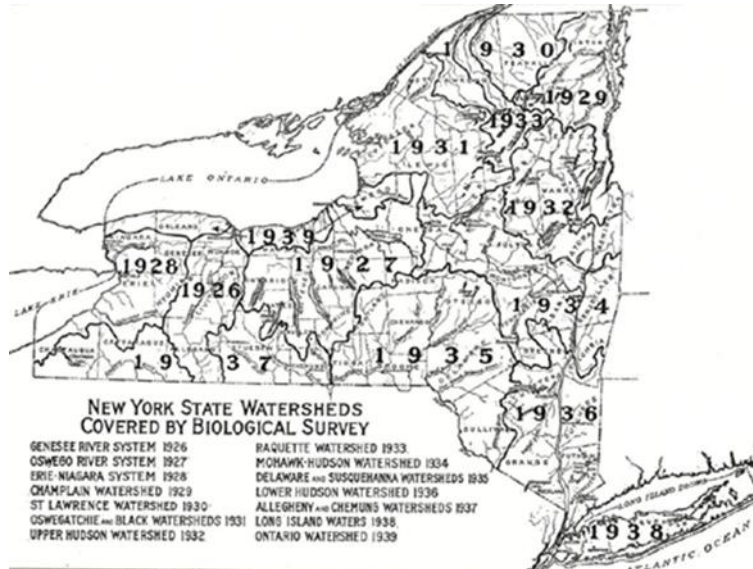


**Distributional changes of stream fishes in New York State:
Comparisons of results from the New York State Watershed
Surveys of the 1930s and modern surveys from the 2000s**



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Abstract

The historic New York State watershed surveys conducted from 1926-1939 are considered to be the most comprehensive surveys of their type, and provide a detailed snapshot of the composition and distribution of the state's fish fauna at a time before rapid population growth and development took place. The surveys included 4,058 stream sites for which presence-absence data for stream fishes are available. Stream surveys of similar scope were conducted from 1996-2010, and included 3,057 sites. Combined, these surveys provide a unique opportunity to assess changes in the composition and distribution of stream fishes in New York resulting from 70-80 years of environmental change. Changes in proportion of sites individual species were detected at were assessed at both the watershed and statewide scale using two-way contingency table analysis. Combined, the two surveys detected 162 unique species comprising 75 genera and 27 families. Twelve species were unique to the historic survey and 11 to the modern survey. Changes in distribution were common both within watersheds and across the state. Statistically significant changes in statewide distribution (measured as proportion of sites where detected) were observed in 48% of the species present in the surveys. Expansions of range were much more common than contractions, with 82% of those species exhibiting significant changes having increased in proportion of sites where detected. Species of the families Percidae and Centrarchidae exhibited the most consistent patterns of increase, while contracted ranges were observed only in species of the families Cyprinidae, Catostomidae, and Salmonidae. Large scale changes in distribution (as measured by net change in number of watersheds observed in) were also commonly observed. Of the species sampled in both surveys, 70% exhibited a shift in distribution of one or more watersheds. As with site level changes, most changes in watershed occurrence were in the direction of increased distribution (60%). Bray-Curtis similarity coefficients consistently indicated a trend towards homogenization of fish fauna across the state in the time between the two surveys. On average, watersheds were 4% more similar to each other during the modern survey than during the historic survey. Similarly, watersheds on average were 3% more similar to the state as a whole during the modern survey. These results document widespread changes in the distributional patterns of many of New York's stream fish species over the last 70-80 years. These broad scale analyses will hopefully set the stage for more detailed studies of specific taxa or geographic areas that will allow an understanding of the mechanisms underlying the shifts in stream fish distributions in New York.

Introduction

New York State is home to a relatively diverse freshwater fish fauna, with some 179 species that spend all or some part of their life history in inland waters (Carlson et al. 2016). New York ranks 13th among the lower 48 states in freshwater fish diversity (Warren and Burr 1994). Beginning in 1926 and extending through 1939, surveys of the fish resources of New York State were conducted by the State of New York Conservation Department. The New York State Watershed Surveys included fish collections at over 4000 stream sites and were the first such statewide efforts conducted in the United States. They are considered the most comprehensive surveys of their type (Daniels 2011). Results from the surveys provide a solid foundation for assessment of the impacts of population growth, development and landscape level changes in habitat availability and quality on the diversity and distribution of freshwater fishes in the state. From 1996 to 2010, stream fish surveys of similar intensity were conducted by the New York State Department of Environmental Conservation. These surveys included collections at over 3,000 sites. Combined, the two surveys offer a unique opportunity to assess changes in the composition and distribution of stream fish species in New York State over a period of 60-80 years. The objectives of this report are to present a broad overview of the results of the two surveys with analyses of changes in the distribution of fishes in New York streams both within individual watersheds and statewide.

METHODS

Historic survey

The historic New York State Watershed Surveys were conducted during the field seasons of 1926-1939, involving one or more crews sampling fish each season. Seines of varying sizes were the most common collecting technique, but were often complimented with angling, set lines, various trap and fyke nets, gill nets and dredges (Daniels 2011). Detailed summaries of gears used and activities associated with the individual watershed surveys were published as supplements to the annual reports of the then New York State Department of Conservation. Surveys of 17 watersheds began with the Genesee River watershed in 1926 and concluded with the tributaries of Lake Ontario in 1939 (Figure 1; Moore 1927, 1928, 1929, 1930, 1931, 1932, 1933, 1934, 1935, 1936, 1937, 1938, 1939, 1940). Detailed field notes were maintained during surveys and archived, which, combined with catalog records at museums where the collections were vouchered, created a record of catches at each collection site for all watersheds. Due to the nature of records from the earliest surveys, data could only be consistently and reliably reconstructed in the form of presence-absence for each species at each site sampled. While the historic watershed surveys sampled all water types, the present study deals only with stream fish surveys and excludes data from standing waters and large rivers. In total, the historic surveys included 4,058 stream

sites from which presence-absence data were available (Figure 2). For analyses, sites were assigned to one of 18 watershed basins (Newark Bay was treated as distinct from the Lower Hudson River watershed; Figure 3). Number of sites varied among watersheds, primarily as a function of watershed size, and ranged from a low of 36 in the Newark Bay watershed to 463 in the Lower Hudson River watershed (Table 1). Intensity of stream sampling effort within watersheds also varied, ranging from a low of 4 sites per 50 miles (5/100 km) of named streams (Black and Oswegatchie River watersheds) to a high of 19 sites per 50 miles (24/100 km) (Newark Bay watershed).

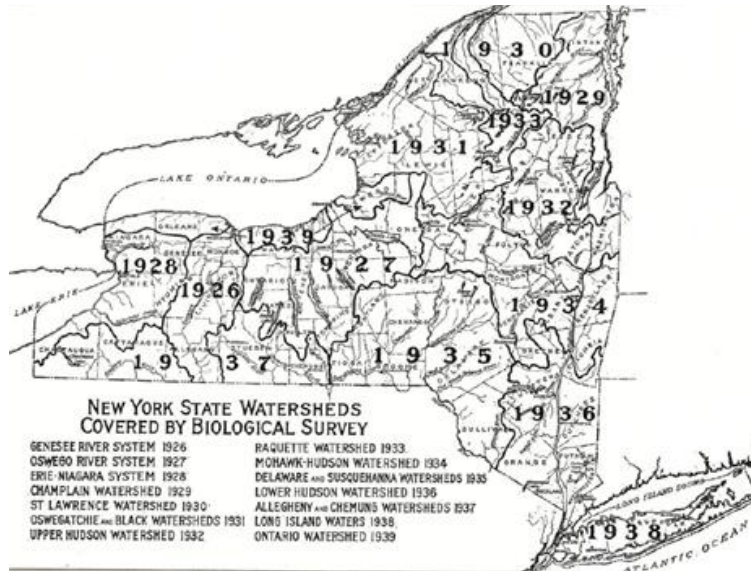


Figure 1. The watersheds of New York State and year surveyed by the historic New York Watershed Survey.

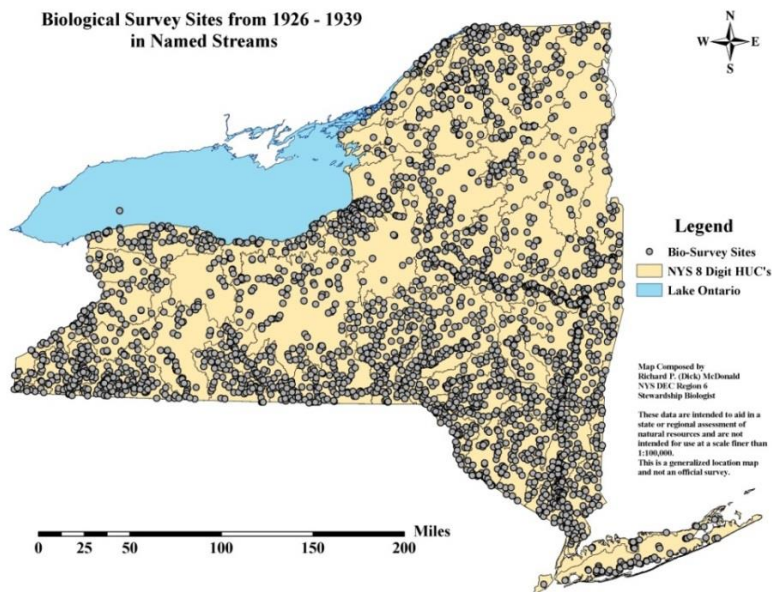


Figure 2. Stream fish sampling sites from the historic New York State Watershed Survey.

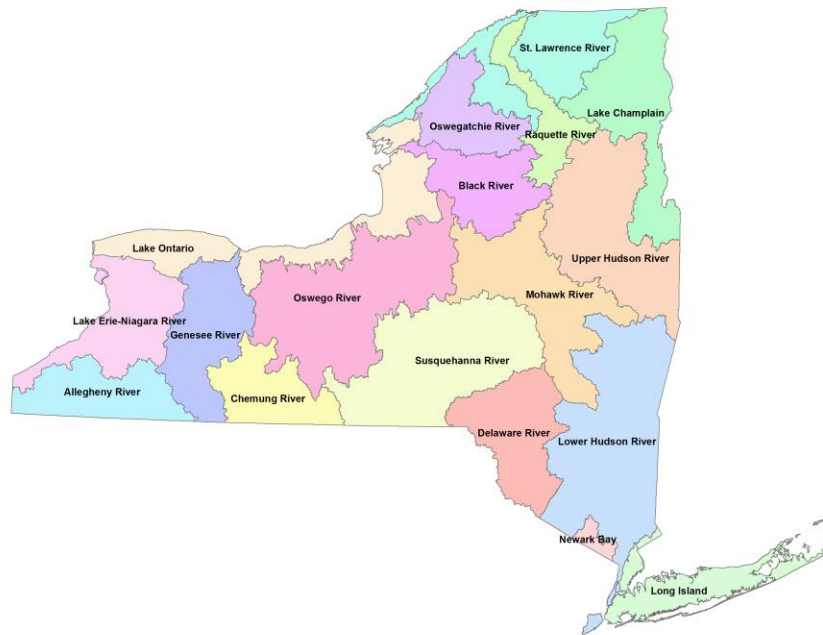


Figure 3. The watersheds of New York State.

Table 1. Number of stream sites sampled in each watershed during the historic and modern watershed surveys.

Watershed	Historic survey	Modern survey
Allegheny River	304	462
Black River	110	116
Chemung River	197	41
Delaware River	336	188
Genesee River	148	54
Lake Champlain	106	110
Lake Erie – Niagara	161	148
Lake Ontario	364	346
Long Island	133	94
Lower Hudson River	463	224
Mohawk River	358	178
Newark Bay	36	29
Oswegatchie River	83	152
Oswego River	253	203
Raquette River	183	60
St. Lawrence River	266	344
Susquehanna River	369	200
Upper Hudson River	188	108
Total	4,058	3,057

Modern survey

A second statewide survey of stream fishes was conducted between 1996 and 2010. Collections were made primarily with backpack electrofishing (varying models with outputs of 1-4 amps direct current), supplemented by varying sizes of seines, gill nets, trap nets, and boat electrofishers when conditions warranted. The modern survey was not intended to be a true replicate of the historic survey and site selection was based on a combination of factors including: 1) duplication of historic samples at sites where uncommon species were detected; and 2) balanced spatial coverage of streams in each watershed. In total, the modern survey included 3,057 sites (Figure 4). Number of sites varied among watersheds, ranging from a low of 29 in the Newark Bay watershed to 462 in the Allegheny River watershed (Table 1). Sampling intensity ranged from 1.6 sites per 50 miles (2/100 km) of named streams (Chemung, Genesee and Upper Hudson River watersheds) to a high of 16 sites per 50 miles (20/100 km) of named stream (Allegheny River watershed).

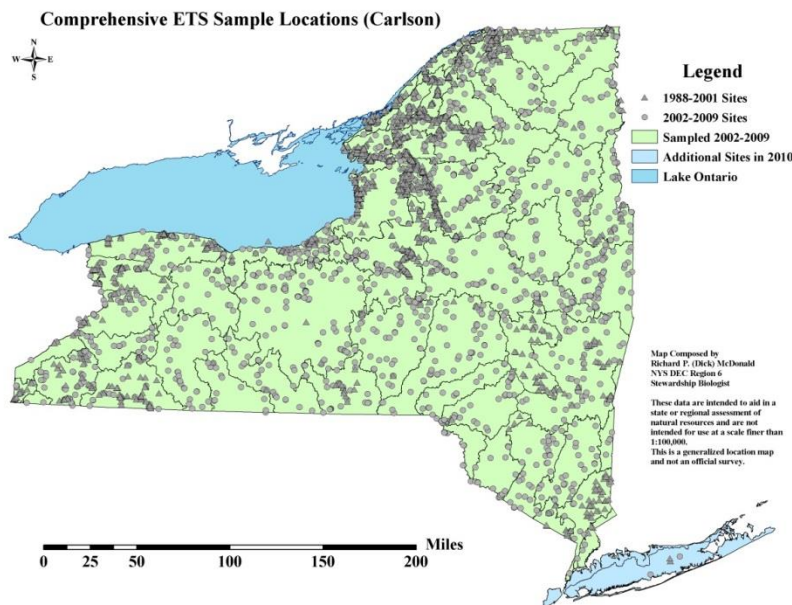


Figure 4. Stream fish sampling sites from the modern New York State stream survey. Note that the figure includes some sites which were sampled prior to the survey period used in analyses.

Analyses

Data from both surveys were summarized as presence-absence of each species at each site in each watershed. Therefore, the output was the proportion of sites in each watershed where each species was detected in each survey. Statistical analyses of changes in proportion of sites where species were detected in each survey were conducted using two-way contingency table analysis with significance determined using Fisher's exact test (Sokal and Rohlf 1969). Analyses were conducted using program JMP. Because of the statistical power associated with the large sample sizes in the

surveys and due to multiple tests being conducted on data from each watershed (one test per species), acceptance level for significance was adjusted to correct for Bonferroni's inequality ($\alpha = 0.05/n$, where n = the number of species in the watershed; Snedecor and Cochran 1980) to provide more conservative determinations of significance. For visualization of sample variability in figures, 95% confidence intervals were estimated for presence-absence proportions using the equation;

$$95\% \text{ CI} = 1.96 * \sigma_p, \text{ where } \sigma_p = \sqrt{(pq)/(n - 1)}$$

Where σ_p is the standard error of the estimated proportion, p is the probability of a species being present, $q = 1-p$, and n is the number of sites in the watershed (Hayak and Buzas 1997).

Multivariate analyses were conducted to assess potential for homogenization of the stream fish fauna in New York State over the period of the two studies (e.g., Rahel 2000, 2010; Carlson and Daniels 2004). Input data were the proportion of sites each species occurred in in each watershed. Data were 4th root transformed to ensure that rare species were given sufficient weight in the analyses (Clarke et al. 2014). Bray-Curtis similarity coefficients were calculated to assess changes in similarity of each watershed to all other watersheds and each watershed to statewide patterns (Bray and Curtis 1957; Clarke et al. 2014). Non-metric multidimensional scaling was used to visually assess changes in watershed similarity (Clarke et al. 2014).

Caveats

The presence-absence data presented here are, strictly interpreted, occurrence data, and analyses represent measures of changes in distribution of species, not abundance. Hayek and Buzas (1997) review studies showing the strong relationship between occurrence and abundance, so significant changes identified here may well reflect changes in abundance, but readers should bear in mind that only distributional changes are explicitly analyzed here. Additionally, analyses were made of data from stream sites only. While species that primarily occupy lake and large river habitats were frequently detected in both surveys, the data set is not appropriate for interpretation of distributional changes of species that are infrequent or seasonal inhabitants of stream habitats.

Potential biases are inherent in the data due to the use of multiple gears with varying efficiencies in both surveys and the addition of backpack electrofishing as a sampling method in the modern survey. Differences in sampling methods when comparisons of historic with modern surveys are attempted are common and unavoidable (Quinn and Kwak 2003; Pollino et al. 2004; Jacquemin and Pyron 2011). Pollino et al. (2004) argued that aggregation of catches by multiple gears within surveys could reduce bias due to gear efficiency differences, an approach used here. While electrofishing is generally considered a more effective sampling approach than seining, Bayley et al. (1989) found no significant differences between a backpack electrofisher and a minnow seine for either species richness efficiency or efficiency of catch for major stream

species groups in Illinois streams. The influence of catchability differences that may exist between electrofishing and other gears should be lessened by the analysis of presence-absence data rather than raw abundance data. Winemiller et al. (2008) and Jacquemin and Pyron (2011) argued that analyzing catches as presence-absence rather than abundance, combined with large sample sizes, provided a conservative approach to comparisons of surveys with different sampling approaches, and analyses presented here also follow that approach. Based on these earlier studies, results presented here should minimize the probability of Type II errors associated with differing collection methodologies across the two surveys. Nonetheless, the potential influence of differences in collection methods cannot be eliminated entirely. For species groups with strong benthic associations, such as lampreys and darters, the advantages of electrofishing over seining should not be ignored, and results presented here should be interpreted cautiously.

Finally, the sample sizes (i.e., number of sites) associated with these analyses are large, even when approached on an individual watershed level. Despite the elevated standards for significance imposed by the Bonferroni corrections, the statistical power of the data sets will result in statistically significant findings in cases when actual changes in the proportion of sites a species was detected at were small. There are no established means for differentiating between cases where differences are statistically significant but of little import ecologically and cases where shifts in distribution reflect ecologically significant events. Results of all tests are presented here and readers should be advised to interpret ecological ramifications cautiously in instances where changes in proportion of sites a species occurs at are small.

RESULTS

Statewide summary - diversity

Combined, the two surveys detected 162 unique species of fish (including one intentional hybrid) comprising 75 genera and 27 families (Table 2). Smith (1985) reported 167 species, 69 genera and 27 families of inland fishes in New York. Differences in species richness between the surveys and Smith's comprehensive review lie primarily in Smith's inclusion of more anadromous species (e.g., Atlantic sturgeon *Acipenser oxyrinchus*, shortnose sturgeon *Acipenser brevirostrum*, hickory shad *Alosa mediocris*). Differences in number of genera represented in the two surveys result largely from nomenclatural and taxonomic changes in the intervening years. The historic and modern surveys each detected 151 unique species, but differences in species lists did occur. Twelve species detected by the historic survey were not observed in the modern survey. Eleven species detected during the modern survey had not been observed in the historic survey, including four intentional introductions and two recent invasive species (Table 3).

Table 2. Fish species collected in the historic stream surveys (N = 4,058 sites) and modern stream surveys (N = 3,057 sites) of New York State. Watersheds where each species was detected in each survey (Allegheny River – AL; Black River – BL; Chemung River – CG; Delaware River – DL; Genesee River – GN; Lake Champlain – CH; Lake Erie – Niagara – EN; Lake Ontario – ON; Long Island – LI; Lower Hudson River – LH; Mohawk River – MH; Newark Bay – NW; Oswegatchie River – OE; Oswego River – OO; Raquette River – RQ; St. Lawrence River – SL; Susquehanna River – SQ; Upper Hudson River – UH). Nomenclature and taxonomy follow Page et al. (2013).

