Multivariate Morphological Variation in Channel Catfish from Three Louisiana Lakes[1]

C. G. Lutz, *School of Forestry, Wildlife, and Fisheries, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA 70803*

W. R. Wolters, *School of Forestry, Wildlife, and Fisheries, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA 70803*

A. J. Joubert, *School of Forestry, Wildlife, and Fisheries, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA 70803*

C. F. Bryan, *School of Forestry, Wildlife, and Fisheries, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA 70803*

W. E. Kelso, *School of Forestry, Wildlife, and Fisheries, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA 70803*

Abstract: Channel catfish (*Ictalurus punctatus*) were obtained from 3 lakes in southeastern Louisiana during the fall of 1986. A truss network of morphological measurements was developed, resulting in 10 variables measured on each individual fish. Morphological variables were adjusted to remove the effect of standard length through least-squares regression. Multivariate analysis of variance of adjusted variables yielded significant ($P < 0.01$) differences among lakes. Factor analysis of the partial correlation matrix of adjusted variables yielded 4 non-orthogonal dimensions descriptive of body shape variation, interpretable as: 1) overall depth of body, 2) length of posterior portion of body, 3) caudal peduncle depth and location of anal and adipose fin insertions, and 4) location of dorsal fin insertion. Univariate analysis of factor scores showed significant ($P < 0.05$) differences among lake populations only on the first factor. Discrimant analysis based on adjusted variables correctly classified individual catfish to lake of origin at an overall rate of 84%. Results indicate that multivariate discrimination of catfish harvested from these lakes is suffi-

[1]Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript No. *87-86-1435*.

ciently accurate to facilitate formulation and enforcement of management regulations pertaining to these stocks.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 41:136–144

In most commercial fisheries, the unit on which management practices are effected is defined as a stock. Members of a stock display similar production characteristics (e.g. natality, growth, mortality, recruitment), but may not necessarily comprise a single, genetically distinct population. Often, genetically distinct groups of individuals within a species show no substantial differences in these characteristics, and, accordingly, should be managed as a single stock. Conversely, morphological differences between stocks should not necessarily be equated with genetic differences. Within a species, identification of individual stocks may be critical to the formulation of management programs by fish and wildlife agencies. In cases where management programs in a given watershed differ substantially from those in nearby watersheds, it may become necessary to determine the stock origin of individual fish to allow enforcement of harvesting regulations.

Electrophoretic techniques have recently permitted recognition of distinct genetic populations within fish species (Avise and Smith 1974, Philipp et al. 1983, Fitzsimmons et al. 1985, Mork et al. 1985). If genetically indistinct populations are harvested from very different habitats, it may be necessary to employ non-genetic recognition techniques to determine the stock from which individual animals are harvested. In any case, it is often impractical to employ electrophoretic stock identification techniques when discrimination is needed quickly or when fresh specimens are not immediately available. Use of morphometric data has been found to be a reliable method of stock differentiation in several species of fish (Copeman 1977; Winans 1984, 1985). Such data can be collected from living, frozen, or preserved specimens with relative ease. One of the most commonly applied results of such multivariate analyses is the Mahalanobis distance, which allows a comparison of the overall pairwise similarity between a number of groups of observations.

Problems of stock identification have recently become an important issue in the management of channel catfish (*Ictalurus punctatus*) populations in several lakes in southeastern Louisiana. A large percentage of channel catfish harvested from Lake Maurepas and Lac DesAllemands are consistently near or below Louisiana's minimum commercial size limit of 28 cm total length (TL). Approximately 50% of the fish in these lakes are sexually mature at 20 to 22 cm TL (pers. commun., Mark McElroy, biologist, La. Dep. Wildl. and Fish.), and commercial fishermen argue that harvest of these fish is no more harmful to the stocks in these lakes than harvesting fish of comparable maturity from other lakes within the state. Due to a concerted and well-organized effort on the part of local commercial fishermen and a ready local market for small fish, the minimum size restriction has been lifted

