecol. 56:27-34.

Bond, C. E. 1963. Distribution and ecology of freshwater sculpins (genus *Cottus*) in Oregon. University of Michigan. Ann Arbor, Michigan. Ph.D. Dissertation.

Felly, J. D. 1984. Multivariate identification of morphological environmental relationships within the Cyprinidae (Pisces). Copeia 1984:442-455.

Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Board Can. 15:607-624.

Finger, T. B. 1979. Patterns of interactive segregation in three species of sculpins (*Cottus*) in western Oregon. Oregon State University. Corvallis, Oregon. Ph.D. Dissertation.

Grossman, G. D., and M. C. Freeman. 1987. Microhabitat use in a stream fish assemblage. J. Zool. 212:151-176.

Hanski, I. 1982. Dynamics of regional distribution: the core and satellite species hypothesis. Oikos 38:210-221.

Hughes, R. M., E. Rexstad, and C. E. Bond. 1987. The relationship of aquatic ecoregions, river basins, and physiographic provinces to the ichthyogeographic regions of Oregon. Copeia 1987:423-432.

Ikusemiju, K. 1967. The life history and ecology of *Cottus* sp. in Lake Washington. University of Washington. Seattle, Washington. M.S. Thesis.

Lamborne, B. 1986. BIOS: Biological data management system. Field survey component. Preliminary design. U.S. Environmental Protection Agency. Washington, D.C. 36 p.

Leidy, R. A., and P. L. Fiedler. 1985. Human disturbance and patterns of fish species diversity in the San Francisco Bay drainage, California. Biol. Cons. 33:247-267.

Li, H. W., C. B. Schreck, C. E. Bond and E. Rexstad. 1987. Factors influencing changes in fish assemblages of Pacific Northwest streams. *In* W. J. Matthews and D. C. Heins, (eds.) Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press. Norman, Oklahoma. Pp. 193-202.

Mathews, S. B. 1962. The ecology of the Sacramento perch, *Archoplites interruptus*, from selected areas of California and Nevada. University of California. Berkeley, California. M. A. Thesis.

Matthews, W. J. 1985. Distribution of midwestern fishes on multivariate environmental gradients, with emphasis on *Notropis lutrensis*. American Midland Naturalist 113:225-237.

Minckley, W. L. 1973. Fishes of Arizona. Arizona Game and Fish Dept. Phoenix, Arizona.

Morrow, J. E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Co. Anchorage, Alaska.

Moyle, P. B. 1976. Inland fishes of California. University of California Press. Berkeley, California.

Moyle, P. B., and R. D. Nichols. 1973. Ecology of some native and introduced fishes of the Sierra Nevada foothills in central California. Copeia 1973:478-490.

Ostle, B., and R. W. Mensing. 1975. Statistics in research, third ed. Iowa State University Press. Ames, Iowa.

Rexstad, E. 1987. Computer database and cartographic system for museum collections. Sci. Software 3:295-300.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada. Ottawa, Ontario, Canada. 966 p.

Simpson, J. C., and R. L. Wallace. 1978. Fishes of Idaho. University Press of Idaho. Moscow, Idaho.
U.S. Fish and Wildlife Service. 1980. Habitat Evaluation Procedures (HEP). Division of Ecological Services. ESM 102. Release 2-80. Washington, DC. 146 p.

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Whittier, T. R., R. M. Hughes, and D. P. Larsen. 1988. The correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Can. J. Fish. Aquat. Sci. 45:1264-1278.
Wydoski, R. S., and R. R. Whitney. 1979. Inland fishes of Washington. University of Washington Press. Seattle, Washington.