Species	Historic survey	Modern survey
Family Petromyzontidae		
<i>Ichthyomyzon bdellium</i>	Ohio lamprey	-
<i>Ichthyomyzon fossor</i>	Northern brook lamprey	EN
<i>Ichthyomyzon greeleyi</i>	Mountain brook lamprey	AL
<i>Ichthyomyzon unicuspis</i>	Silver lamprey	CH, SL
<i>Lethenteron appendix</i>	American brook lamprey	AL, CH, EN, OO
<i>Petromyzon marinus</i>	Sea lamprey	DL, ON, LI, LH, OO, SL, SQ
Family Acipenseridae		
<i>Acipenser fulvescens</i>	Lake sturgeon	OE, SL
Family Lepisosteidae		
<i>Lepisosteus osseus</i>	Longnose gar	CH, EN, OE, OO, SL
Family Amiidae		
<i>Amia calva</i>	Bowfin	ON, OE, RQ, SL
Family Hiodontidae		
<i>Hiodon tergisus</i>	Mooneye	EN, OE, SL
Family Anguillidae		
<i>Anguilla rostrata</i>	American eel	BL, CG, DL, ON, LI, LH, MH, NW, OE, OO, SQ, UH
Family Clupeidae		
<i>Alosa aestivalis</i>	Blueback herring	LI, LH, MH
<i>Alosa pseudoharengus</i>	Alewife	GN, ON, LI, LH, MH, OO, SL
<i>Alosa sapidissima</i>	American shad	DL, LI, LH, SL
<i>Dorosoma cepedianum</i>	Gizzard shad	ON, LI
Family Cyprinidae		
<i>Camptostoma anomalum</i>	Central stoneroller	AL, CG, GN, EN, ON, OE, OO, SQ
<i>Carassius auratus</i>	Goldfish	EN, ON, LI, LH, MH, NW, OO, SQ, UH
<i>Chrosomus eos</i>	Northern redbelly dace	AL, BL, CH, EN, ON, LH, MH, OE, OO, RQ, SL, UH
<i>Chrosomus neogaeus</i>	Finescale dace	AL, BL, CH, ON, OE, RQ, SL
<i>Clinostomus elongatus</i>	Redside dace	AL, BL, CG, GN, EN, ON, MH, OE, OO, SQ
<i>Couesius plumbeus</i>	Lake chub	BL, DL, CH, ON, LH, MH, OE, RQ, SL, UH
<i>Cyprinella analostana</i>	Satinfin shiner	BL, CG, DL, LH, MH, SQ, UH
<i>Cyprinella spiloptera</i>	Spotfin shiner	AL, BL, CG, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ, UH
<i>Cyprinus carpio</i>	Common carp	AL, BL, CG, DL, EN, ON, LI, LH, MH, NW, OO, RQ, SL, SQ, UH
<i>Erimystax dissimilis</i>	Streamline chub	AL
<i>Erimystax x-punctatus</i>	Gravel chub	AL
<i>Exoglossum laurae</i>	Tonguetied minnow	AL, GN
<i>Exoglossum maxillingua</i>	Cutlip minnow	BL, CG, DL, GN, CH, ON, LH, MH, NW, OE, OO, RQ, SL, SQ, UH

Species		Historic survey	Modern survey
<i>Hybognathus hankinsoni</i>	Brassy minnow	GN, CH, ON, LH, MH, OE, RQ, SL, UH	AL, BL, LH, OE, OO, RQ, SL
<i>Hybognathus regius</i>	Eastern silvery minnow	DL, GN, CH, ON, LH, MH, OO, UH	BL, CH, ON, LH, MH, OE, OO, SL, UH
<i>Hybopsis amblops</i>	Bigeye chub	AL, EN, ON	AL, EN
<i>Luxilus chrysocephalus</i>	Striped shiner	AL, GN, EN, ON, OO	AL, GN, EN, ON, OO
<i>Luxilus cornutus</i>	Common shiner	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Lythrurus umbratilis</i>	Redfin shiner	EN, ON	AL, EN, ON
<i>Macrhybopsis storeriana</i>	Silver chub	EN	-
<i>Margariscus margarita</i> and <i>M. nachtriebi</i> ¹	Pearl dace	AL, BL, CG, GN, CH, ON, LH, MH, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, GN, CH, ON, LH, MH, OE, OO, RQ, SL, SQ, UH
<i>Nocomis biguttatus</i>	Hornyhead chub	GN, EN, ON, MH, OO	AL, BL, GN, EN, ON, MH, OE, OO, SQ
<i>Nocomis micropogon</i>	River chub	AL, CG, EN, ON, OO, SQ	AL, CG, EN, ON, SQ
<i>Notemigonus crysoleucus</i>	Golden shiner	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Notropis amoenus</i>	Comely shiner	CG, DL, LH, MH, NW, SQ	DL, LH, OO, SQ
<i>Notropis anogenus</i>	Pugnose shiner	SL	SL
<i>Notropis atherinoides</i>	Emerald shiner	GN, CH, EN, ON, MH, OO, SL, SQ, UH	AL, DL, CH, EN, ON, LH, MH, OE, OO, SL, RQ, SQ
<i>Notropis bifrenatus</i>	Bridle shiner	CG, DL, CH, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	DL, GN, CH, ON, OE, OO, RQ, SL, SQ, UH
<i>Notropis buccatus</i>	Silverjaw minnow	-	AL
<i>Notropis chalybaeus</i>	Ironcolor shiner	DL, NW	DL
<i>Notropis dorsalis</i>	Bigmouth shiner	AL, GN, EN, OO	AL, CG, GN, EN
<i>Notropis heterodon</i>	Blackchin shiner	AL, GN, CH, ON, SL, SQ, UH	GN, CH, ON, SL
<i>Notropis heterolepis</i>	Blacknose shiner	AL, BL, CG, GN, CH, EN, ON, MH, OE, OO, RQ, SL, SQ	AL, BL, CH, EN, ON, OE, OO, RQ, SL, UH
<i>Notropis hudsonius</i>	Spottail shiner	AL, BL, CG, DL, GN, CH, EN, ON, LH, MH, OE, OO, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LH, MH, OE, OO, SL, SQ, UH
<i>Notropis photogenis</i>	Silver shiner	AL	AL
<i>Notropis procne</i>	Swallowtail shiner	CG, DL, OO, SQ	CG, DL, SQ
<i>Notropis rubellus</i>	Rosyface shiner	AL, CG, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ, UH	AL, CG, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ, UH
<i>Notropis stramineus</i>	Sand shiner	AL, GN, CH, EN, ON, SL	AL, CG, GN, CH, EN, ON, LH, RQ, SL, SQ, UH
<i>Notropis volucellus</i>	Mimic shiner	AL, GN, CH, EN, ON, OO, RQ, SL	AL, CG, DL, GN, CH, EN, ON, OE, OO, RQ, SL, SQ, UH
<i>Pimephales notatus</i>	Bluntnose minnow	AL, BL, CG, DL, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ, UH
<i>Pimephales promelas</i>	Fathead minnow	AL, BL, CG, GN, CH, EN, ON, LI, LH, MH, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, OE, OO, RQ, SL, SQ, UH
<i>Rhinichthys atratulus atratulus</i> ²	Eastern blacknose dace	BL, CG, DL, CH, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	BL, CG, DL, CH, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Rhinichthys atratulus meleagris</i> ²	Western blacknose dace	AL, GN, EN, ON	AL, GN, EN, ON
<i>Rhinichthys cataractae</i>	Longnose dace	AL, BL, CG, DL, GN, CH, EN, ON, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Rhodeus sericeus</i>	Bitterling	LH	-
<i>Scardinius erythrophthalmus</i>	Rudd	LH	GN, EN, ON, LH, NW, SL
<i>Semotilus atromaculatus</i>	Creek chub	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Semotilus corporalis</i>	Fallfish	CG, DL, CH, EN, ON, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	BL, CG, DL, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
Family Catastomidae			
<i>Carpoides cyprinus</i>	Quillback	CG, EN	AL, BL, CG, EN, SQ

Species		Historic survey	Modern survey
<i>Catostomus catastomus</i>	Longnose sucker	BL, DL, CH, ON, LH, MH, OE, RQ, SL, SQ, UH	BL, DL, GN, CH, LH, MH, OO, UH
<i>Catostomus commersonii</i>	White sucker	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Catostomus utawana</i>	Summer sucker	OE	BL, OE, UH
<i>Erimyzon oblongus</i>	Eastern creek chubsucker	CG, DL, ON, LI, LH, MH, NW, OO, SQ	CG, DL, ON, LI, LH, MH, NW, OE, OO, SQ, UH
<i>Erimyzon sucetta</i>	Lake chubsucker	EN, ON	-
<i>Hypentelium nigricans</i>	Northern hog sucker	AL, CG, DL, GN, EN, ON, LH, MH, OO, SQ, UH	AL, BL, CG, DL, GN, EN, ON, MH, OO, SQ, UH
<i>Minytrema melanops</i>	Spotted sucker	-	EN
<i>Moxostoma anisurum</i>	Silver redhorse	AL, GN, CH, EN, ON, OO, RQ, SL	AL, GN, CH, EN, ON, OE, OO, RQ, SL
<i>Moxostoma brevisceps</i>	Smallmouth redhorse	AL	AL
<i>Moxostoma carinatum</i>	River redhorse	-	AL
<i>Moxostoma duquesnei</i>	Black redhorse	AL, GN, EN	AL, EN
<i>Moxostoma erythrum</i>	Golden redhorse	AL, GN, EN, ON	AL, GN, EN, ON
<i>Moxostoma macrolepidotum</i>	Shorthead redhorse	GN, CH, EN, ON, MH, OE, OO, RQ, SL, SQ	GN, CH, EN, ON, MH, OO, RQ, SL, SQ
<i>Moxostoma valenciennesi</i>	Greater redhorse	CH, ON, RQ, SL	AL, GN, CH, EN, ON, OE, RQ, SL
Family Cobitidae			
<i>Misgurnus anguillicaudatus</i>	Oriental weatherfish	-	AL, LH
Family Ictaluridae			
<i>Ameiurus catus</i>	White catfish	LH	-
<i>Ameiurus melas</i>	Black bullhead	GN, ON, OO, UH	CH, ON
<i>Ameiurus natalis</i>	Yellow bullhead	EN, ON, LH, MH, NW, OO, UH	AL, CG, DL, CH, EN, ON, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Ameiurus nebulosus</i>	Brown bullhead	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Ictalurus punctatus</i>	Channel catfish	CH, EN, OE, OO, RQ, SL	AL, GN, CH, EN, ON, LI, OE, SL
<i>Noturus flavus</i>	Stonecat	AL, BL, GN, CH, EN, ON, LH, MH, RQ, SL, UH	AL, GN, CH, EN, ON, MH, OO, RQ, SL
<i>Noturus gyrinus</i>	Tadpole madtom	DL, EN, ON, LH, MH, NW, OE, OO, SL, SQ, UH	DL, EN, ON, LH, OE, OO, SL
<i>Noturus insignis</i>	Margined madtom	CG, DL, ON, LH, MH, SQ	BL, CG, DL, LH, MH, OE, OO, RQ, SQ, UH
<i>Noturus miurus</i>	Brindled madtom	AL, ON	AL, EN, ON, MH, OO
Family Osmeridae			
<i>Osmerus mordax</i>	Rainbow smelt	LI, LH, RQ	EN, ON
Family Salmonidae			
<i>Coregonus artedii</i>	Cisco	SL	-
<i>Coregonus clupeaformis</i>	Lake whitefish	MH, RQ, SL	-
<i>Oncorhynchus kisutch</i>	Coho salmon	-	ON
<i>Oncorhynchus mykiss</i>	Rainbow trout	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, DL, CH, EN, ON, LI, LH, MH, NW, OO, SL, SQ, UH
<i>Oncorhynchus tshawytscha</i>	Chinook salmon	-	ON, RQ, SL
<i>Salmo salar</i>	Atlantic salmon	CH, OO, RQ	CH, ON, OO, RQ
<i>Salmo trutta</i>	Brown trout	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Salvelinus fontinalis</i>	Brook trout	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Salvelinus namaycush</i>	Lake trout	SL	-
Family Esocidae			
<i>Esox americanus americanus</i>	Redfin pickerel	DL, CH, LI, LH, MH, NW, SQ, UH	DL, CH, LI, LH, MH, NW, UH
<i>Esox americanus vermiculatus</i>	Grass pickerel	EN, ON, OO, SL	AL, EN, ON, OO, SL

Species		Historic survey	Modern survey
<i>Esox lucius</i>	Northern pike	BL, CG, GN, CH, EN, ON, OE, OO, RQ, SL, UH	AL, BL, CG, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ, UH
<i>Esox masquinongy</i>	Muskellunge	AL, CH, EN, OE, RQ, SL	AL, CH, EN, OE, RQ, SL
<i>Esox niger</i>	Chain pickerel	BL, CG, DL, GN, CH, ON, LI, LH, MH, NW, OE, OO, SL, SQ, UH	AL, BL, CQ, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, SL, SQ, UH
<i>E. masquinongy</i> x <i>E. lucius</i>	Tiger muskellunge	-	MH, SL, SQ
<i>Umbra limi</i>	Central mudminnow	AL, GN, CH, EN, ON, MH, OE, OO, RQ, SL	AL, BL, CG, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ, UH
<i>Umbra pygmaea</i>	Eastern mudminnow	LI, LH, NW	LI, LH, NW
Family Osmeridae			
<i>Osmerus mordax</i>	Rainbow smelt	LI, LH, RQ	EN, ON
Family Percopsidae			
<i>Percopsis omiscomaycus</i>	Trout-perch	AL, GN, CH, EN, ON, LH, MH, SL, UH	AL, GN, CH, EN, ON, LH, MH, OO, SL, UH
Family Aphredoderidae			
<i>Aphredoderus syanus</i>	Pirate perch	EN, ON, LI	ON, LI
Family Gadidae			
<i>Lota Lota</i>	Burbot	AL, BL, CH, RQ, SL, SQ	AL, BL, OE, OO, SL, SQ
<i>Microgadus tomcod</i>	Atlantic tomcod	LI	LH
Family Atherinopsidae			
<i>Labidesthes sicculus</i>	Brook silverside	AL, EN, ON, MH, OO, SL	AL, GN, CH, EN, ON, MH, OE, OO, RQ, SL, UH
Family Fundulidae			
<i>Fundulus diaphanus</i>	Banded killifish	CG, DL, GN, CH, ON, LI, LH, MH, NW, OE, OO, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Fundulus heteroclitus</i>	Mummichog	LI, LH	LI, LH
Family Poeciliidae			
<i>Gambusia affinis</i>	Western mosquitofish	-	LI
Family Gasterosteidae			
<i>Apeltes quadracus</i>	Fourspine stickleback	LI, LH, UH	LI, LH
<i>Culaea inconstans</i>	Brook stickleback	AL, BL, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ
<i>Gasterosteus aculeatus</i>	Threespine stickleback	GN, ON, LI, OO, SL	ON, LI
<i>Gasterosteus pungitius</i>	Ninespine stickleback	LI	LI
Family Cottidae			
<i>Cottus bairdii</i>	Mottled sculpin	AL, CG, GN, EN, ON, OO, SL, SQ	AL, CG, DL, GN, CH, EN, ON, OO, SL, SQ
<i>Cottus cognatus</i>	Slimy sculpin	BL, CG, DL, CH, ON, LH, MH, OE, OO, RQ, SL, SQ, UH	BL, CG, DL, CH, ON, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
Family Moronidae			
<i>Morone americana</i>	White perch	LI, LH, MH, SL, UH	AL, BL, CH, EN, ON, LI, LH, NW, OO, SL, UH
<i>Morone chrysops</i>	White bass	EN, ON, OO	AL, EN, MH
<i>Morone saxatilis</i>	Striped bass	LI, LH, MH	LI, LH, UH
Family Centrarchidae			
<i>Acantharchus pomotis</i>	Mud sunfish	NW	-
<i>Ambloplites rupestris</i>	Rock bass	AL, BL, CG, DL, GN, CH, EN, ON, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Enneacanthus gloriosus</i>	Bluespotted sunfish	DL, LH, NW	DL, LH, NW
<i>Enneacanthus obesus</i>	Banded sunfish	LI	LI

Species		Historic survey	Modern survey
<i>Lepomis auritus</i>	Redbreast sunfish	CG, DL, CH, LI, LH, MH, NW, RQ, SQ, UH	CG, DL, CH, LI, LH, MH, NW, RQ, SQ, UH
<i>Lepomis cyanellus</i>	Green sunfish	CG, LH	AL, BL, CG, DL, GN, EN, ON, LI, LH, MH, NW, OO, SL, SQ
<i>Lepomis gibbosus</i>	Pumpkinseed	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Lepomis gulosus</i>	Warmouth	LH	LH
<i>Lepomis macrochirus</i>	Bluegill	AL, CG, DL, ON, LI, LH, NW, OE, OO, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, SL, SQ, UH
<i>Lepomis peltastes</i>	Northern sunfish	ON	EN, ON
<i>Micropterus dolomieu</i>	Smallmouth bass	AL, BL, CG, DL, GN, CH, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Micropterus salmoides</i>	Largemouth bass	AL, BL, CG, DL, GN, CH, ON, LI, LH, MH, NW, OE, OO, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Pomoxis annularis</i>	White crappie	AL, EN, ON, LH, MH	AL, CG, CH, EN, ON, LH
<i>Pomoxis nigromaculatus</i>	Black crappie	AL, DL, CH, ON, LH, MH, OO, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
Family Percidae			
<i>Ammocrypta pellucida</i>	Eastern sand darter	SL	AL, CH, OE, SL
<i>Etheostoma blennioides</i>	Greenside darter	AL, GN, EN, ON, MH, OO	AL, CG, GN, EN, ON, MH, OO, SQ
<i>Etheostoma caeruleum</i>	Rainbow darter	AL, EN, ON	AL, GN, EN, ON, MH
<i>Etheostoma camurum</i>	Bluebreast darter	-	AL
<i>Etheostoma exile</i>	Iowa darter	GN, CH, ON, OE, SL	CH, ON, OE, RQ, SL
<i>Etheostoma flabellare</i>	Fantail darter	AL, BL, CG, GN, CH, EN, ON, MH, OE, OO, RQ, SL	AL, BL, CG, GN, CH, EN, ON, MH, OE, OO, RQ, SL, SQ, UH
<i>Etheostoma fusiforme</i>	Swamp darter	LI	LI
<i>Etheostoma maculatum</i>	Spotted darter	AL	AL
<i>Etheostoma nigrum</i>	Johnny darter	AL, BL, CG, GN, EN, ON, OE, RQ, SL	AL, CG, GN, EN, ON, OE, OO, RQ, SL
<i>Etheostoma olmstedi</i>	Tessellated darter	BL, CG, DL, CH, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	BL, CG, DL, GN, CH, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Etheostoma variatum</i>	Varigate darter	AL	AL
<i>Etheostoma zonale</i>	Banded darter	AL	AL, CG, SQ
<i>Perca flavescens</i>	Yellow perch	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, GN, CH, EN, ON, LI, LH, MH, NW, OE, OO, RQ, SL, SQ, UH
<i>Percina caprodes</i>	Logperch	AL, BL, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, UH	AL, BL, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, UH
<i>Percina copelandi</i>	Channel darter	CH, EN, OE, RQ, SL	AL, EN, OE, RQ, SL
<i>Percina evides</i>	Gilt darter	AL	-
<i>Percina macrocephala</i>	Longhead darter	AL	AL
<i>Percina maculata</i>	Blackside darter	AL, GN, EN, ON, OO	AL, GN, EN, ON, OO
<i>Percina peltata</i>	Shield darter	CG, DL, LH, SQ	CG, DL, LH, SQ
<i>Sander canadensis</i>	Sauger	CH, EN	-
<i>Sander vitreus</i>	Walleye	AL, CG, DL, GN, CH, EN, ON, LH, MH, OE, OO, RQ, SL, SQ, UH	AL, BL, CG, DL, EN, ON, LI, MH, OE, OO, SL, SQ
<i>Sander glaucus</i>	Blue pike	EN, ON	-
Family Scianidae			
<i>Aplodinotus grunniens</i>	Freshwater drum	CH, EN, ON, OO	CH, EN, ON, OO
Family Gobiidae			
<i>Neogobius melanostomus</i>	Round goby	-	EN, ON, SL

¹Two species of pearl dace, the Allegheny pearl dace *Margariscus margarita* and the northern pearl dace *M. nachtriebi* are currently recognized in the American Fisheries Society species list (Page et al. 2013), but we combine them here as historic data do not allow differentiation in historic records.

²The western longnose dace *Rhinichthys obtusus* was removed from the American Fisheries Society species list (Page et al. 2013) so we denote the eastern and western forms as subspecies and analyze them separately.

Table 3. Fish species unique to the historic and modern stream fish surveys of New York State.

Species detected only in the historic survey	Species detected only in the modern survey
Gravel chub	Ohio lamprey
Silver chub	Silverjaw minnow
Bitterling	Spotted sucker
Lake chubsucker	River redbhorse
White catfish	Oriental weatherfish
Cisco	Coho salmon
Lake whitefish	Chinook salmon
Lake trout	Tiger muskellunge
Mud sunfish	Western mosquitofish
Gilt darter	Bluebreast darter
Sauger	Round goby
Blue pike	

The family Cyprinidae was the most diverse in both surveys, followed by the families Percidae, Catastomidae and Centrarchidae (Figures 5 and 6). Thirteen of the 27 families of fishes in New York were represented by only a single species. The rank order of diversity by family agrees well with national surveys, but representation of national diversity in New York State differs among families (Warren and Burr 1994). New York waters are home to only 14% of the species of Percidae in the United States as summarized by Warren and Burr (1994), and includes 20-23% of the known species of the families Cyprinidae, Salmonidae, Catastomidae, and Ictaluridae. However, 47% of the species of Centrarchidae of the United States are found in New York.

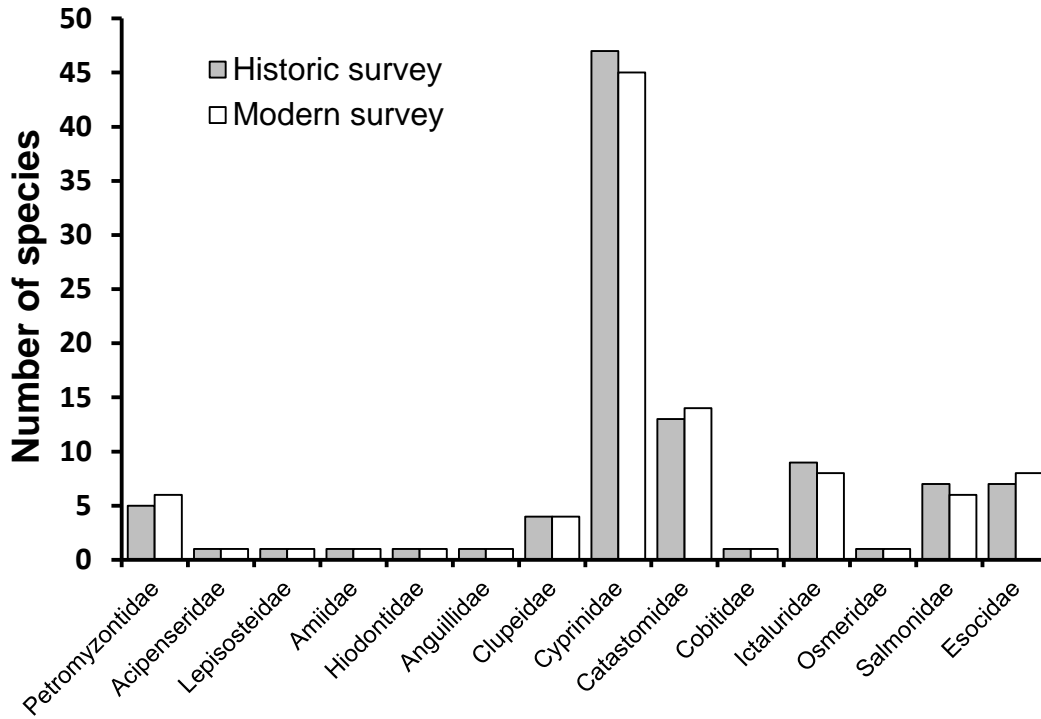


Figure 5. Number of fish species observed by family in the historic and modern stream fish surveys of New York State.