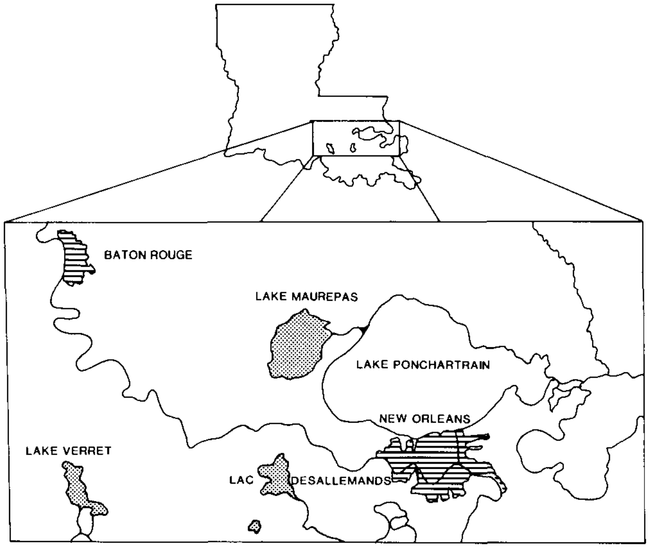

Figure 1. Geographic location and proximity of Lac DesAllemands, Lake Maurepas, and Lake Verret.

in these 2 lakes. In nearby Lake Verret (Fig. 1), however, approximately 50% of channel catfish attain sexual maturity at 28 cm TL, and the minimum size limit is still enforced.

Objectives of this study were to describe morphological differences among populations of channel catfish harvested from these 3 lakes and to determine the value of a set of easily-obtained external measurements in the discrimination of sub-legal (<28 cm TL) fish from these populations. Should it become necessary to further revise specific size limits for 1 or all of these lakes, such a method of differentiation could be of great value in formulation and enforcement of management regulations for the fishery.

Methods

During October 1986, 46, 38, and 44 sub-legal channel catfish were collected by traps from Lake Verret, Lake Maurepas, and Lac Desallemands, respectively, by biologists of the Louisiana Department of Wildlife and Fisheries. Catfish were transported live to the laboratory after capture. Individual fish were placed on a white background with a ruler to provide calibration for later measurements and photographed with a fixed camera mounted directly overhead. Slides of these photographs were then projected on a screen from a fixed projector, and a set of 10 morphometric variables between fixed "landmarks" on the body (Fig. 2) (including standard length, SL) was taken on each individual using an electronic calipers to

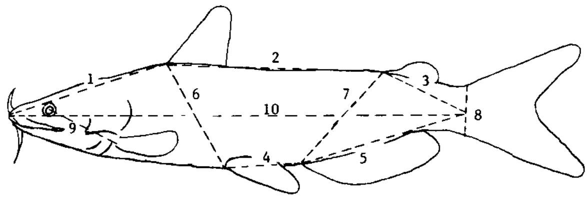

Figure 2. Morphological measurements used in multivariate analyses of 3 channel catfish (*Ictalurus punctatus*) stocks in southeastern Louisiana: 1) Tip of snout to anterior insertion of dorsal fin, 2) Anterior insertion of dorsal fin to anterior insertion of adipose fin, 3) Anterior insertion of adipose fin to vertical midpoint of posterior measure of standard length, 4) Anterior insertion of pelvic fin to anterior insertion of anal fin, 5) Anterior insertion of anal fin to vertical midpoint of posterior measure of standard length, 6) Anterior insertion of dorsal fin to anterior insertion of pelvic fin, 7) Anterior insertion of anal fin to anterior insertion of adipose fin, 8) Depth of caudal peduncle at posterior measure of standard length, 9) Center of eye to anterior insertion of pectoral fin, and 10) Standard length.

store data in a microcomputer file via a digital interfacing device. Since sex and state of maturity were difficult to ascertain objectively on many sampled fish, these factors were not considered in analyses of morphological measurements.