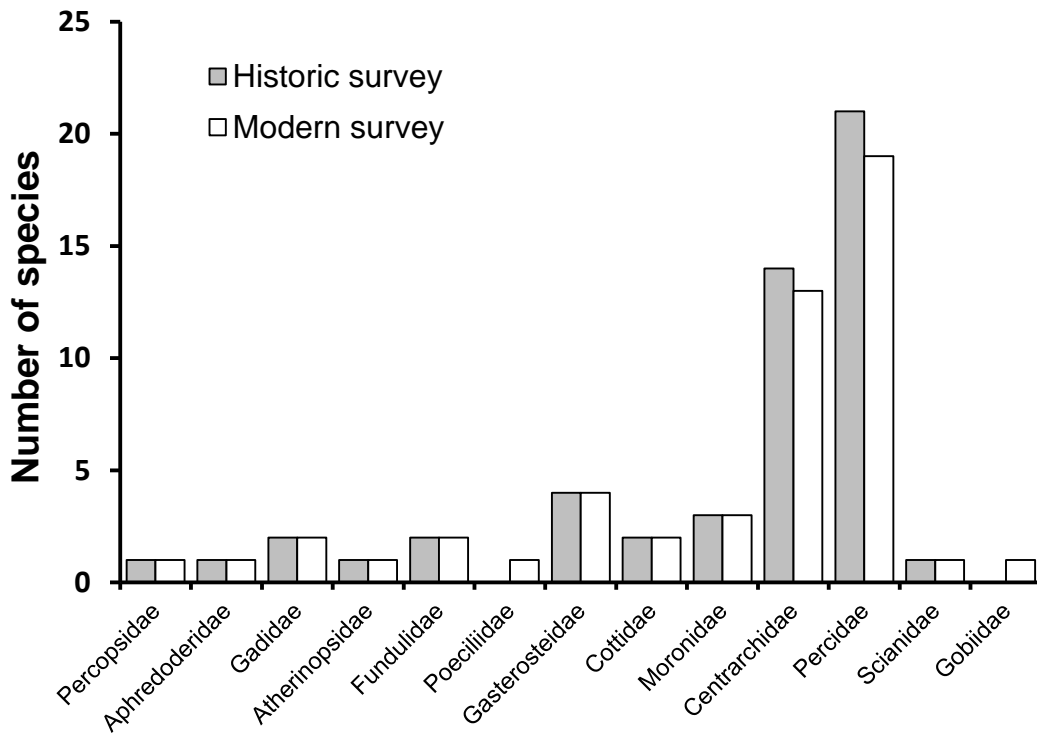


Figure 6. Number of fish species observed by family in the historic and modern stream fish surveys of New York State.

The Great Lakes watersheds were home to the greatest diversity of fish species in both surveys (Figure 7). Tributaries of Lake Ontario held the greatest diversity of species with 91 observed in the historic survey, followed by the St. Lawrence River watershed, the Lake Erie-Niagara and the Oswego River watersheds. Lake Ontario tributaries also held the greatest diversity of species in the modern survey, with 93 species. The Allegheny River watershed had the second highest species diversity in the modern survey, followed by the St. Lawrence River and Lake Erie-Niagara watersheds. The least diverse watershed in both surveys was the Newark Bay watershed (34 species in the modern survey) followed by the Long Island watershed with 44 species in the modern survey. Detailed results of analyses of individual watersheds can be found in Appendix 1.

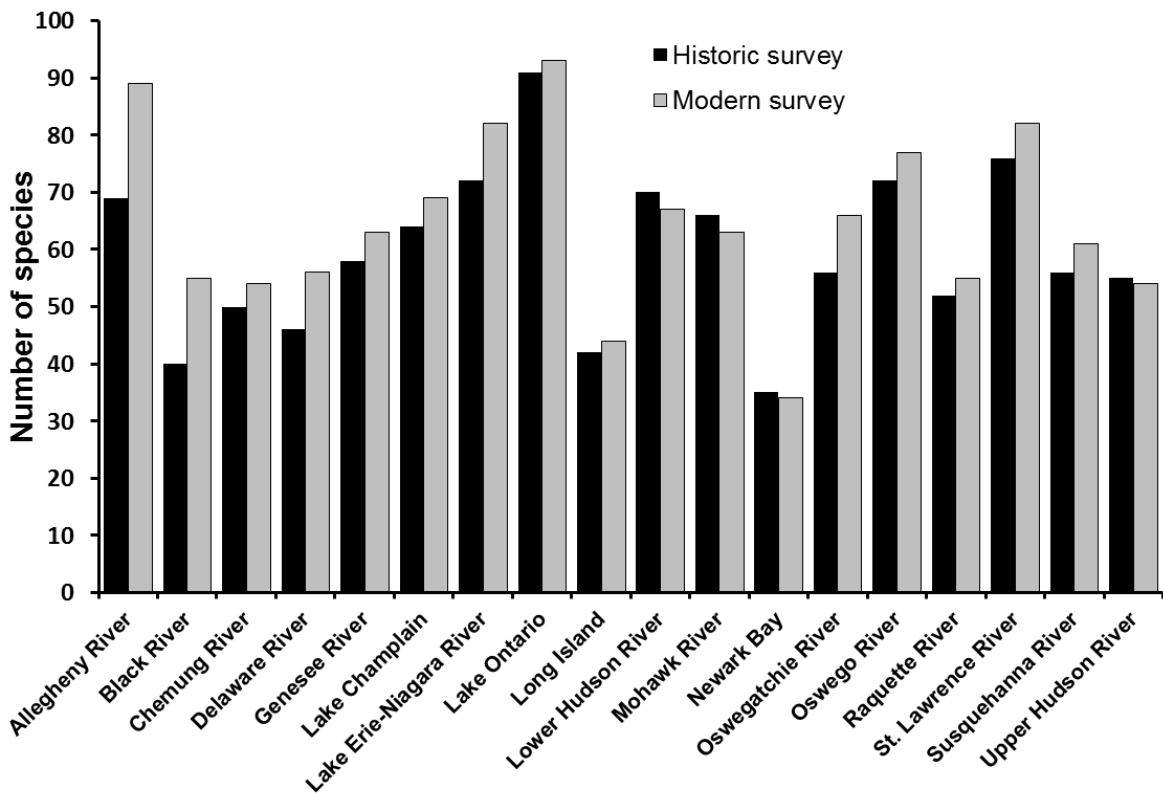


Figure 7. Number of fish species observed in watersheds sampled during the historic and modern stream fish surveys of New York State.

Frequency of encounter distributions for individual fish species from both surveys were strongly skewed, with most species encountered at only a small proportion of all sampled sites (Figure 8). Of the 151 species encountered statewide during the historic survey, 121 (80.1%) were observed at 5% or fewer of sites sampled. During the

modern survey, 107 of 151 species (70.9%) were encountered at 5% or fewer of sampled sites. Seven species were found at only a single site in the historic survey (northern brook lamprey, lake trout, summer sucker, banded sunfish, warmouth, eastern sand darter, swamp darter). Five species were encountered at only one site in the modern survey (mooneye, coho salmon, round whitefish, spotted sucker, Atlantic tomcod). Widely distributed species were the exception in both surveys. Only 17 species (11.3%) were encountered at 10% or more of sampling sites during the historic survey while 30 species (19.9%) were encountered at that frequency during the modern survey. White sucker was the most commonly encountered species in both surveys, detected at 50.5% of all sites in the historic survey and 52.7% of sites during the modern survey. Common shiner (44.1%) and creek chub (36.5%) ranked second and third in frequency during the historic survey, while pumpkinseed (40.1%) and bluntnose minnow (33.9%) ranked second and third in the modern survey.

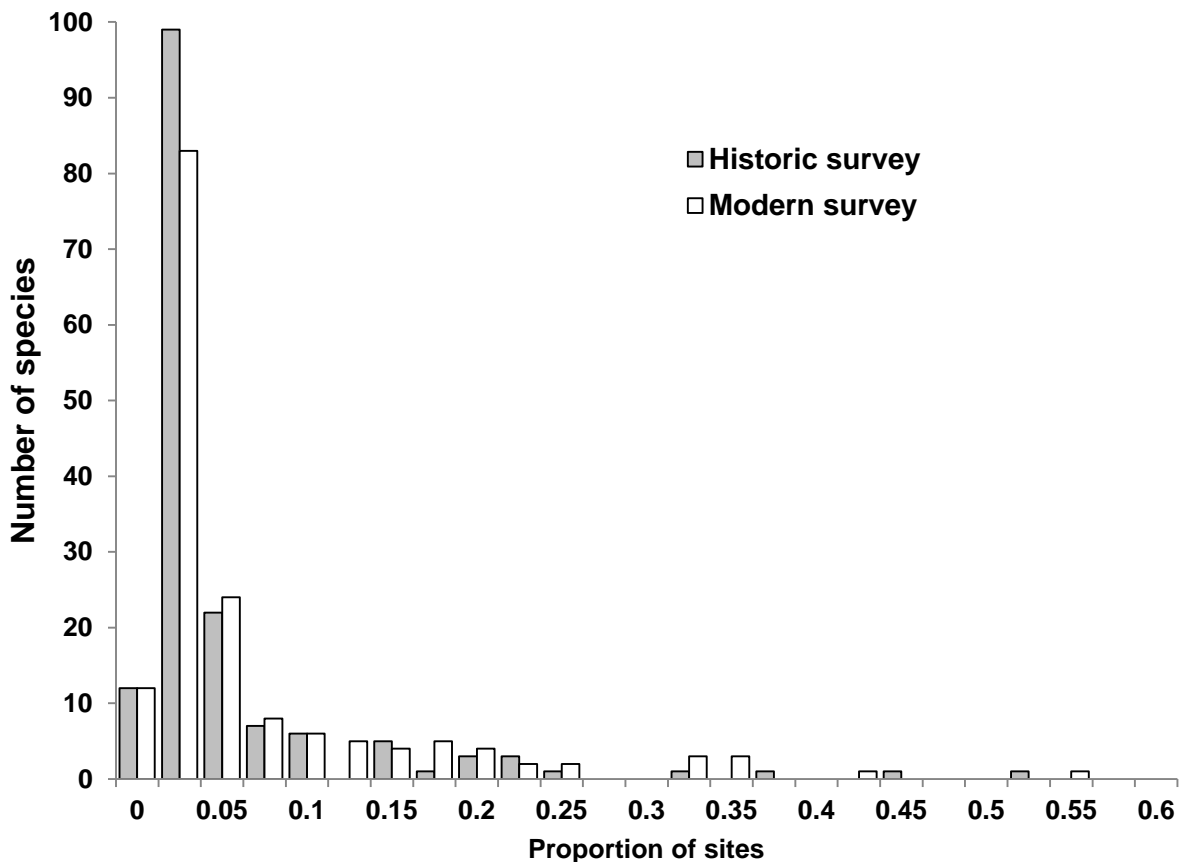


Figure 8. Frequency with which individual fish species were encountered at sampling sites in the historic and modern stream fish surveys of New York State.

Twenty-seven of the 151 species (17.9%) observed during the historic surveys were limited to only a single watershed in New York State (Figure 9). Twenty-three of the 151 species (15.2%) collected during the modern survey were limited to only a single watershed. Of species detected in the historic surveys, 43.7% were found in 4 or fewer watersheds while 40.4% were in 4 or fewer watersheds in the modern surveys. Ten species (6.6%) were found in all 18 watersheds during the historic surveys while 14 (9.2%) were in all watersheds in the modern survey. Results of the historic survey found 15.2% of all species in 15 or more of the 18 watersheds while 23.8% were in 15 or more watersheds in the modern survey. Trends towards increasing frequency of species in greater numbers of watersheds primarily resulted from range expansions of existing species (see below).

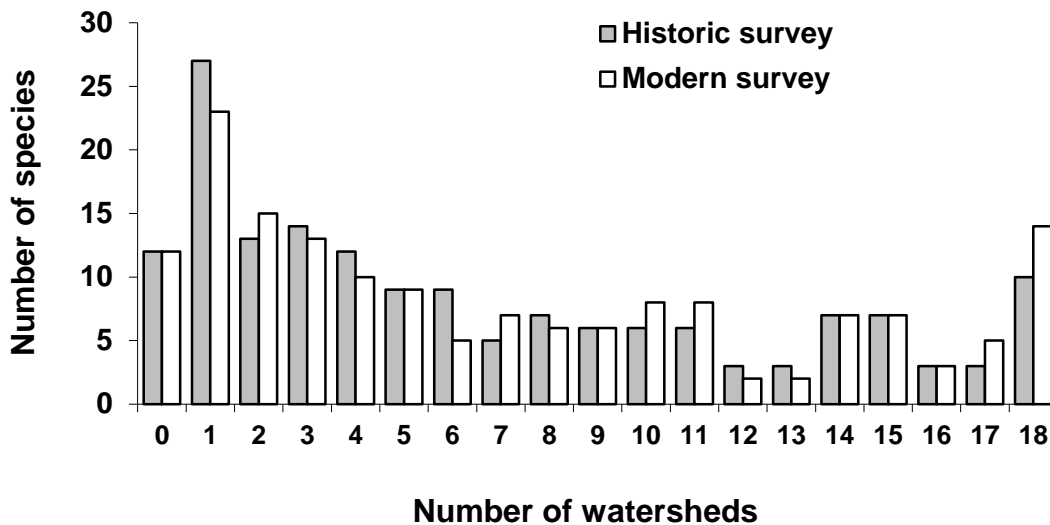


Figure 9. Frequency with which individual fish species occurred in a given number of watersheds in the historic and modern stream fish surveys of New York State.

Statewide summary – analyses of changes

Of the 139 species encountered in both surveys, only 15 (10.8%) exhibited less than a 20% change in the proportion of sites they were observed at statewide (Figure 10, Table 4). Forty-four species (31.7%) were observed at a reduced proportion of sampling sites during the modern survey, while 95 species (68.3%) exhibited an increase in proportion of sites where detected. Of the species that declined in proportion of sites where detected, mooneye exhibited the greatest decline, with an 87% reduction. Comely shiner exhibited an 86% reduction in the proportion of sites

sampled at, followed by Atlantic tomcod and lake chub (both -78%). The largest increase in occurrence was observed for the eastern sand darter, with an increase in proportion of sites detected at of 6,935%. Green sunfish exhibited an increase of 6,140%, followed by northern brook lamprey (2,161%) and gizzard shad (1,717%).

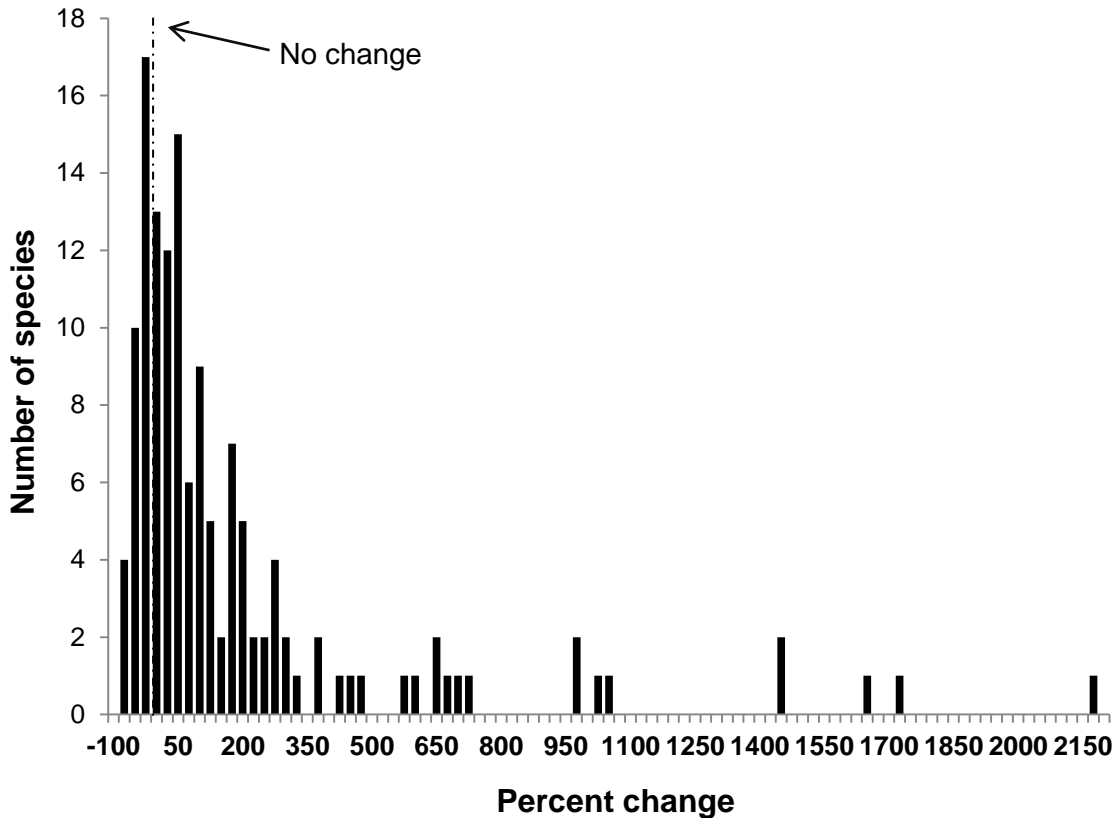


Figure 10. Percent change in the proportion of sites individual fish species were detected at between the historic and modern stream fish surveys of New York State. For purposes of scale, the eastern sand darter (6,935% increase) and green sunfish (6,140% increase) are not shown on this figure.

Statistically significant changes in distribution of stream fishes in the years between surveys were widespread (Table 4; Figures 11-23). Significant changes were detected in 48.1% of the species present in New York State. Of the species exhibiting significant distribution changes, 82.1% showed expanded ranges while 17.9% exhibited contracted distributions.

Table 4. Number of watersheds where individual fish species exhibited significant change in proportion of sites where detected, net change in the number of watersheds individual fish species were detected in, catches (proportion of sites where detected) of fish species statewide in New York State from historic and modern stream fish surveys, and results of Fisher's exact test for differences in statewide distribution (total number of species represented: 162, Bonferroni inequality correction for significance: $0.05/162 = 0.0003$; significant changes in distribution indicated in **bold**).

Species	Number of watersheds with significant decreases	Number of watersheds with significant increases	Net change in number of watersheds detected in	Proportion of statewide sites – Historic (n = 4058)	Proportion of statewide sites – Modern (n = 3057)	Direction of change	Fisher's exact test p-value
Family Petromyzontidae							
Ohio lamprey		1	+1	0.0000	0.0085	INC	<0.0001
Northern brook lamprey			+1	0.0002	0.0056	INC	<0.0001
Mountain brook lamprey			0	0.0005	0.0036		0.0033
Silver lamprey			0	0.0012	0.0007		0.7061
American brook lamprey		3	+3	0.0025	0.0429	INC	<0.0001
Sea lamprey			+3	0.0052	0.0101		0.0167
Family Acipenseridae							
Lake sturgeon			+1	0.0005	0.0075	INC	<0.0001
Family Lepisosteidae							
Longnose gar		1	+3	0.0027	0.0092		0.0005
Family Amiidae							
Bowfin		1	+3	0.0030	0.0164	INC	<0.0001
Family Hiodontidae							
Mooneye			-2	0.0025	0.0003		0.0295
Family Anguillidae							
American eel		3	-5	0.0424	0.0644	INC	<0.0001
Family Clupeidae							
Blueback herring			+1	0.0047	0.0036		0.5808
Alewife			-1	0.0116	0.0098		0.4902
American shad			-2	0.0025	0.0020		0.8023
Gizzard shad		1	+9	0.0007	0.0134	INC	<0.0001
Family Cyprinidae							
Central stoneroller	1	3	+3	0.1343	0.1721	INC	<0.0001
Goldfish			-2	0.0067	0.0052		0.5372
Northern redbelly dace		2	-1	0.0118	0.0435	INC	<0.0001
Finescale dace			-5	0.0027	0.0010		0.1142
Redside dace	2		-2	0.0688	0.0357	DEC	<0.0001
Lake chub	3		-7	0.0089	0.0020	DEC	0.0001
Satinfin shiner	2		+2	0.0446	0.0141	DEC	<0.0001
Spotfin shiner		8	+1	0.0382	0.1102	INC	<0.0001
Common carp		3	+3	0.0338	0.0716	INC	<0.0001
Streamline chub		1	0	0.0025	0.0196	INC	<0.0001
Gravel chub			-1	0.0010	0.0000		0.1398
Tonguetied minnow	1		0	0.0237	0.0079	DEC	<0.0001
Cutlip minnow		2	0	0.1856	0.1973		0.2226
Brassy minnow		1	-2	0.0076	0.0105		0.2497
Eastern silvery minnow			+1	0.0145	0.0177		0.3382
Bigeye chub	1		-1	0.0148	0.0056	DEC	0.0002
Striped shiner		2	0	0.0172	0.0484	INC	<0.0001
Common shiner	4	1	-1	0.4414	0.3186	DEC	<0.0001
Redfin shiner			+1	0.0025	0.0033		0.6521
Silver chub			-1	0.0010	0.0000		0.1398
Pearl dace	1		0	0.0397	0.0186	DEC	<0.0001
Hornyhead chub		1	+4	0.0136	0.0164		0.3715
River chub			-1	0.0463	0.0438		0.6451
Golden shiner	1	6	0	0.1424	0.1871	INC	<0.0001

Species	Number of watersheds with significant decreases	Number of watersheds with significant increases	Net change in number of watersheds detected in	Proportion of statewide sites – Historic (n = 4058)	Proportion of statewide sites – Modern (n = 3057)	Direction of change	Fisher's exact test p-value
Comely shiner	1		-2	0.0271	0.0039	DEC	<0.0001
Pugnose shiner			0	0.0022	0.0013		0.4170
Emerald shiner			+3	0.0202	0.0347	INC	0.0002
Bridle shiner	1	1	-4	0.0463	0.0275	DEC	<0.0001
Silverjaw minnow			+1	0.0000	0.0029		0.0005
Ironcolor shiner			-1	0.0015	0.0010		0.7407
Bigmouth shiner	1		0	0.0140	0.0124		0.6026
Blackchin shiner			-3	0.0089	0.0049		0.0640
Blacknose shiner			-3	0.0202	0.0121		0.0088
Spottail shiner	3		0	0.0902	0.0671		0.0004
Silver shiner			0	0.0116	0.0291	INC	<0.0001
Swallowtail shiner	1		-1	0.0131	0.0046	DEC	0.0002
Rosyface shiner	1	4	0	0.0653	0.1407	INC	<0.0001
Sand shiner			+5	0.0340	0.0605	INC	<0.0001
Mimic shiner		4	+5	0.0426	0.1220	INC	<0.0001
Bluntnose minnow		7	0	0.1757	0.3386	INC	<0.0001
Fathead minnow		10	+1	0.0269	0.1361	INC	<0.0001
Eastern blacknose dace	2	1	0	0.3068	0.2352	DEC	<0.0001
Western blacknose dace	1	1	0	0.0557	0.0762		0.0005
Longnose dace		4	+1	0.1826	0.2179	INC	0.0002
Bitterling			-1	0.0010	0.0000		0.1398
Rudd			+5	0.0010	0.0036		0.0329
Creek chub	2	1	0	0.3655	0.3369		0.0131
Fallfish	4	2	+2	0.2124	0.1694	DEC	<0.0001
Family Catostomidae							
Quillback		1	+3	0.0010	0.0105	INC	<0.0001
Longnose sucker			-3	0.0150	0.0062		0.0004
White sucker		3	0	0.5047	0.5273		0.0616
Summer sucker			+2	0.0002	0.0016		0.0907
Eastern creek chubsucker			+2	0.0382	0.0193	DEC	<0.0001
Lake chubsucker			-2	0.0017	0.0000		0.0223
Northern hog sucker		3	0	0.0998	0.1479	INC	<0.0001
Spotted sucker			+1	0.0000	0.0003		0.4297
Silver redhorse		1	+1	0.0081	0.0465	INC	<0.0001
Smallmouth redhorse			0	0.0005	0.0075	INC	<0.0001
River redhorse			+1	0.0000	0.0013		0.0340
Black redhorse		1	-1	0.0025	0.0183	INC	<0.0001
Golden redhorse		2	0	0.0140	0.0530	INC	<0.0001
Shorthead redhorse			-1	0.0148	0.0134		0.6859
Greater redhorse			+4	0.0027	0.0072		0.0075
Family Cobitidae							
Oriental weatherfish			+2	0.0000	0.0013		0.0340
Family Ictaluridae							
White catfish			-1	0.0007	0.0000		0.2647
Black bullhead			-2	0.0012	0.0013		1.0000
Yellow bullhead		3	+8	0.0049	0.0396	INC	<0.0001
Brown bullhead	1	3	0	0.1429	0.1776	INC	<0.0001
Channel catfish			+2	0.0020	0.0029		0.4660
Stonecat		1	-2	0.0126	0.0373	INC	<0.0001
Tadpole madtom			-4	0.0153	0.0150		1.0000
Margined madtom		6	+4	0.0382	0.0622	INC	<0.0001
Brindled madtom			3	0.0015	0.0052		0.0080
Family Osmeridae							
Rainbow smelt			-1	0.0007	0.0013		0.4721
Family Salmonidae							
Cisco			-1	0.0007	0.0000		0.2647
Lake whitefish			-3	0.0010	0.0000		0.1398
Coho salmon			+1	0.0000	0.0003		0.4297
Rainbow trout		1	-4	0.0271	0.0327		0.1789

Species	Number of watersheds with significant decreases	Number of watersheds with significant increases	Net change in number of watersheds detected in	Proportion of statewide sites – Historic (n = 4058)	Proportion of statewide sites – Modern (n = 3057)	Direction of change	Fisher's exact test p-value
Chinook salmon		1	+3	0.0000	0.0049	INC	<0.0001
Atlantic salmon			+1	0.0012	0.0043		0.0157
Brown trout		4	0	0.0966	0.1312	INC	<0.0001
Brook trout	3		-1	0.1269	0.0756	DEC	<0.0001
Lake trout			-1	0.0002	0.0000		1.0000
Family Esocidae							
Redfin pickerel		2	-1	0.0126	0.0360	INC	<0.0001
Grass pickerel		1	+1	0.0113	0.0242	INC	<0.0001
Northern pike		3	+1	0.0409	0.0762	INC	<0.0001
Muskellunge			0	0.0047	0.0101		0.0092
Chain pickerel	1	1	+2	0.0808	0.0723		0.1931
Tiger muskellunge			+3	0.0000	0.0016		0.0146
Central mudminnow		7	+5	0.0192	0.0877	INC	<0.0001
Eastern mudminnow			0	0.0091	0.0108		0.5444
Family Percopsidae							
Trout-perch			+1	0.0172	0.0193		0.5309
Family Aphredoderidae							
Pirate perch			-1	0.0054	0.0075		0.2920
Family Gadidae							
Burbot			0	0.0022	0.0095	INC	<0.0001
Atlantic tomcod			0	0.0015	0.0003		0.2508
Family Atherinopsidae							
Brook silverside		1	+5	0.0069	0.0327	INC	<0.0001
Family Fundulidae							
Banded killifish		5	+4	0.0456	0.0831	INC	<0.0001
Mummichog	1		0	0.0143	0.0056		0.0004
Family Poeciliidae							
Western mosquitofish			+1	0.0000	0.0010		0.0793
Family Gasterosteidae							
Fourspine stickleback			-1	0.0089	0.0056		0.1256
Brook stickleback			0	0.0335	0.0451		0.0127
Threespine stickleback			-3	0.0042	0.0016		0.0820
Ninespine stickleback			0	0.0027	0.0020		0.6278
Family Cottidae							
Mottled sculpin		3	+2	0.0550	0.1204	INC	<0.0001
Slimy sculpin		2	+1	0.0296	0.0399		0.0206
Family Moronidae							
White perch			+6	0.0069	0.0095		0.2298
White bass			0	0.0030	0.0016		0.3301
Striped bass			0	0.0010	0.0026		0.1424
Family Centrarchidae							
Mud sunfish			-1	0.0007	0.0000		0.2647
Rock bass		8	+1	0.1727	0.3068	INC	<0.0001
Bluespotted sunfish			0	0.0027	0.0049		0.1641
Banded sunfish			0	0.0002	0.0007		0.5806
Redbreast sunfish			0	0.0633	0.0445		0.0005
Green sunfish		7	+12	0.0007	0.0461	INC	<0.0001
Pumpkinseed		12	0	0.2112	0.4010	INC	<0.0001
Warmouth			0	0.0002	0.0007		0.5806
Bluegill		13	+6	0.0172	0.1816	INC	<0.0001
Northern sunfish			+1	0.0025	0.0013		0.4187
Smallmouth bass		4	+1	0.2065	0.3036	INC	<0.0001
Largemouth bass		11	+2	0.0917	0.2215	INC	<0.0001

Species	Number of watersheds with significant decreases	Number of watersheds with significant increases	Net change in number of watersheds detected in	Proportion of statewide sites – Historic (n = 4058)	Proportion of statewide sites – Modern (n = 3057)	Direction of change	Fisher's exact test p-value
White crappie	1		+1	0.0076	0.0023		0.0026
Black crappie	1	2	+8	0.0234	0.0465	INC	<0.0001
Family Percidae							
Eastern sand darter		1	+3	0.0002	0.0173	INC	<0.0001
Greenside darter		5	+2	0.0283	0.1102	INC	<0.0001
Rainbow darter		3	+2	0.0382	0.1187	INC	<0.0001
Bluebreast darter			+1	0.0000	0.0029		0.0005
Iowa darter			0	0.0049	0.0052		0.8674
Fantail darter		5	+2	0.0754	0.1714	INC	<0.0001
Swamp darter			0	0.0002	0.0007		0.5806
Spotted darter			0	0.0010	0.0010		1.0000
Johnny darter		4	0	0.0616	0.1541	INC	<0.0001
Tessellated darter		7	+1	0.2302	0.3317	INC	<0.0001
Varigate darter		1	0	0.0059	0.0451	INC	<0.0001
Banded darter		3	+2	0.0111	0.0775	INC	<0.0001
Yellow perch	1	3	0	0.1353	0.2260	INC	<0.0001
Logperch		6	0	0.0505	0.1551	INC	<0.0001
Channel darter		2	0	0.0030	0.0334	INC	<0.0001
Gilt darter			-1	0.0012	0.0000		0.0749
Longhead darter		1	0	0.0022	0.0252	INC	<0.0001
Blackside darter		2	0	0.0200	0.0736	INC	<0.0001
Shield darter		1	0	0.0288	0.0353		0.1321
Sauger			0	0.0005	0.0000		0.5098
Walleye	1		-3	0.0259	0.0353		0.0243
Blue Pike			-2	0.0010	0.0000		0.1398
Family Scianidae							
Freshwater drum			0	0.0025	0.0016		0.6038
Family Gobiidae							
Round goby		2	+3	0.0000	0.0114	INC	<0.0001

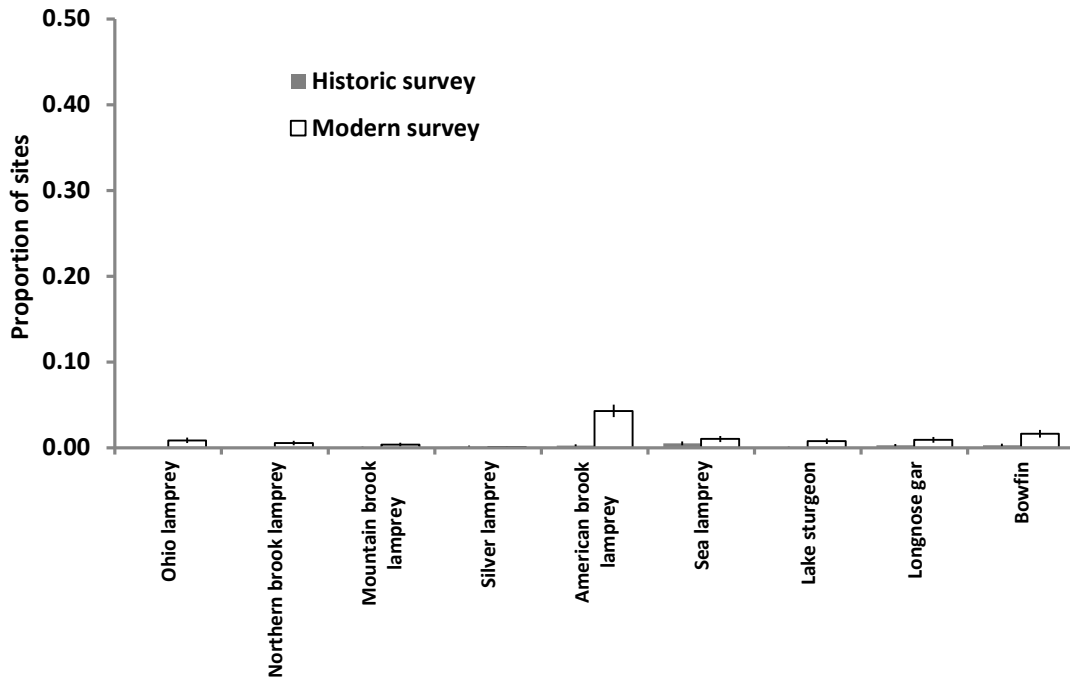


Figure 11. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Families Petromyzontidae, Acipenseridae, Lepisosteidae, and Amiidae. Error bars represent 95% confidence intervals.

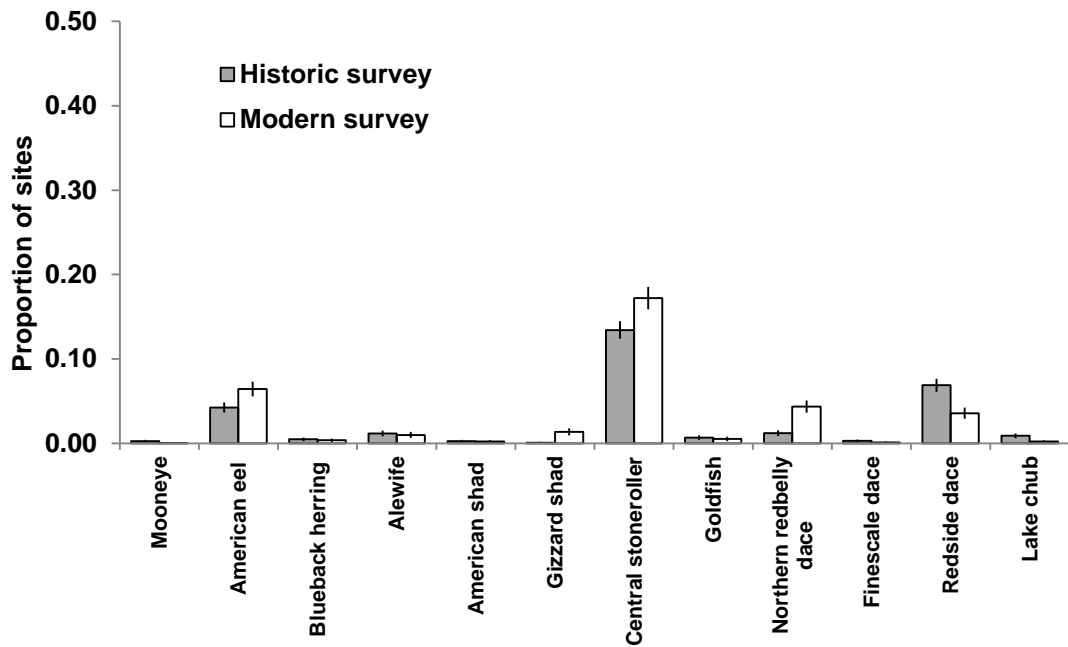


Figure 12. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Families Hiodontidae, Anguillidae, Clupeidae, and Cyprinidae. Error bars represent 95% confidence intervals.

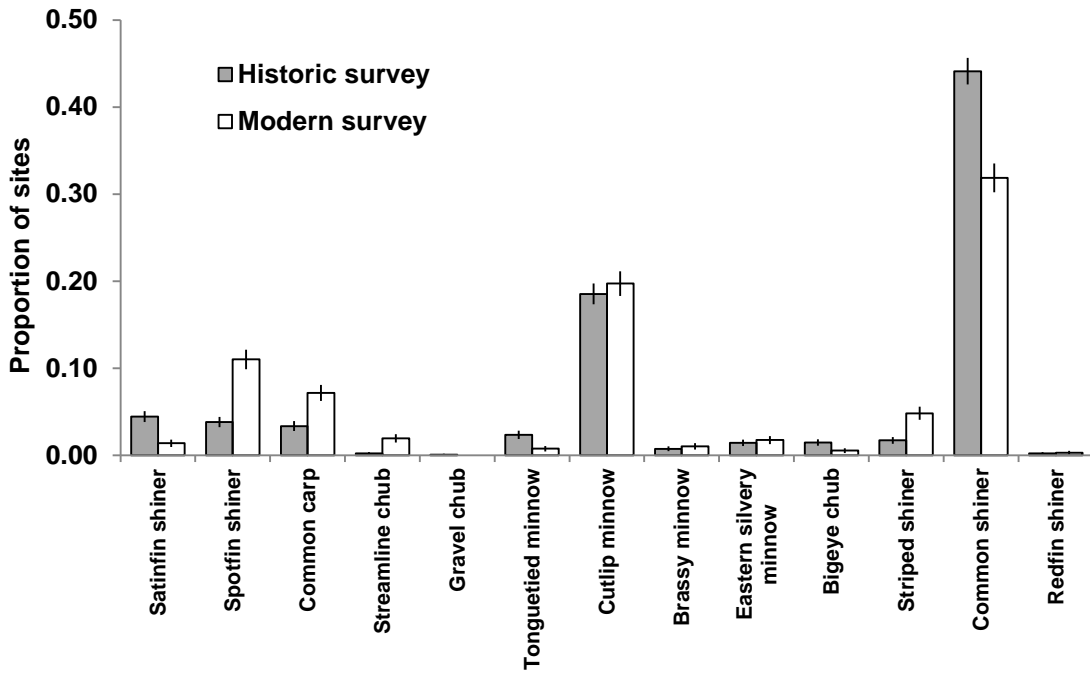


Figure 13. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

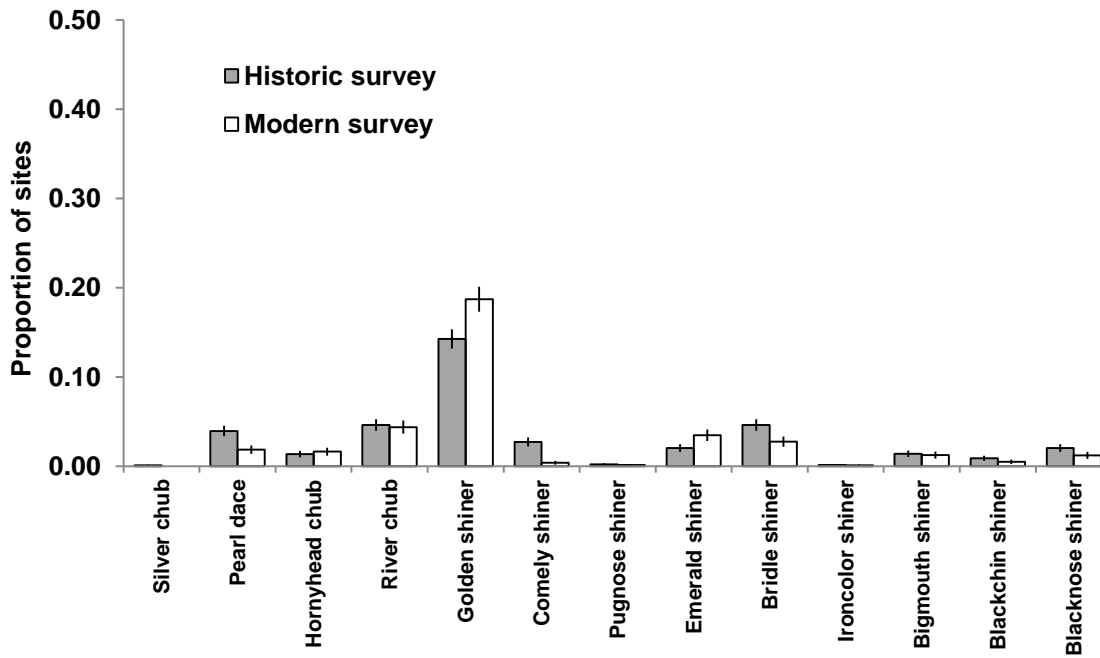


Figure 14. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

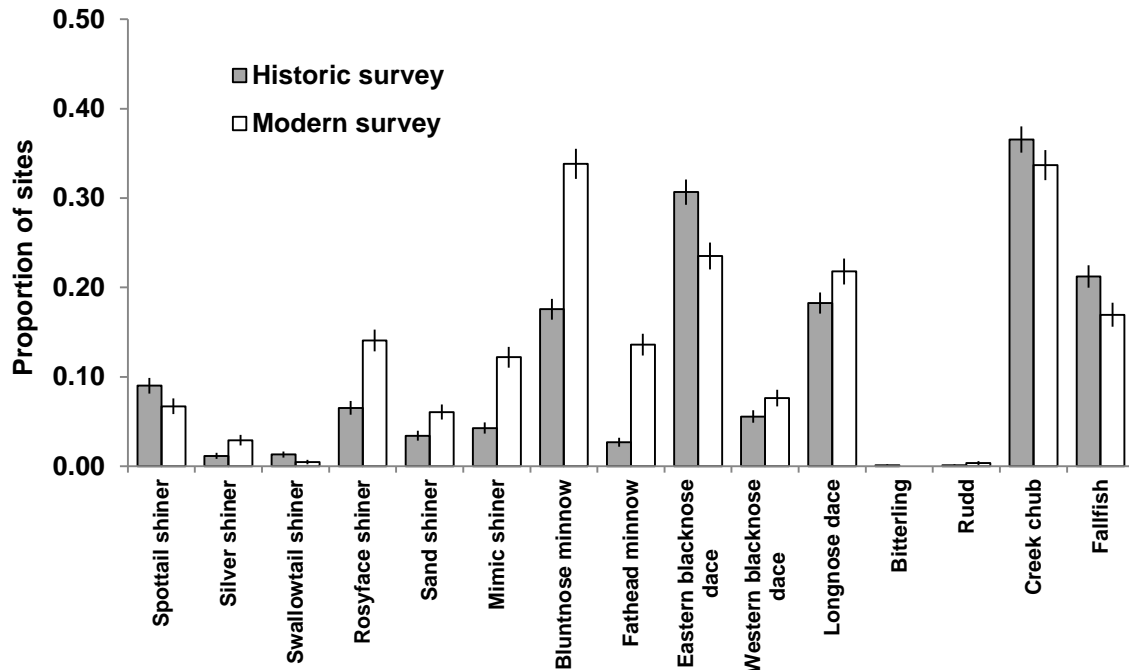


Figure 15. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

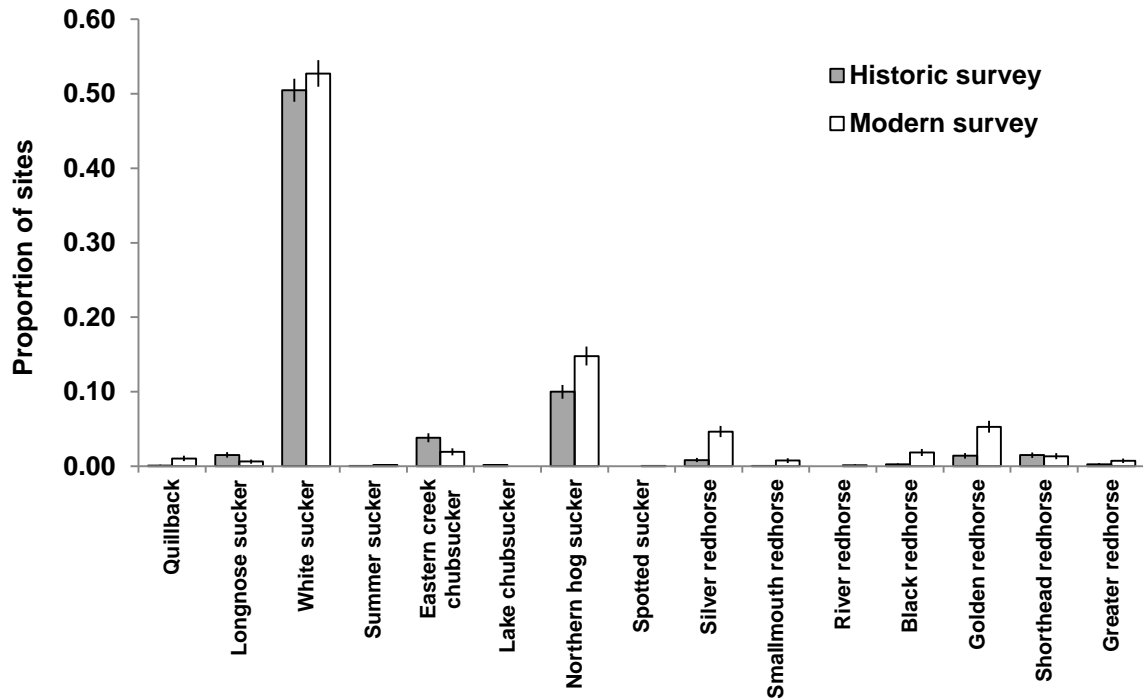


Figure 16. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Family Catostomidae. Error bars represent 95% confidence intervals.