Measurements were adjusted for SL using least squares regressions, and the resulting partial correlation matrix was subjected to principal components and factor analyses using the FACTOR procedure of the Statistical Analysis System (SAS) (SAS Inst. Inc. 1985) to determine the underlying dimensions (factors) of variation in shape, independent of SL. Loadings (variable-factor correlations) on the factors generated from these analyses were compared among lakes, and factor scores computed from standardized scoring coefficients were compared among lakes on a univariate and multivariate basis.

Adjusted variables were used in discriminant analysis by the DISCRIM procedure of SAS (SAS Inst. Inc. 1985) to ascertain the value of the 10 measurements in discriminating among individuals taken from different lakes. Subsequent canonical discriminant analysis was performed with the CANDISC procedure of SAS (SAS Inst. Inc. 1985) on adjusted variables to determine Mahalanobis distances between lake populations and their significance levels.

Results

Sampled fish from the 3 populations were generally of similar size (Table 1). After adjusting for the effect of SL, 5 variables were significantly different ($P < 0.05$) among lakes, and a sixth variable approached significance ($P = 0.056$) (Table 2). These variables all described relative body depth and/or caudal peduncle dimensions (Fig. 2). Multivariate analysis of variance (MANOVA) for all variables yielded highly significant (Wilk's F criterion, $P < 0.01$) differences among lakes.

Table 1. Variation in standard length (mm) within and among samples of channel catfish (*Ictalurus punctatus*) from 3 southeastern Louisiana lakes.

Lake	Standard length			
	Mean	Std. deviation	Minimum	Maximum
DesAllemands	182.2	23.0	131.5	234.0
Maurepas	221.8	18.5	188.2	255.8
Verret	167.2	19.9	143.2	235.5

Table 2. Means of residuals (mm) from linear regression of morphometric variables on standard length, r^2 values from regressions, and significance levels of univariate differences for adjusted variables among populations of channel catfish (*Ictalurus punctatus*) from three southeastern Louisiana lakes.

Variable	Residual mean			r^2	P
	DesAllemands	Maurepas	Verret		
1	1.82	0.66	−0.92	0.23	0.4648
2	2.63	1.41	−2.39	0.03	0.3685
3	1.58	−0.29	−1.13	0.72	0.0017
4	−0.75	0.06	0.60	0.62	0.0561
5	2.98	−0.63	−2.64	0.32	0.0959
6	0.99	0.80	−1.61	0.83	0.0001
7	1.13	0.13	−1.07	0.84	0.0060
8	0.52	−0.33	−0.25	0.64	0.0120
9	1.51	−0.40	−1.16	0.55	0.0001

Principal components and subsequent factor analyses yielded 4 descriptive dimensions (factors) judged to represent meaningful (non-residual) morphological variation among and within lake populations based on scree plots (Cattell and Jaspers 1967) (Table 3). Subsequent to a combination of orthogonal (varimax) followed by oblique (promax) rotation, these 4 correlated factors uniquely explained 17%, 15%, 14%, and 12% of the overall variation in the partial correlation matrix. Based on loadings (variable-factor correlations), factors were interpretable as non-orthogonal dimensions describing variation in 1) body depth, 2) length of the posterior portion of the body, 3) depth of the caudal peduncle and location of anal and adipose fin insertions, and 4) location of dorsal fin insertion. All factors were moderately correlated and all interfactor correlations were positive (Table 3). Lake population scores differed significantly ($P < 0.05$) only on factor 1, but factors 2 and 4 appeared to contribute to significant ($P < 0.05$) multivariate differences among lakes on all factors.