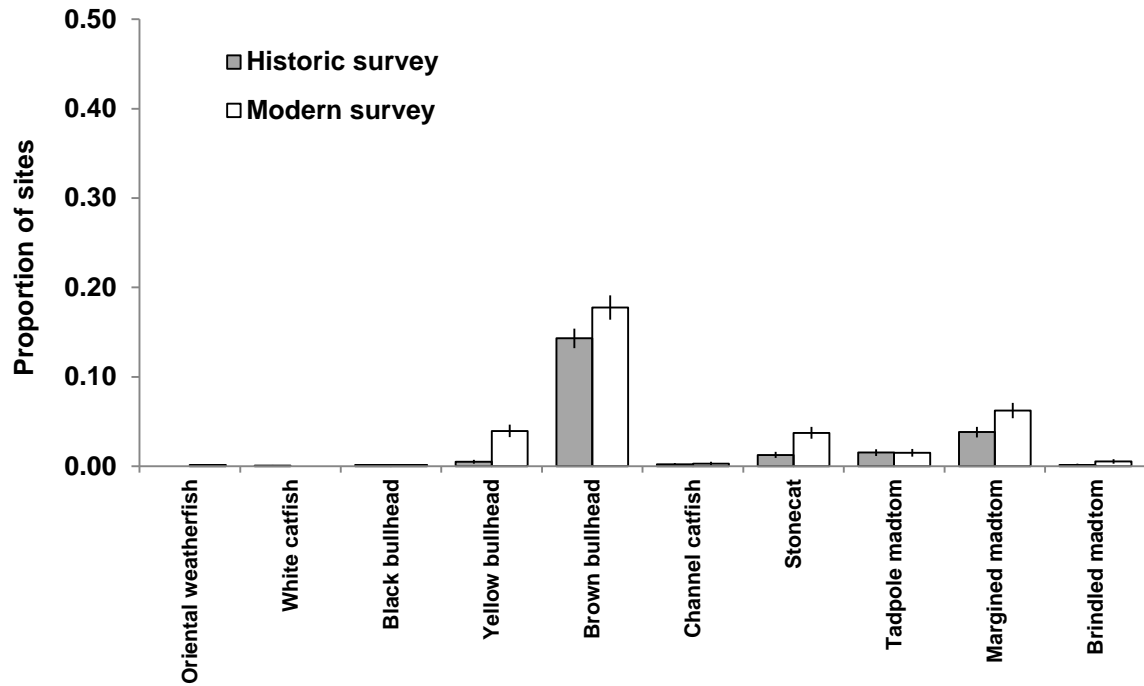


Figure 17. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Families Cobitidae and Ictaluridae. Error bars represent 95% confidence intervals.

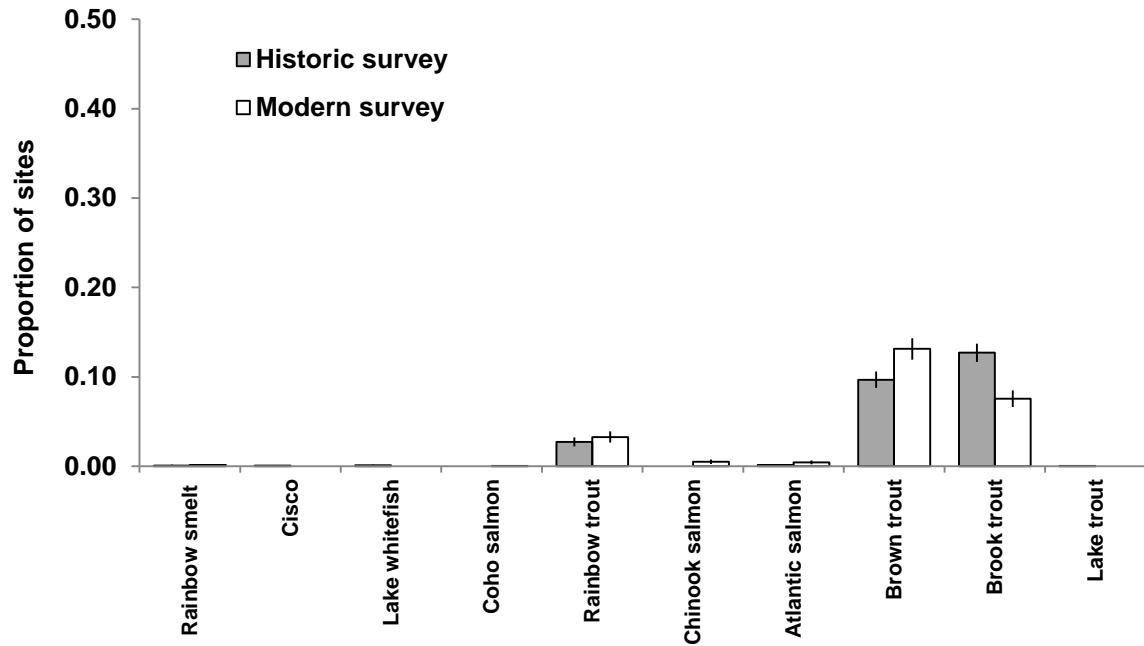


Figure 18. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Families Osmeridae and Salmonidae. Error bars represent 95% confidence intervals.

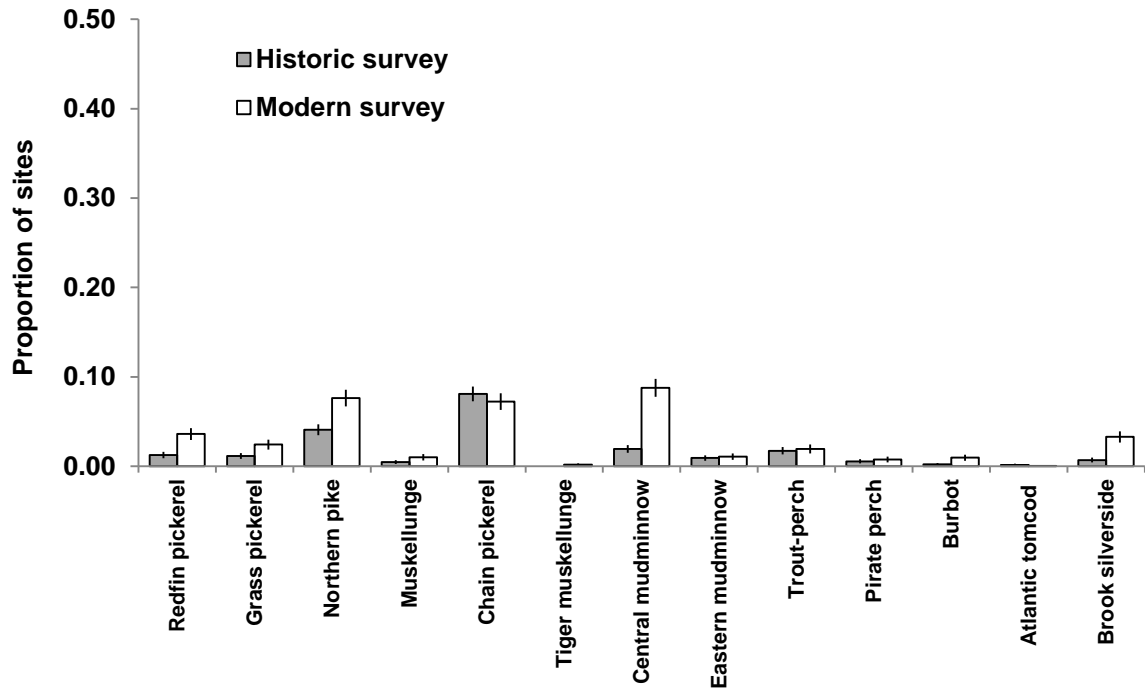


Figure 19. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Families Esocidae, Percopsidae, Aphredoderidae, Gadidae, and Atherinopsidae. Error bars represent 95% confidence intervals.

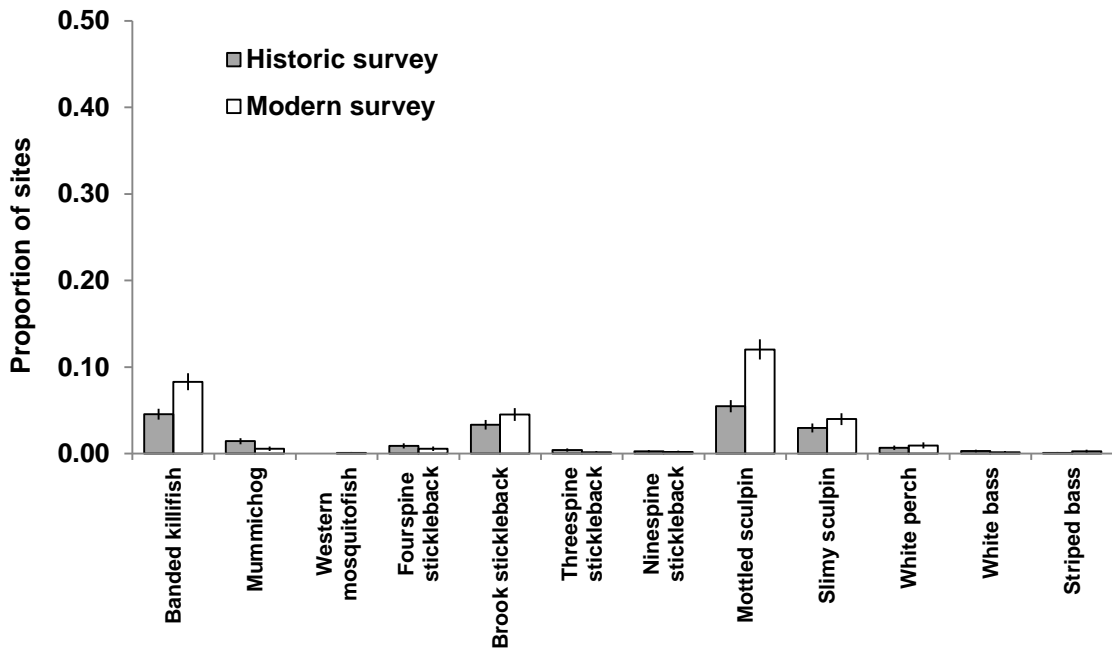


Figure 20. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Families Fundulidae, Poeciliidae, Gasterosteidae, and Moronidae. Error bars represent 95% confidence intervals.

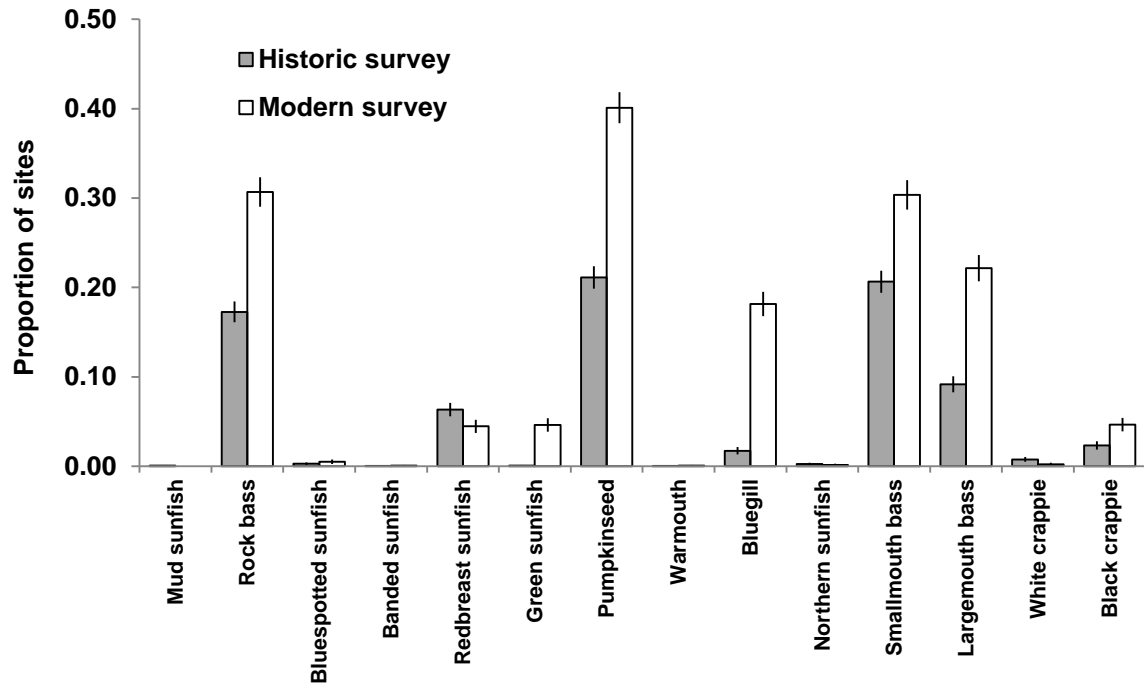


Figure 21. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

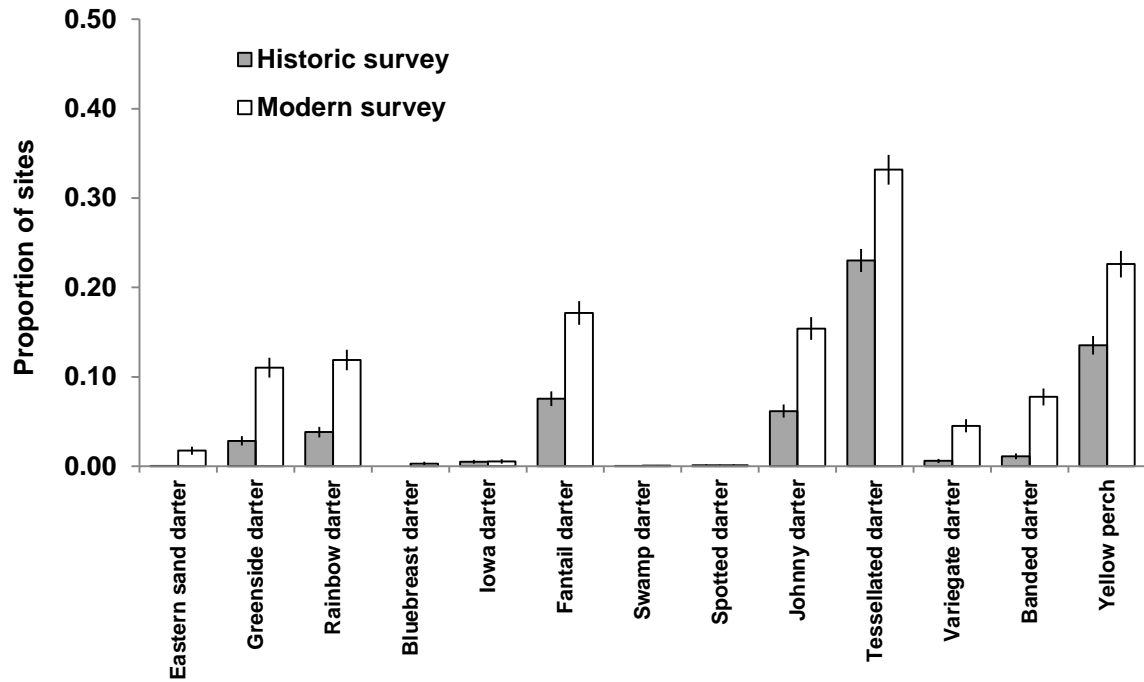


Figure 22. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Family Percidae. Error bars represent 95% confidence intervals.

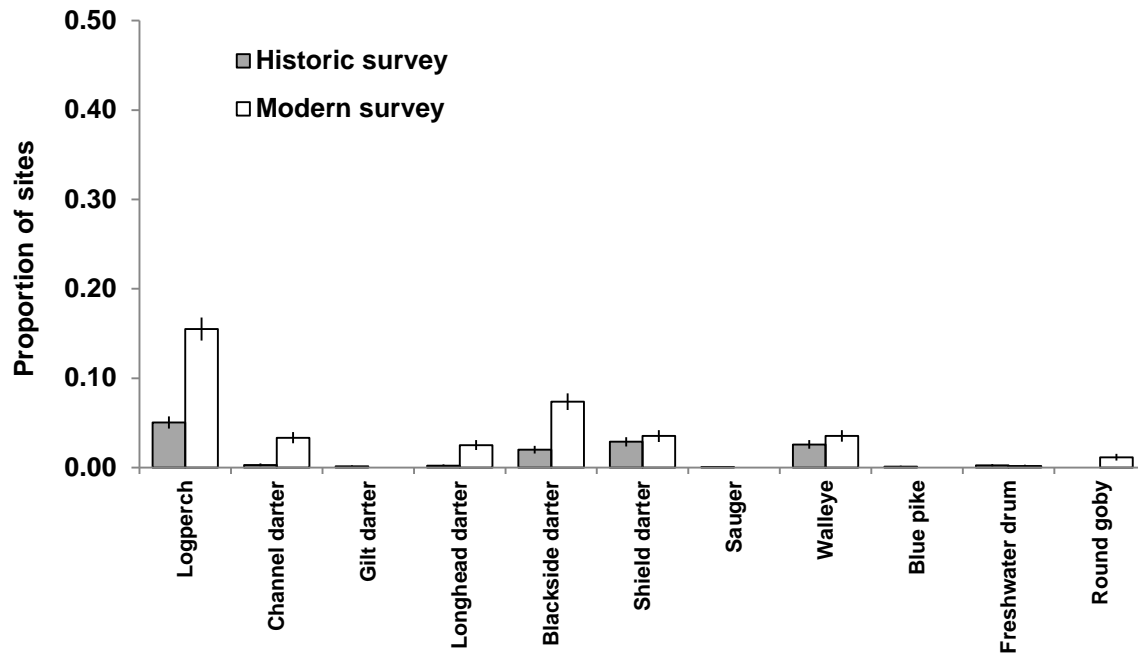


Figure 23. Catches (proportion of sites where detected) of fish species in New York State from historic and modern stream fish surveys. Families Percidae, Scianidae, and Gobiidae. Error bars represent 95% confidence intervals.

Evidence for increased distribution was found for species from 17 of the 27 families of fish in New York (Figures 24 and 24). Species of the family Percidae increased in distribution most consistently, with 68.4% of Percid species exhibiting significant increases, followed by Centrarchidae (53.8%). Note that increases in Percid species were almost exclusively confined to benthic darter species which would likely have been more effectively sampled by electrofishing methods used in the modern survey. Conversely, contractions in distribution were limited to only three families, Cyprinidae, Catostomidae, and Salmonidae. Significant decreases in distribution were observed for 26.7% of Cyprinid species, 16.8 of Salmonids and 7% of Catostomids.

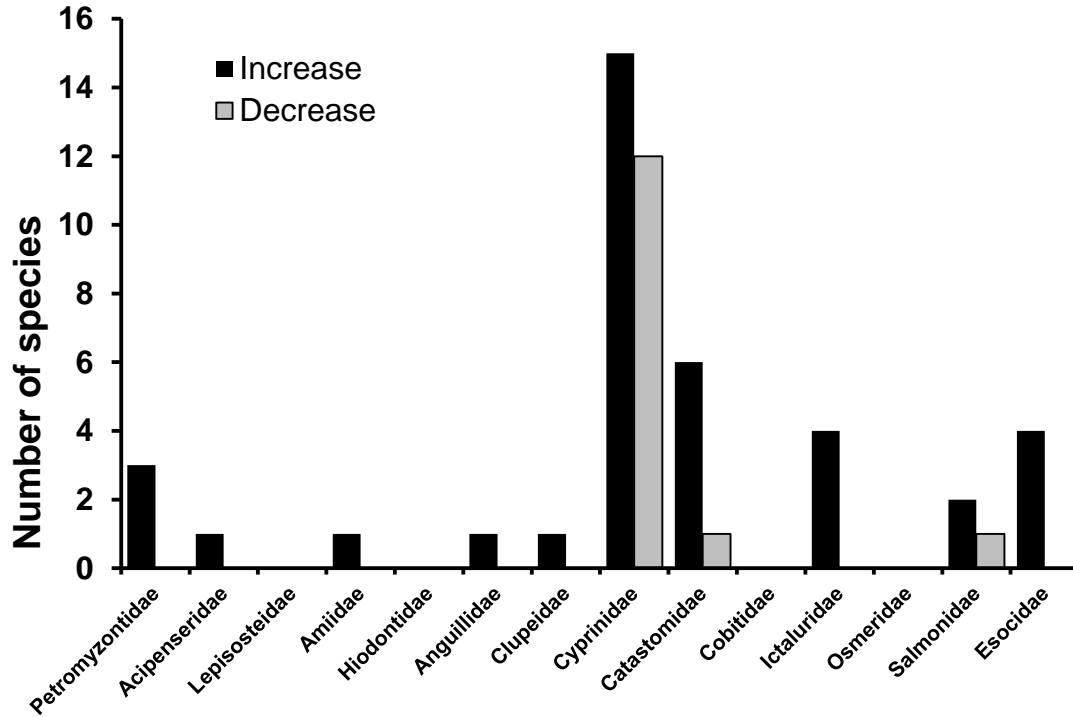


Figure 24. Number of species, by family, exhibiting significant increases or decreases in distribution between the historic and modern stream fish surveys of New York State.

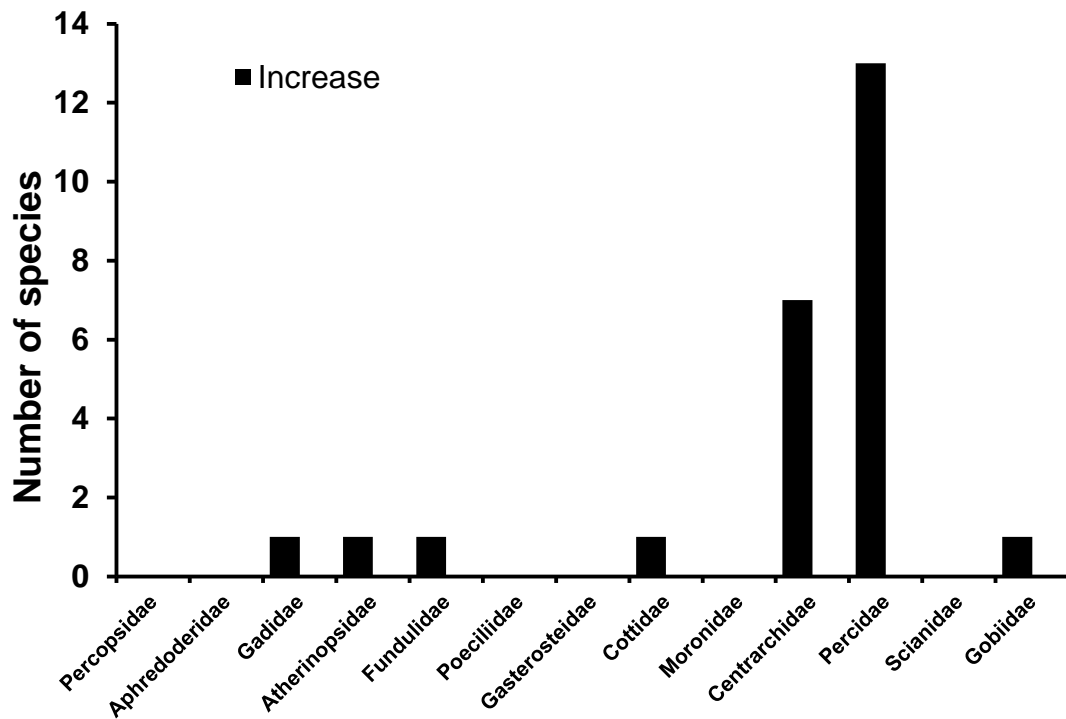


Figure 25. Number of species, by family, exhibiting significant increases or decreases in distribution between the historic and modern stream fish surveys of New York State.

Changes in distribution within individual watersheds followed similar patterns to those observed statewide. Of the 1,135 potential cases, there were 272 occasions (24%) where the range of a species changed significantly within a watershed. Of the occasions where significant changes were detected, 85.3% were increases, while only 14.7% were decreases (Figure 26). Newark Bay was the only watershed where no significant changes in distribution were observed. Results from six watersheds produced only significant increases, while 11 watersheds contained both increasing and decreasing species. In most cases, decreasing species were less than 25% of all species exhibiting significant changes. The exceptions were the Susquehanna River watershed, where 45.5% of species with significant distribution changes were decreasing and the Allegheny River watershed where 33.3% of observed distribution changes were decreases. Detailed results of analyses within individual watersheds can be found in Appendix 1.

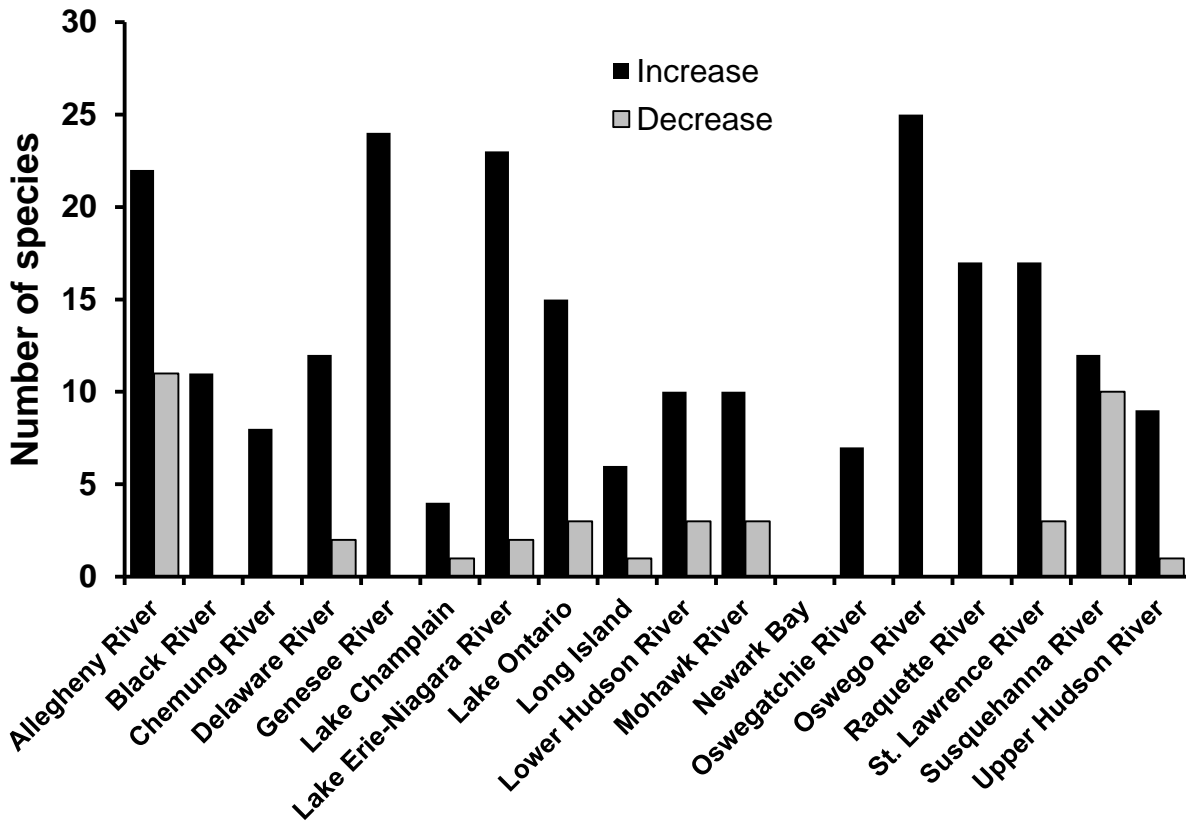


Figure 26. Number of species exhibiting significant increases or decreases in distribution within individual watersheds between the historic and modern stream fish surveys of New York State.

Statewide summary – large scale changes

In addition to detailed analyses of changes in proportions of sites where species were collected within and across watersheds, an examination of larger scale changes was also conducted. In this instance, examination in net change of the number of watersheds a species was collected in was made (e.g., a species found in 14 watersheds in the historic survey and 18 watersheds in the modern survey would have a net change of +4 watersheds). This approach should provide a further buffer to the potential influence of changes in collection methods in the two surveys. In this case, a species would only have to have been found at one site in a watershed to be recorded as present in that watershed for a given survey. This large scale approach should be less sensitive than changes based on individual site data and provide a more robust measure of ecologically significant distributional changes.

Net changes in the number of watersheds individual species were detected in ranged from a reduction of seven watersheds to an increase of 12 (Table 4, Figure 27). Of the 162 species collected during the two surveys, 113 (69.8%) exhibited distributional changes that included addition or loss of entire watersheds from their range within New York (Table 2). Of the species that changed in distribution by one or more watersheds, 68 (60.2%) exhibited increases in watershed occurrence and 45 (39.8%) exhibited decreases. The largest observed change in watershed occurrence was observed with the green sunfish, which expanded from two watersheds to 14. The largest observed decrease was the lake chub, which contracted from 10 watersheds to three. Of the 68 species that exhibited net gains in distribution, 29 increased by three or more watersheds (Table 5). Species with expanded watershed occurrence included representatives of 11 families, led by Cyprinidae (7 species), Ictaluridae (3) and Centrarchidae (3). Of the 45 species exhibiting net losses in watershed occurrence, 12 species had distributional losses of 3 or more watersheds (Table 6). Species exhibiting reductions in watershed occurrence represented 5 families, led by Cyprinidae (5 species) and Salmonidae (2).

Observed shifts in watershed occurrence were more common than occurrences of significant changes in proportion of sites where detected (Table 4). Of the species sampled during the two surveys, 70% exhibited a shift in distribution of one or more watersheds. The number of species with documented changes at the watershed scale exceeded the 48% with significant changes at the site scale statewide. As with the site level analyses, most of the species exhibiting shifts in watershed occurrence resulted from increased distributions (60%).

The relationship between changes in proportion of sites where detected and shifts in watershed occurrence was not consistent across all species. Overall, there was a significant and positive correlation between observed changes in watershed occurrence

and changes in proportion of sites where captured, but the relationship only explained 24% of the variability observed in watershed occurrence shifts (Figure 28; simple linear regression: $df = 136$; $F\text{-ratio} = 42.31$; $r^2 = 0.24$; $p < 0.0001$). Of the 77 species that exhibited significant changes in number of sites detected at, 60% also exhibited shifts in occurrence of at least one watershed in the same direction as the shift in site distribution. However, 31% of species with significant changes in number of sites detected at did not have associated changes in watershed occurrence, and 9% of species with significant changes in site detection had watershed occurrence shifts in the opposite direction (e.g., an increase in number of sites detected at but a reduction in the number of watersheds where observed to occur).

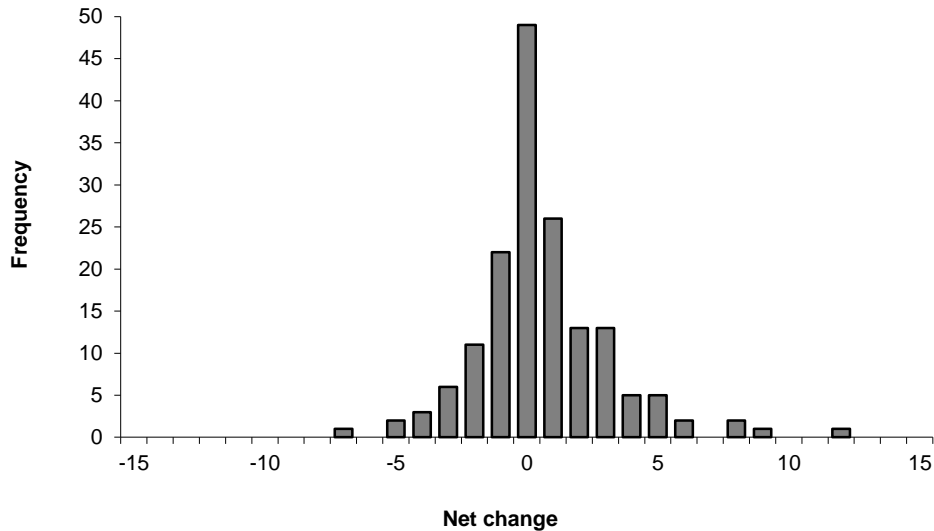


Figure 27. Frequency with which fish species exhibited net changes in watershed occurrence between the historic and modern stream surveys of New York State.

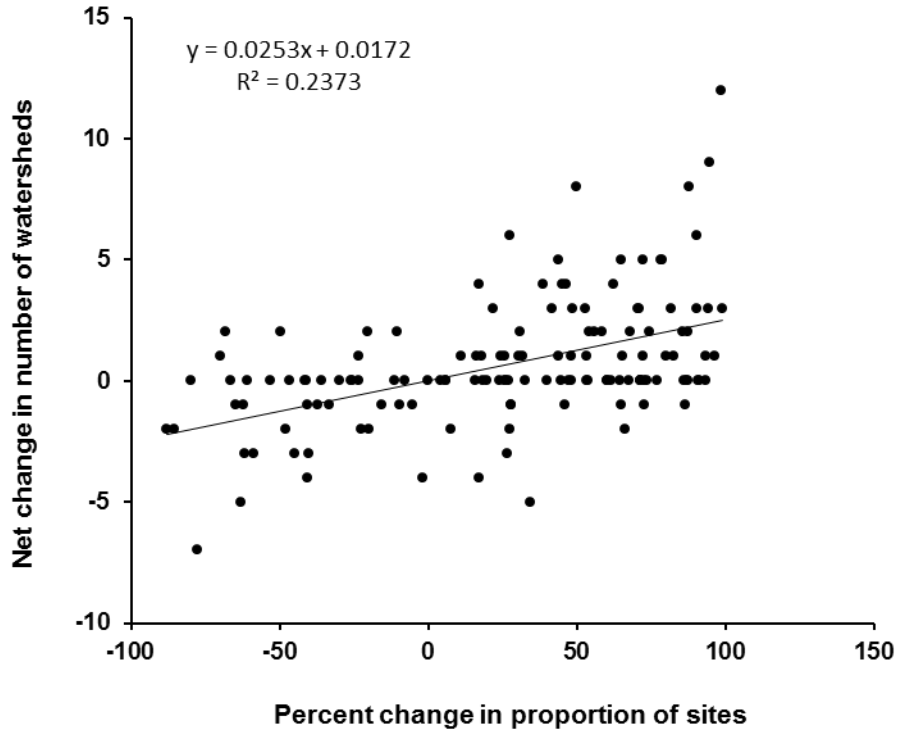


Figure 28. Relationship between net change in watershed occurrence and change in proportion of sites individual fish species were captured at in the historic and modern stream fish surveys of New York State.

Table 5. Fish species for which statewide distribution increased by 3 or more watersheds between the historic and modern stream surveys of New York State.

Species (watershed increase)	
American brook lamprey (3)	Yellow bullhead (8)
Sea lamprey (3)	Margined madtom (4)
Longnose gar (3)	Brindled madtom (3)
Bowfin (3)	Chinook salmon (3)
Gizzard shad (9)	Northern pike (4)
Central stoneroller (3)	Central mudminnow (5)
Common carp (3)	Brook silverside (5)
Hornyhead chub (4)	Banded killifish (4)
Emerald shiner (3)	White perch (6)
Mimic shiner (5)	Green sunfish (12)
Sand shiner (5)	Bluegill (6)
Rudd (5)	Black crappie (8)
Quillback (3)	Eastern sand darter (3)
Greater redhorse (4)	Round goby (3)

Table 6. Fish species for which statewide distribution decreased by 3 or more watersheds between the historic and modern stream surveys of New York State.

Species (watershed decrease)	
American eel (-5)	Longnose sucker (-3)
Lake chub (-7)	Tadpole madtom (-4)
Bridle shiner (-4)	Lake whitefish (-3)
Blackchin shiner (-3)	Rainbow trout (-4)
Blacknose shiner (-3)	Threespine stickleback (-3)
Finescale dace (-5)	Walleye (-3)

Statewide summary – endangered, threatened and special concern species

Of the 25 fish species currently listed as endangered, threatened or of special concern in New York State, 20 were collected in one or both stream fish surveys. Statistically significant changes in distribution of special status fishes were observed for five species, all exhibiting increases in distribution (Table 7; Figures 29-31). Of the special status species exhibiting significant increases, two were benthic species (eastern sand darter, longhead darter) that may have been more efficiently sampled with electrofishing in the modern survey, and one (lake sturgeon) increased as a result of a dedicated restoration stocking program. Two endangered species (silver chub, gilt darter), and three threatened species (gravel chub, lake chubsucker, mud sunfish) were collected only in the historic survey. All these species are currently considered as extirpated from New York State. Bluebreast darter was only collected in the modern survey. Of those species captured in both surveys that did not exhibit statistically significant changes, three increased in distribution and three decreased. While the surveys do allow assessment of changes in special status species, results are likely sensitive not only to gear differences but a higher emphasis on rare species in site selection for the modern survey.

Table 7. Number of watersheds where endangered, threatened, and special concern fish species exhibited significant change in proportion of sites where detected and catches (proportion of sites where detected) of fish species statewide in New York State from historic and modern stream fish surveys, and results of Fisher's exact test for differences in statewide distribution (total number of species represented: 162, Bonferroni inequality correction for significance: $0.05/162 = 0.0003$; significant changes in distribution indicated in **bold**).

Status Species	Number of watersheds with significant decreases	Number of watersheds with significant increases	Proportion of statewide sites – Historic (n = 4058)	Proportion of statewide sites – Modern (n = 3057)	Direction of change	Fisher's exact test p-value
Endangered						
Silver chub			0.0010	0.0000		0.1398
Pugnose shiner			0.0022	0.0013		0.4170
Bluebreast darter			0.0000	0.0029		0.0005
Gilt darter			0.0012	0.0000		0.0749

Status Species	Number of watersheds with significant decreases	Number of watersheds with significant increases	Proportion of statewide sites – Historic (n = 4058)	Proportion of statewide sites – Modern (n = 3057)	Direction of change	Fisher's exact test p-value
Threatened						
Lake sturgeon			0.0005	0.0075	INC	<0.0001
Mooneye			0.0025	0.0003		0.0295
Gravel chub			0.0010	0.0000		0.1398
Lake chubsucker			0.0017	0.0000		0.0223
Mud sunfish			0.0007	0.0000		0.2647
Banded sunfish			0.0002	0.0007		0.5806
Northern sunfish			0.0025	0.0013		0.4187
Eastern sand darter		1	0.0002	0.0173	INC	<0.0001
Swamp darter			0.0002	0.0007		0.5806
Spotted darter			0.0010	0.0010		1.0000
Longhead darter		1	0.0022	0.0252	INC	<0.0001
Special concern						
Mountain brook lamprey			0.0005	0.0036		0.0033
Black redhorse		1	0.0025	0.0183	INC	<0.0001
Streamline chub		1	0.0025	0.0196	INC	<0.0001
Redfin shiner			0.0025	0.0033		0.6521
Ironcolor shiner			0.0015	0.0010		0.7407

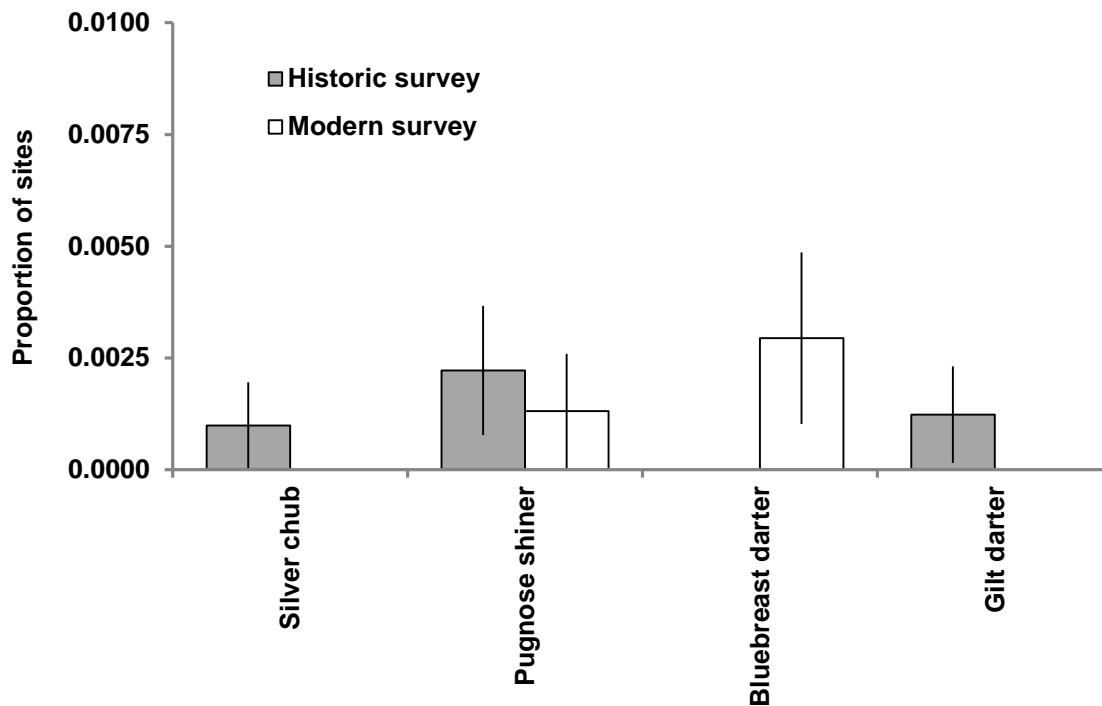


Figure 29. Catches (proportion of sites where detected) of endangered fish species in New York State from historic and modern stream fish surveys. Error bars represent 95% confidence intervals.

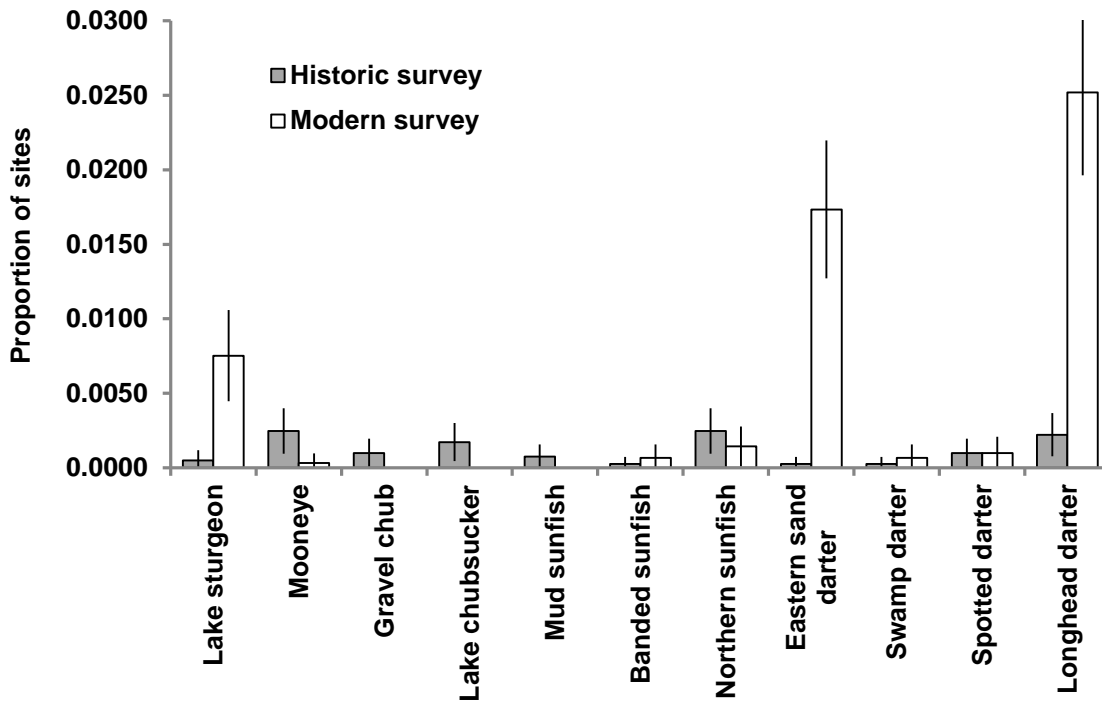


Figure 30. Catches (proportion of sites where detected) of threatened fish species in New York State from historic and modern stream fish surveys. Error bars represent 95% confidence intervals.