Discriminant analysis using length-adjusted variables resulted in an overall correct classification rate to lake of origin of 84% for individual sub-legal fish (Table 4). DesAllemands, Maurepas, and Verret fish were correctly classified at rates of 86%, 71%, and 91%, respectively. All Mahalanobis distances between

Table 3. Factor loadings (variable-factor correlations), portions of total variation, and interfactor correlations after oblique (promax) rotation for the partial correlation matrix of length-adjusted morphometric variables in channel catfish (*Ictalurus punctatus*) from 3 southeastern Louisiana lakes.

Variable	Factor 1	Factor 2	Factor 3	Factor 4
1	—[a]	—	—	0.92
2	—	0.89	—	—
3	0.49	—	0.74	0.57
4	—	—	0.85	—
5	0.40	0.89	—	—
6	0.79	0.41	0.43	0.43
7	0.78	0.48	0.58	0.46
8	0.64	—	0.62	—
9	0.80	—	—	—
Portion of total variation	0.17	0.15	0.14	0.12
		Interfactor correlations		
Factor 1	1.00	0.35	0.41	0.31
Factor 2	0.35	1.00	0.31	0.26
Factor 3	0.41	0.31	1.00	0.32
Factor 4	0.31	0.26	0.32	1.00

[a]Loadings <0.40 omitted to facilitate interpretation of factors.

Table 4. Discriminant analysis classification rates of channel catfish (*Ictalurus punctatus*) from 3 southeastern Louisiana lakes and Mahalanobis distances (with significance levels) between lakes based on length-adjusted variables.

	Number of observations and (percents classified into):		
Lake of origin	DesAllemands	Maurepas	Verret
DesAllemands	38	0	6
	(86.36)	(00.00)	(13.64)
Maurepas	7	25	3
	(20.00)	(71.43)	(08.75)
Verret	3	1	40
	(06.82)	(02.27)	(90.91)
	Mahalanobis distances and ($P >$ distance between):		
	DesAllemands	Maurepas	Verret
DesAllemands	—	(0.0039)	(0.0001)
Maurepas	1.3452	—	(0.0141)
Verret	1.7605	0.9805	—

lakes based on adjusted variables were significant ($P < 0.05$) (Table 4). Canonical discriminant analysis resulted in 2 orthogonal discriminant functions describing multivariate variation within and among lake populations (Table 5, Fig. 3).

Discussion

Population samples from the 3 lakes in this study exhibited significant differences in shape exclusive of size, both on a univariate and multivariate basis. Major differences in shape among populations were related to body depth and the relative size of the posterior body region, both on a univariate and multivariate basis. Results of analyses performed in this study may be directly applicable to problems of minimum size restriction enforcement in the lakes in question.

Problems in enforcement of minimum size limits within the lakes included in this study will most commonly be encountered with sub-legal fish of unknown origin. Discrimination between populations based on adjusted variables indicates the negligible importance of standard length in discrimination of such sub-legal fish. Use of shape, independent of size, will probably be an effective means of discriminating among these populations for enforcement purposes.

Ideally, functions for discrimination should minimize the possibility of incorrectly classifying legally harvested fish. Discriminant functions can be modified based on a cost of misclassification criterion to reduce directional misclassification to a pre-set level. In this study, individual fish harvested from Lac DesAllemands and Lake Maurepas were incorrectly classified from SL-adjusted data as originating from Lake Verret 14% and 9% of the time, respectively, based on length-adjusted data.

Table 5. Canonical discriminant analysis canonical variable (discriminant function) coefficients and population sample means based on adjusted variables from sub-legal (<28 mm TL) channel catfish (*Ictalurus punctatus*) from 3 southeastern Louisiana lakes.

Variable coefficients	Canonical variable 1	Canonical variable 2
1	0.0021760516	0.0020322936
2	−0.0103067684	−0.0124359970
3	0.2055689499	0.0695963816
4	−0.3384301580	−0.0213397483
5	0.0240067624	0.0205905123
6	0.0247941237	−0.3863006052
7	0.0039004089	0.0353614331
8	0.0517177626	0.3794636325
9	0.2011312918	0.0817716567
	Population sample means	
DesAllemands	0.9626	0.1353
Maurepas	−0.2141	−0.5165
Verret	−0.7923	0.2755

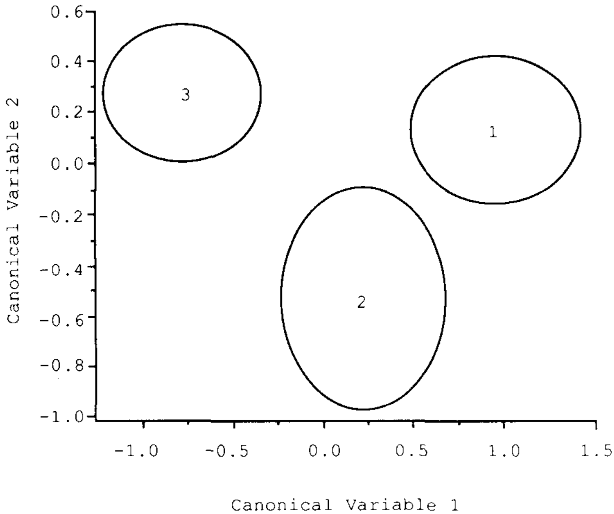

Figure 3. Ninety-five percent confidence ellipses of means on canonical variables (discriminant functions) for sub-legal channel catfish (*Ictalurus punctatus*) from 3 southeastern Louisiana lakes: 1) Lac DesAllemands, 2) Lake Maurepas, and 3) Lake Verret.

[1]Mention of commercial products or firms does not imply endorsement by the U.S. Fish and Wildlife Service.

Use of functions from this study for discriminating groups of several or many fish of a common origin would be expected to yield classification rates with very little error within the populations sampled. Such functions would provide an objective means of formulating and enforcing management regulations. Nevertheless, morphological variation of various size and age classes throughout the year within these 3 lakes and the relationships between these populations and those of numerous smaller watersheds in the area should be investigated prior to the final formulation of discriminant functions for management and enforcement purposes.

Literature Cited

Avise, J. C. and M. H. Smith. 1974. Biochemical genetics of sunfish, I. Geographic variation and subspecific intergradation in the bluegill, *Lepomis macrochirus*. Evolution 28:295–305.

Cattell, R. B. and J. Jaspers. 1967. A general plasmode (No. 30–10–5–2) for factor analytic exercises and research. Multivar. Behav. Res. Monogr. 67:1–212.

Copeman, D. G. 1977. Population differences in Rainbow Smelt, *Osmerus mordax:* multivariate analysis of mesural and meristic data. J. Fish. Res. Board Can. 34:1220–1229.

Fitzsimmons, J. M., J. S. Rogers, and R. C. Cashner. 1985. Karyologic and electrophoretic studies of the genus *Cynoscion* (Sciaenidae, Perciformes) from the northern Gulf of Mexico. Japan. J. Ichthyol. 31:444–448.

Mork, J., N. Ryman, G. Stahl, F. Utter, and G. Sundnes. 1985. Genetic variation in Atlantic Cod (*Gadus morhua*) throughout its range. Can. J. Fish. Aquat. Sci. 42:1580–1587.

Philipp, D. P., W. F. Childers, and G. S. Whitt. 1983. A biochemical genetic evaluation of the Northern and Florida subspecies of Largemouth Bass. Trans. Am. Fish. Soc. 112:1–20.

SAS Institute, Inc. 1985. SAS user's guide: Statistics, 5th ed. Cary, N.C. 956pp.
Winans, G. A. 1984. Multivariate morphometric variability in Pacific Salmon. Technical demonstration. Can. J. Fish. Aquat. Sci. 41:1150–1159.
———. 1985. Geographic variation in the milkfish *Chanos chanos*. II. Multivariate morphological evidence. Copeia 1985:890–898.