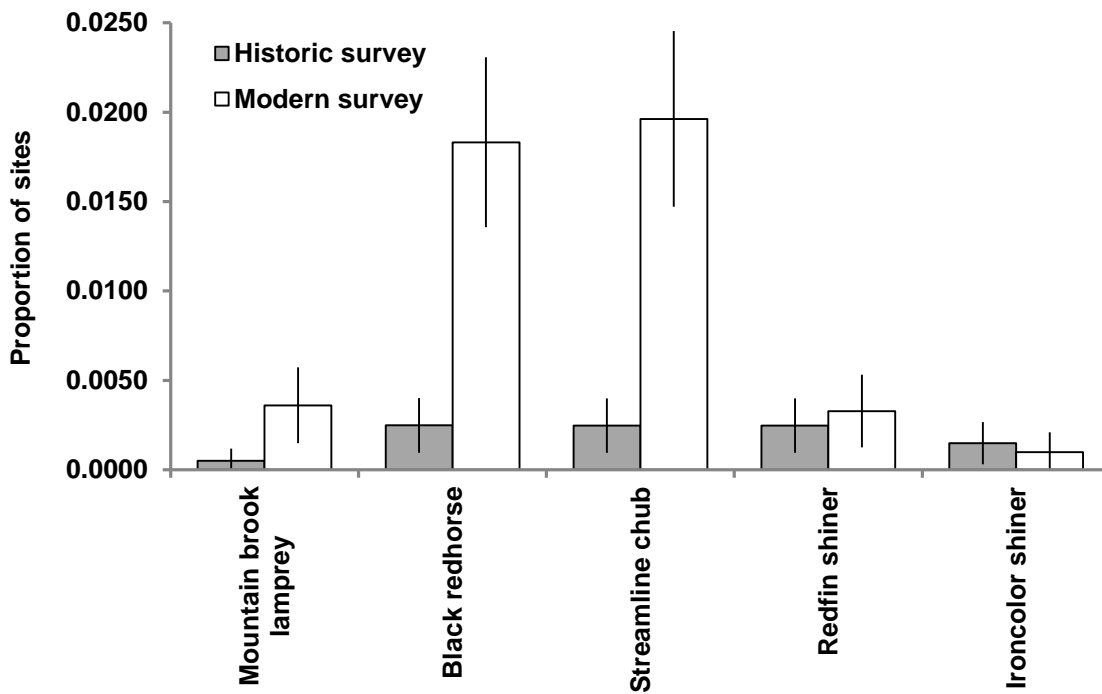


Figure 31. Catches (proportion of sites where detected) of special concern fish species in New York State from historic and modern stream fish surveys. Error bars represent 95% confidence intervals.

Statewide summary – homogenization of stream fish fauna

Similarity of individual watersheds to all other watersheds increased for all 18 watersheds (Figure 32). On average, watersheds were 4.1% more similar during the modern survey than during the historic survey. The largest shift was observed in the Lake Erie-Niagara River watershed, which increased in similarity to other watersheds by 10.5% between the two surveys. The smallest shift was observed for the Newark Bay watershed, which increased in similarity to other watersheds by 1.3%. Comparisons of individual watersheds to the statewide data produced similar results. Thirteen of the 18 watersheds increased in similarity to statewide patterns (Figure 33). Watersheds that decreased in similarity to statewide patterns included those associated with the New York State Barge Canal (Lake Ontario, Mohawk River, Upper and Lower Hudson River) as well as Newark Bay. On average, individual watersheds were 2.9% more similar to the state during the modern survey than during the historic survey. The greatest increase in similarity was observed for the Allegheny River watershed (9.4%) while the largest decrease was observed for the Lower Hudson River watershed (-4.0%). The non-metric multidimensional plot of watershed similarity shows a strong tendency towards convergence, supporting analytical evidence of homogenization across watersheds (Figure 34).

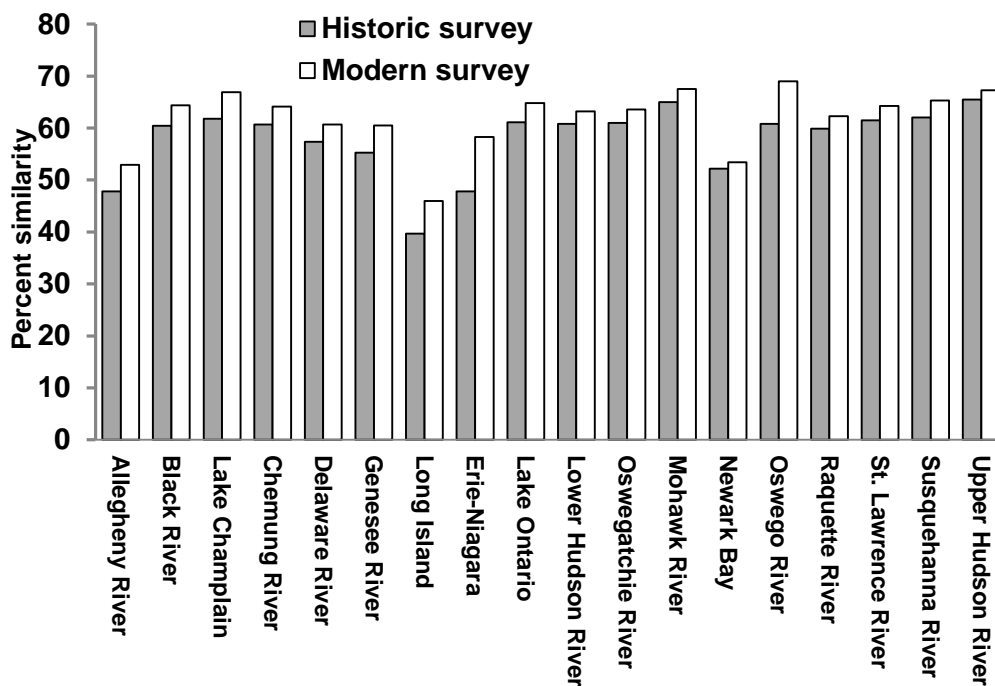


Figure 32. Bray-Curtis similarity comparisons of each watershed to all other watersheds from the historic and modern stream fish surveys of New York State.

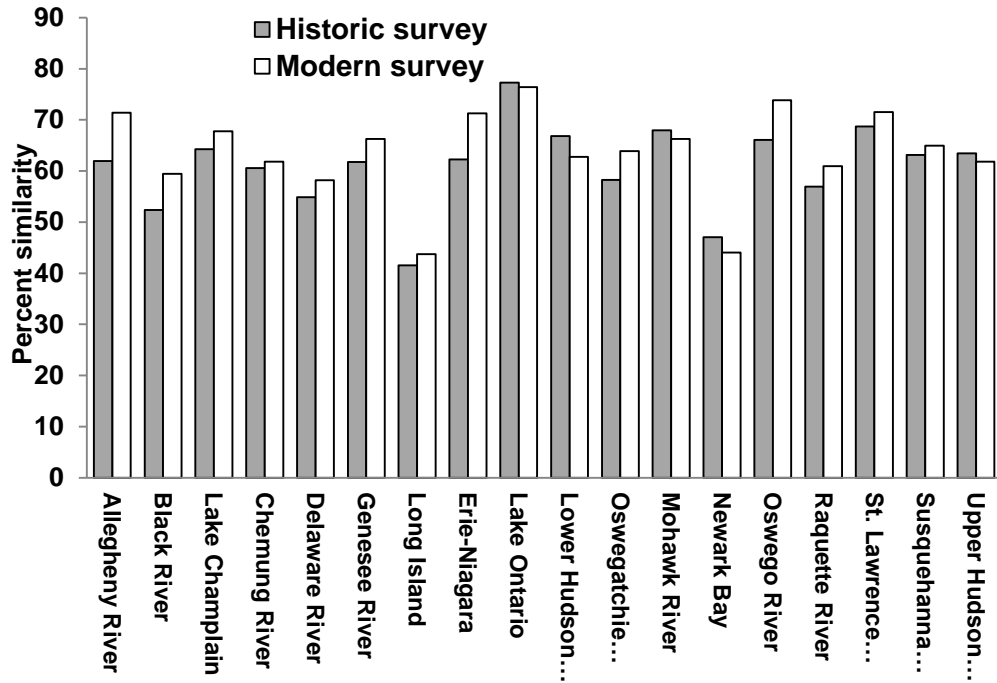


Figure 33. Bray-Curtis similarity comparisons of each watershed to statewide data from the historic and modern stream fish surveys of New York State.

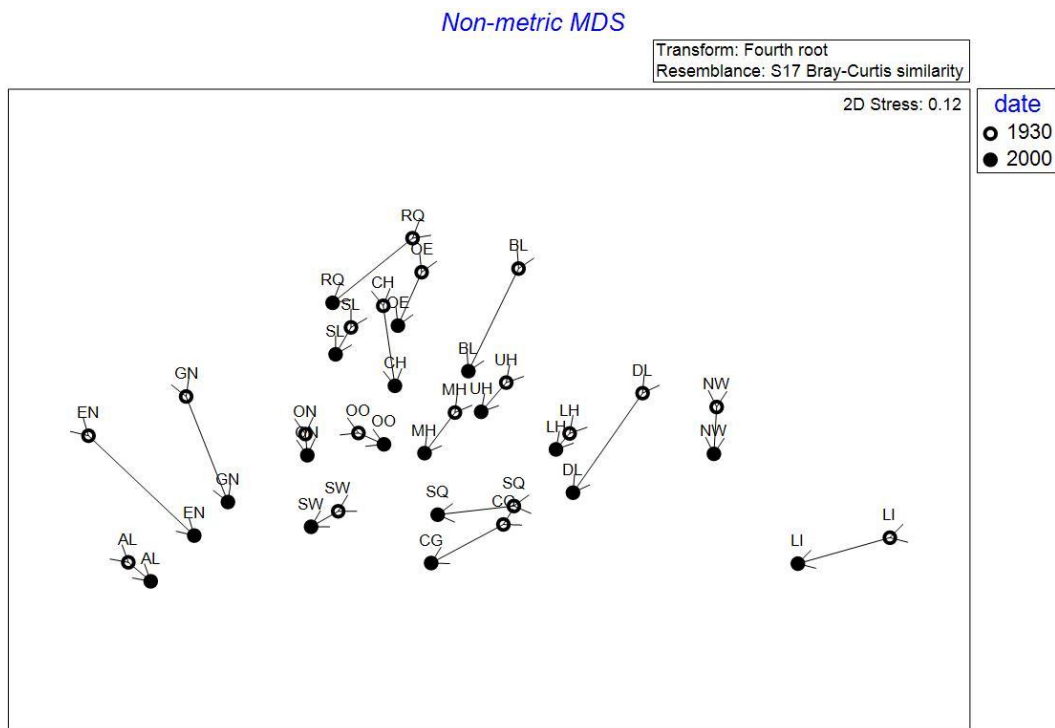


Figure 34. Non-metric multi-dimensional scaling plot of changes in similarity among watersheds between the historic and modern stream surveys of New York State.

DISCUSSION

Comparisons of fish distributions from the historic and modern stream fish surveys revealed widespread changes that included representative species from 63% of the fish families represented in New York State. On a statewide scale, 48% of the fish species represented in the two surveys exhibited statistically significant changes in distribution. Of those, 82% significantly increased in the proportion of sites where they were detected while 18% showed contracting ranges. Similarly, significant shifts in distribution within individual watersheds were also common, with 24% of potential cases exhibiting significant changes. As with the statewide results, most changes within watersheds were increases in distribution (85%).

The high occurrence of significant changes in distribution of stream fishes in New York State was potentially influenced by the addition of electrofishing as a collecting method in the modern survey. However, the approach used here of analyzing catches as presence-absence rather than total catch should provide a conservative assessment of changes (Winemiller et al. 2008; Jacquemin and Pryon 2011). Additionally, previous studies have not found large discrepancies in species richness efficiency between seines and backpack electrofishers for fish taxa common the New York's streams (Bayley et al. 1989). Nonetheless, some species with strong benthic associations (e.g., lampreys, American eel and darters) might be expected to be better represented in samples from the modern survey, regardless of changes in distribution.

Analyses of changes in the number of watersheds each species was detected in should have provided a robust buffer to gear influence at the site level, as a species only had to be detected at a single site within a watershed to be considered as present. Shifts in watershed occurrence by individual species were more common than significant changes in proportion of sites where detected. Overall agreement between observed distributional shifts at the site level and shifts in watershed occurrence was observed, but high levels of variability suggested that changes in detection at the site level alone only explained 24% of observed shifts in watershed occurrence. To the extent that site-level differences in fish distributions may have been influenced by differences in gears employed in the two surveys, it does not appear that those differences were a primary driver of shifts in watershed occurrence. These results suggest that distributional changes observed in this study were not simply a function of changes in gears used in the surveys.

The high frequency of observed changes in fish distribution should perhaps not be surprising given the large scale shifts in habitat availability and quality that almost certainly took place between the first survey in the 1930s and the modern survey in the early 2000s. Over the course of the time elapsed between the two surveys, the population of New York State has increased by more than 50%, from 12,588,066 to

18,976,457, representing an increase in population density from 266.6 to 401.9 people per square mile (Hobbs and Stoops 2002). Concomitant with this population growth have been large scale changes in land use. Between 1982 and 1997 alone, despite a less than 3% population growth in upstate New York, urbanization in the area increased by 30% (New York State Department of Conservation 2005). The increase in developed land since 1973 has come through conversion of both forested land and agricultural lands (Taylor 2016). Population growth and the related shift in land use to developed and residential areas can lead to both loss and fragmentation of aquatic habitats, which can have significant impacts on fish distribution and the ability of habitats to support more sensitive species. Among other potential stressors that could have impacted fish distributions over the time span of this study is increasing temperatures. Mean annual air temperatures in New York State have increased steadily since around 1975 and are some 2° F higher now than they were at the time of the historic surveys (National Oceanic and Atmospheric Administration - National Climatic Data Center 2014). The potential for climate to contribute to the observed changes in fish distributions in New York State is evidenced by the fact that two species exhibiting the largest increases in distribution, green sunfish and gizzard shad are warmwater species, while large losses were observed in the coolwater lake chub.

In addition to changes in land use in New York State in the time between the two surveys, there have also been major policy enactments that have been directed at environmental protection. The Environmental Protection Agency was established in 1970 and with it regulatory control of air quality. The Clean Water Act in its modern form was passed in 1972. Concurrent with the passage of the Clean Water Act, the Great Lakes Water Quality Agreement was passed in 1972, affecting many New York watersheds. The Endangered Species Act was signed in 1973. Shifts in forested land to developed land between 1973 and 2000 were almost matched by shifts of agricultural land to grassland/shrubland, and increases in forested land over the same time period resulted primarily from succession of grassland/shrubland habitats (Taylor 2016).

Given land use changes, environmental protection efforts, and larger scale impacts such as climate change, the stream fishes of New York have almost certainly experienced dynamic environmental conditions in the period between the two surveys. The present report is intended to provide an overview of the results of comparisons of fish distributions from the historic and modern stream surveys by looking at broader patterns. Certainly, much additional insight could be gained by more detailed assessments of individual watersheds, species or species groups supported by finer scale supporting data on landscape changes or other local factors that might affect stream fishes. It is hoped that readers with specific interests will be able to use the results presented here as a starting point for more detailed studies.

ACKNOWLEDGEMENTS

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APPENDIX

INDIVIDUAL WATERSHED RESULTS

ALLEGHENY RIVER WATERSHED



Table A1. Catches (proportion of sites where detected) of fish species in the Allegheny River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 93, Bonferroni inequality correction for significance: $0.05/93 = 0.0005$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=304)	Proportion of sites – Modern (n=462)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
Ohio lamprey	0.000	0.056	+	<0.0001
Mountain brook lamprey	0.007	0.024		0.088
American brook lamprey	0.020	0.169	+	<0.0001
Family Clupeidae				
Gizzard shad	0.000	0.002		1.000
Family Cyprinidae				
Central stoneroller	0.688	0.468	-	<0.0001
Goldfish	0.000	0.002		1.000
Northern redbelly dace	0.010	0.002		0.307
Finescale dace	0.003	0.000		0.397
Redside dace	0.303	0.141	-	<0.0001
Spotfin shiner	0.013	0.041		0.030
Common carp	0.030	0.102	+	<0.0001
Streamline chub	0.033	0.130	+	<0.0001
Gravel chub	0.013	0.000		0.025
Tonguetied minnow	0.309	0.050	-	<0.0001
Brassy minnow	0.000	0.002		1.000
Bigeye chub	0.184	0.022	-	<0.0001
Striped shiner	0.023	0.149	+	<0.0001
Common shiner	0.711	0.370	-	<0.0001
Redfin shiner	0.000	0.004		0.521
Pearl dace	0.184	0.022	-	<0.0001
Hornyhead chub	0.000	0.002		1.000
River chub	0.168	0.169		1.000
Golden shiner	0.036	0.074		0.040
Emerald shiner	0.000	0.024		0.004
Silverjaw minnow	0.000	0.020		0.014
Bigmouth shiner	0.118	0.048	-	0.0004
Blackchin shiner	0.003	0.000		0.397
Blacknose shiner	0.033	0.002		0.0006
Spottail shiner	0.007	0.039		0.005
Silver shiner	0.155	0.193		0.209
Rosyface shiner	0.332	0.353		0.587
Sand shiner	0.197	0.240		0.184
Mimic shiner	0.250	0.290		0.247
Bluntnose minnow	0.513	0.558		0.236
Fathead minnow	0.056	0.110		0.009
Longnose dace	0.115	0.180		0.018
Western blacknose dace	0.431	0.366		0.082
Creek chub	0.595	0.470		0.0007
Family Catostomidae				
Quillback	0.000	0.041	+	<0.0001
White sucker	0.540	0.619		0.030
Northern hog sucker	0.368	0.435		0.072
Silver redhorse	0.043	0.091		0.014
Smallmouth redhorse	0.007	0.050		0.0006

Species	Proportion of sites – Historic (n=304)	Proportion of sites – Modern (n=462)	Direction of change	Fisher's exact test <i>p</i> -value
River redhorse	0.000	0.009		0.156
Black redhorse	0.016	0.108	+	<0.0001
Golden redhorse	0.148	0.245		0.001
Greater redhorse	0.000	0.002		1.000
Family Cobitidae				
Oriental weatherfish	0.000	0.004		0.521
Family Ictaluridae				
Yellow bullhead	0.000	0.071	+	<0.0001
Brown bullhead	0.099	0.069		0.175
Channel catfish	0.000	0.002		1.000
Stonecat	0.049	0.115		0.002
Brindled madtom	0.010	0.015		0.748
Family Salmonidae				
Rainbow trout	0.020	0.004		0.064
Brown trout	0.079	0.171	+	0.0002
Brook trout	0.072	0.007	-	<0.0001
Family Esocidae				
Grass pickerel	0.000	0.093	+	<0.0001
Northern pike	0.000	0.048	+	<0.0001
Muskellunge	0.026	0.011		0.151
Chain pickerel	0.000	0.002		1.000
Central mudminnow	0.010	0.033		0.051
Family Percopsidae				
Trout-perch	0.069	0.093		0.286
Family Gadidae				
Burbot	0.007	0.009		1.000
Family Atherinopsidae				
Brook silverside	0.010	0.004		0.391
Family Fundulidae				
Banded killifish	0.000	0.007		0.281
Family Gasterosteidae				
Brook stickleback	0.066	0.001	-	<0.0001
Family Cottidae				
Mottled sculpin	0.227	0.470	+	<0.0001
Family Moronidae				
White perch	0.000	0.002		1.000
White bass	0.000	0.004		0.521
Family Centrarchidae				
Rock bass	0.128	0.171		0.125
Green sunfish	0.000	0.009		0.156
Pumpkinseed	0.217	0.208		0.786
Bluegill	0.053	0.121		0.001
Smallmouth bass	0.349	0.400		0.171
Largemouth bass	0.079	0.117		0.112
White crappie	0.040	0.002	-	<0.0001
Black crappie	0.099	0.015	-	<0.0001

Species	Proportion of sites – Historic (n=304)	Proportion of sites – Modern (n=462)	Direction of change	Fisher's exact test <i>p</i> -value
Family Percidae				
Eastern sand darter	0.000	0.033		0.0007
Greenside darter	0.253	0.522	+	<0.0001
Rainbow darter	0.368	0.576	+	<0.0001
Bluebreast darter	0.000	0.020		0.014
Fantail darter	0.441	0.509		0.076
Spotted darter	0.013	0.007		0.445
Johnny darter	0.428	0.584	+	<0.0001
Varigate darter	0.079	0.299	+	<0.0001
Banded darter	0.148	0.407	+	<0.0001
Yellow perch	0.060	0.178	+	<0.0001
Logperch	0.115	0.333	+	<0.0001
Channel darter	0.000	0.108	+	<0.0001
Gilt darter	0.016	0.000		0.010
Longhead darter	0.030	0.167	+	<0.0001
Blackside darter	0.197	0.394	+	<0.0001
Walleye	0.007	0.024		0.088

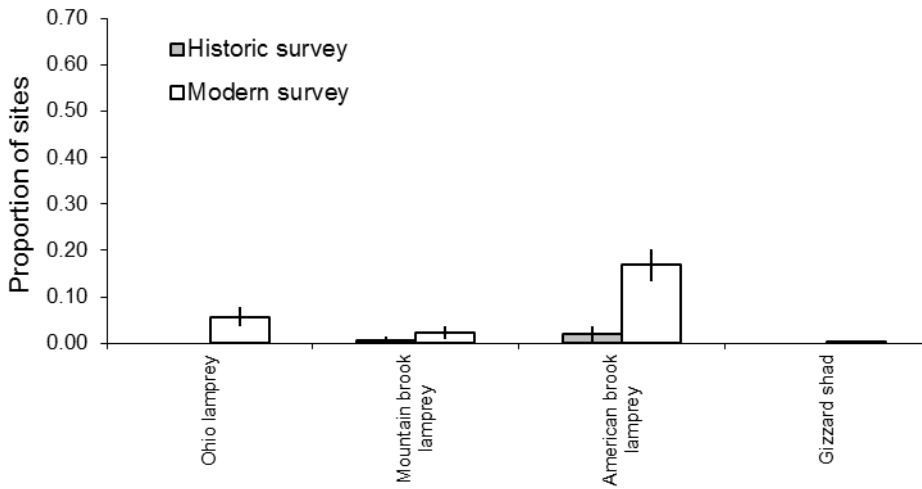


Figure A1-1. Catches (proportion of sites where detected) of fish species in the Allegheny River Watershed from historic and modern stream surveys. Families Petromyzontidae and Clupeidae. Error bars represent 95% confidence intervals.

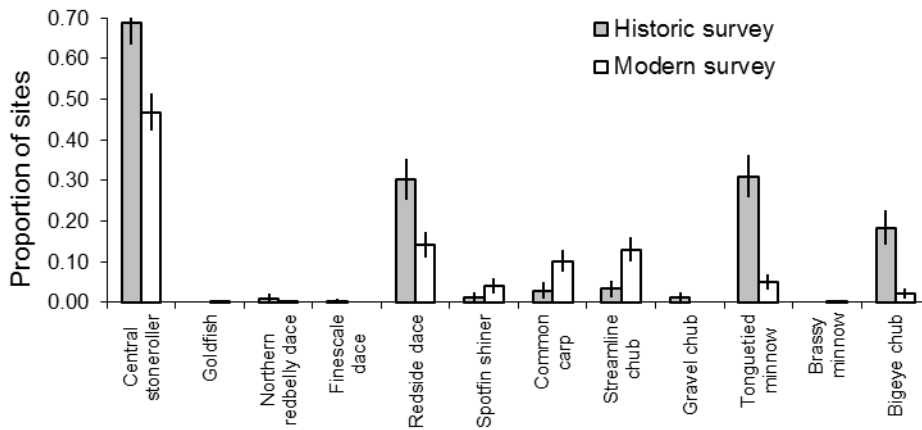


Figure A1-2. Catches (proportion of sites where detected) of fish species in the Allegheny River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

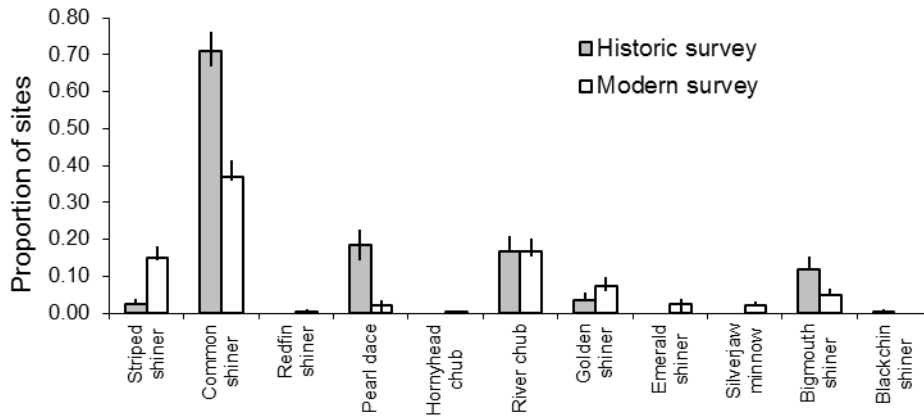


Figure A1-3. Catches (proportion of sites where detected) of fish species in the Allegheny River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

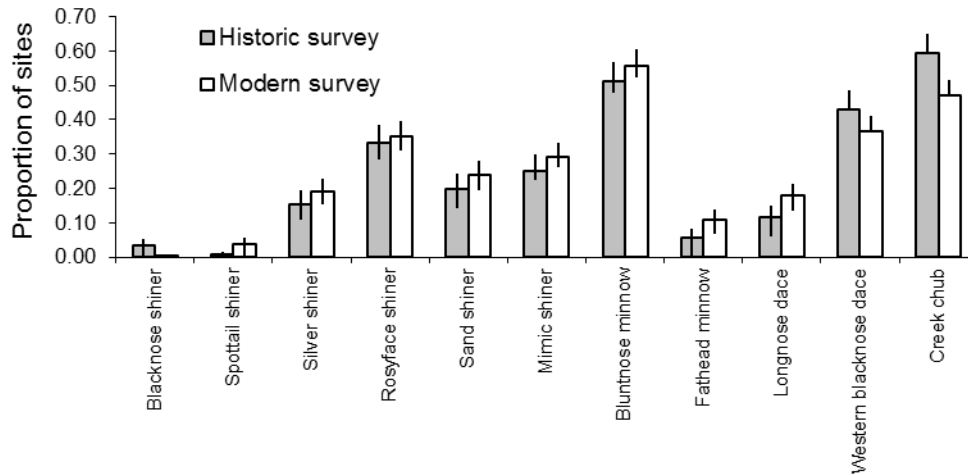


Figure A1-4. Catches (proportion of sites where detected) of fish species in the Allegheny River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

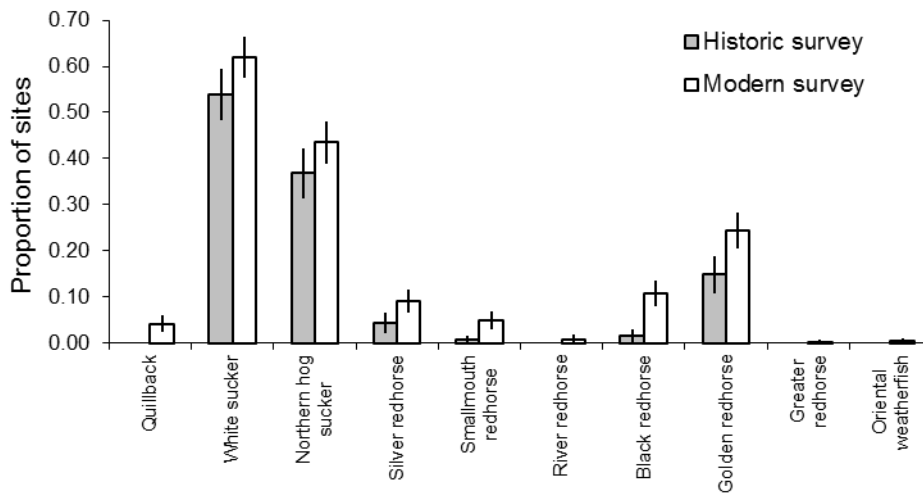


Figure A1-5. Catches (proportion of sites where detected) of fish species in the Allegheny River Watershed from historic and modern stream surveys. Families Catastomidae and Cobitidae. Error bars represent 95% confidence intervals.

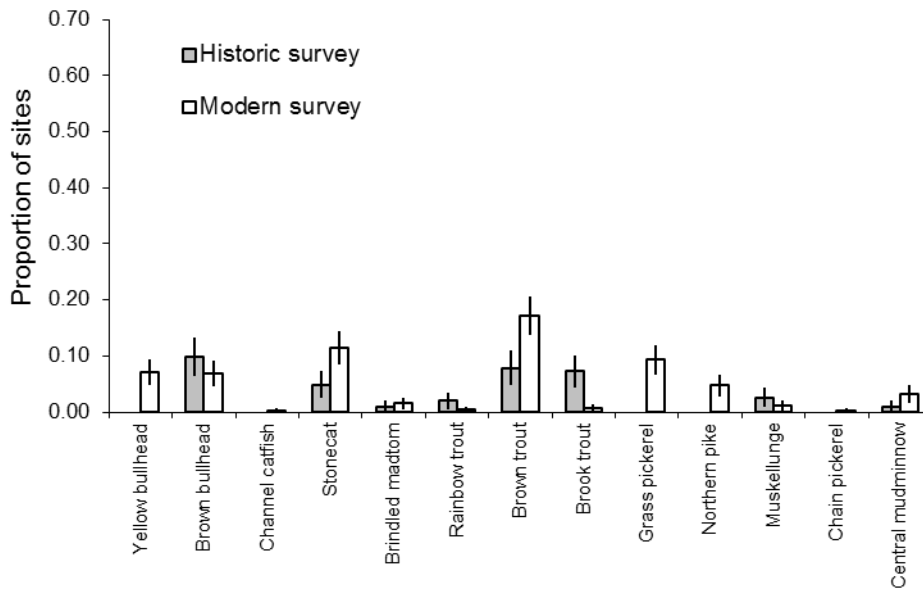


Figure A1-6. Catches (proportion of sites where detected) of fish species in the Allegheny River Watershed from historic and modern stream surveys. Families Ictaluridae, Salmonidae, and Esocidae. Error bars represent 95% confidence intervals.

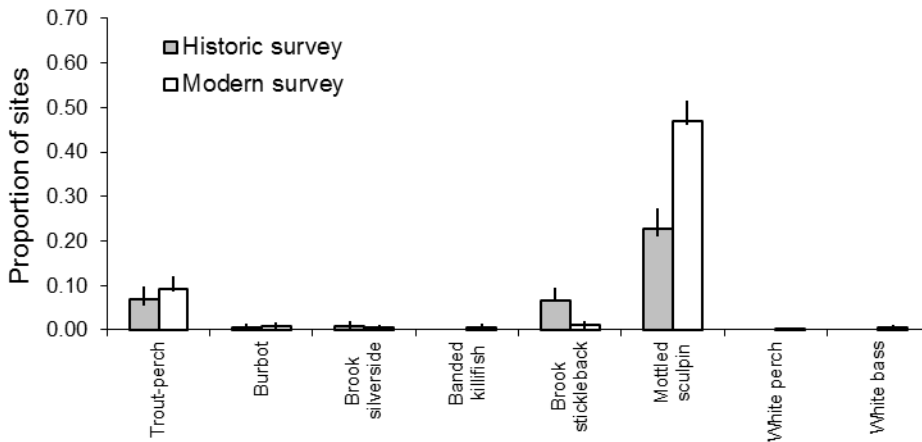


Figure A1-7. Catches (proportion of sites where detected) of fish species in the Allegheny River Watershed from historic and modern stream surveys. Families Percopsidae, Gadidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

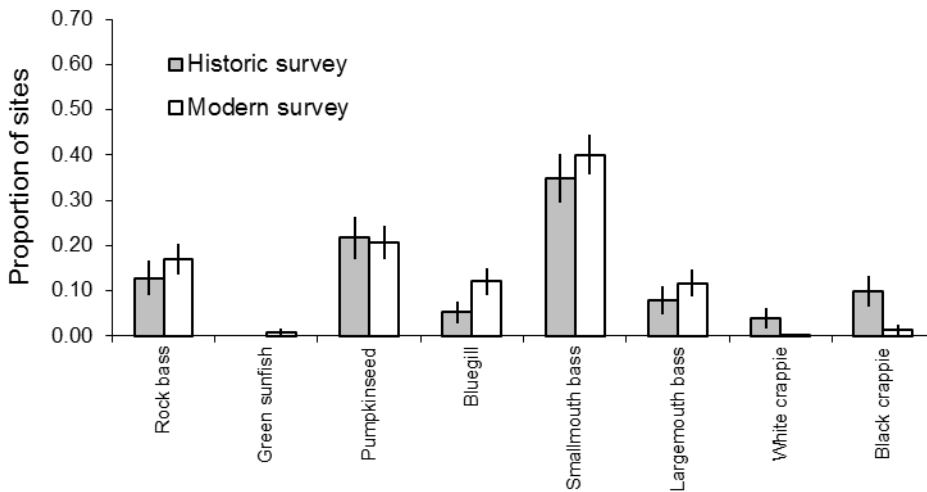


Figure A1-8. Catches (proportion of sites where detected) of fish species in the Allegheny River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

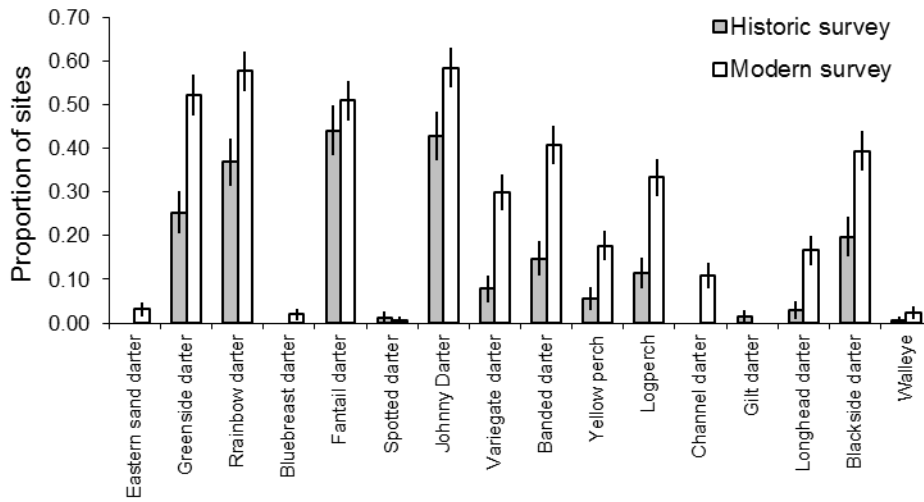


Figure A1-9. Catches (proportion of sites where detected) of fish species in the Allegheny River Watershed from historic and modern stream surveys. Family Percidae. Error bars represent 95% confidence intervals.

BLACK RIVER WATERSHED



Table A2. Catches (proportion of sites where detected) of fish species in the Black River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 60, Bonferroni inequality correction for significance: $0.05/60 = 0.0008$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=110)	Proportion of sites – Modern (n=116)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
Sea lamprey	0.000	0.009		1.000
Family Lepisosteidae				
Longnose gar	0.000	0.009		1.000
Family Amiidae				
Bowfin	0.000	0.009		1.000
Family Anguillidae				
American eel	0.018	0.000		0.236
Family Clupeidae				
Gizzard shad	0.000	0.009		1.000
Family Cyprinidae				
Central stoneroller	0.000	0.017		0.498
Northern redbelly dace	0.036	0.129		0.015
Finescale dace	0.009	0.000		0.487
Redside dace	0.073	0.069		1.000
Lake chub	0.018	0.000		0.236
Satinfin shiner	0.018	0.121		0.003
Spotfin shiner	0.018	0.009		0.614
Common carp	0.009	0.103		0.003
Cutlip minnow	0.200	0.112		0.097
Brassy minnow	0.000	0.009		1.000
Eastern silvery minnow	0.000	0.009		1.000
Common shiner	0.427	0.319		0.100
Pearl dace	0.009	0.026		0.622
Hornyhead chub	0.000	0.095	+	0.0008
Golden shiner	0.091	0.302	+	<0.0001
Blacknose shiner	0.009	0.009		1.000
Spottail shiner	0.064	0.112		0.245
Bluntnose minnow	0.018	0.086		0.034
Fathead minnow	0.009	0.138	+	0.0002
Eastern blacknose dace	0.518	0.353		0.016
Longnose dace	0.136	0.138		1.000
Creek chub	0.473	0.388		0.227
Fallfish	0.000	0.276	+	<0.0001
Family Catostomidae				
Quillback	0.000	0.017		0.498
Longnose sucker	0.082	0.009		0.009
White sucker	0.491	0.379		0.107
Summer sucker	0.000	0.009		1.000
Northern hog sucker	0.000	0.086		0.002
Family Ictaluridae				
Brown bullhead	0.136	0.353	+	0.0002

Species	Proportion of sites – Historic (n=110)	Proportion of sites – Modern (n=116)	Direction of change	Fisher's exact test <i>p</i> -value
Stonecat	0.009	0.000		0.487
Margined madtom	0.000	0.112	+	0.0002
Family Salmonidae				
Rainbow trout	0.018	0.026		1.000
Brown trout	0.127	0.060		0.109
Brook trout	0.382	0.207		0.005
Family Esocidae				
Northern pike	0.036	0.035		1.000
Chain pickerel	0.100	0.319	+	<0.0001
Central mudminnow	0.000	0.164	+	<0.0001
Family Gadidae				
Burbot	0.009	0.060		0.066
Family Fundulidae				
Banded killifish	0.000	0.060		0.014
Family Gasterosteidae				
Brook stickleback	0.055	0.078		0.597
Family Cottidae				
Slimy sculpin	0.046	0.035		0.743
Family Moronidae				
White perch	0.000	0.009		1.000
Family Centrarchidae				
Rock bass	0.100	0.328	+	<0.0001
Green sunfish	0.000	0.009		1.000
Pumpkinseed	0.155	0.362	+	0.0005
Bluegill	0.000	0.017		0.498
Smallmouth bass	0.173	0.233		0.322
Largemouth bass	0.027	0.052		0.500
Black crappie	0.000	0.009		1.000
Family Percidae				
Fantail darter	0.055	0.043		0.764
Johnny darter	0.009	0.000		0.487
Tessellated darter	0.264	0.276		0.882
Yellow perch	0.064	0.190		0.005
Logperch	0.018	0.026		1.000
Walleye	0.000	0.112	+	0.0002

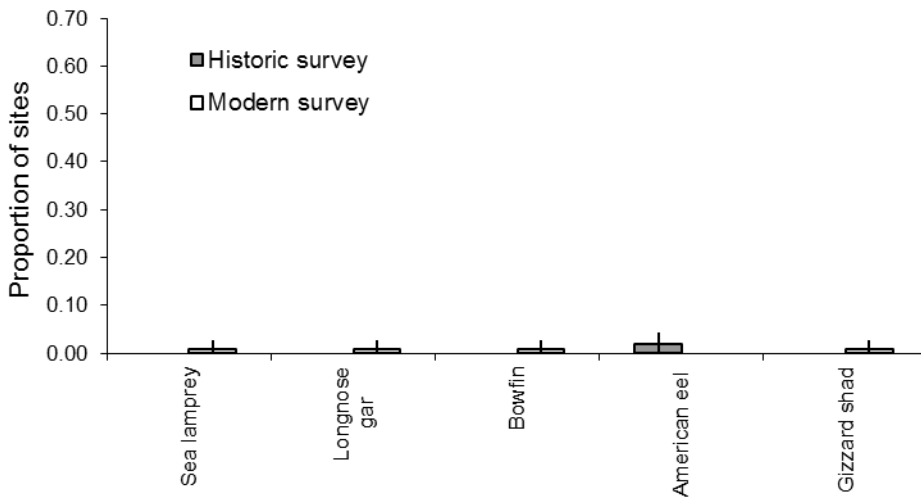


Figure A2-1. Catches (proportion of sites where detected) of fish species in the Black River Watershed from historic and modern stream surveys. Families Petromyzontidae, Lepisosteidae, Amiidae, and Clupeidae. Error bars represent 95% confidence intervals.

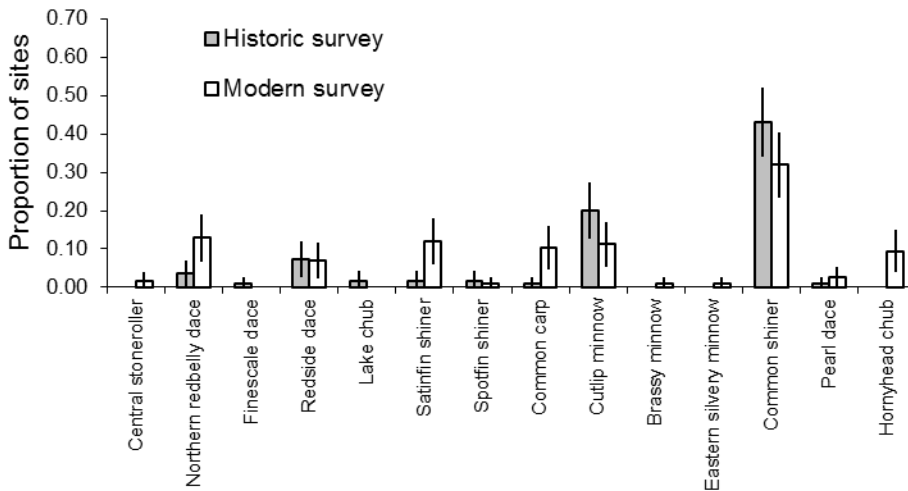


Figure A2-2. Catches (proportion of sites where detected) of fish species in the Black River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

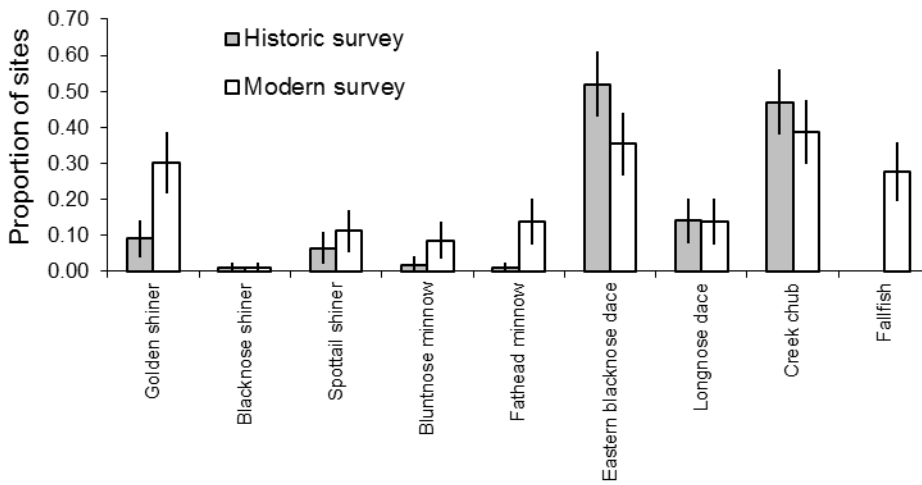


Figure A2-3. Catches (proportion of sites where detected) of fish species in the Black River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

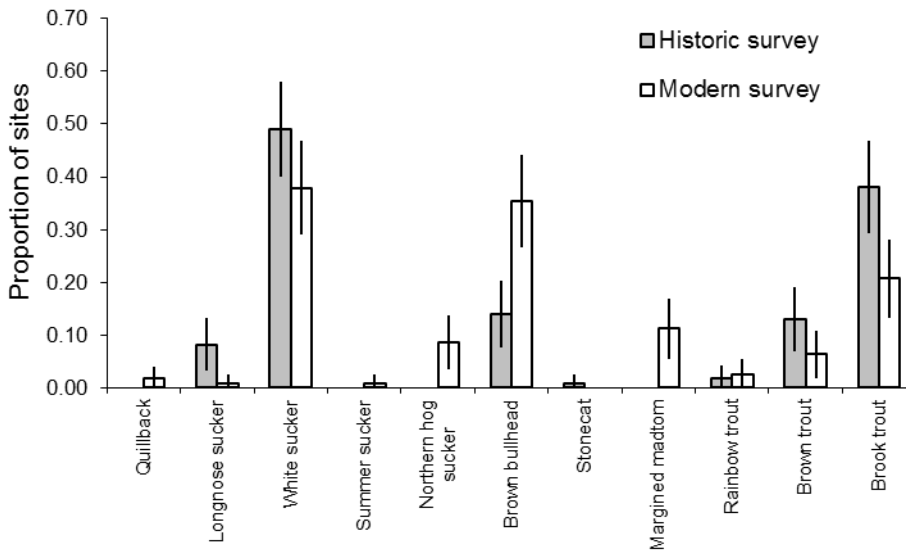


Figure A2-4. Catches (proportion of sites where detected) of fish species in the Black River Watershed from historic and modern stream surveys. Families Catastomidae, Ictaluridae, and Salmonidae. Error bars represent 95% confidence intervals.

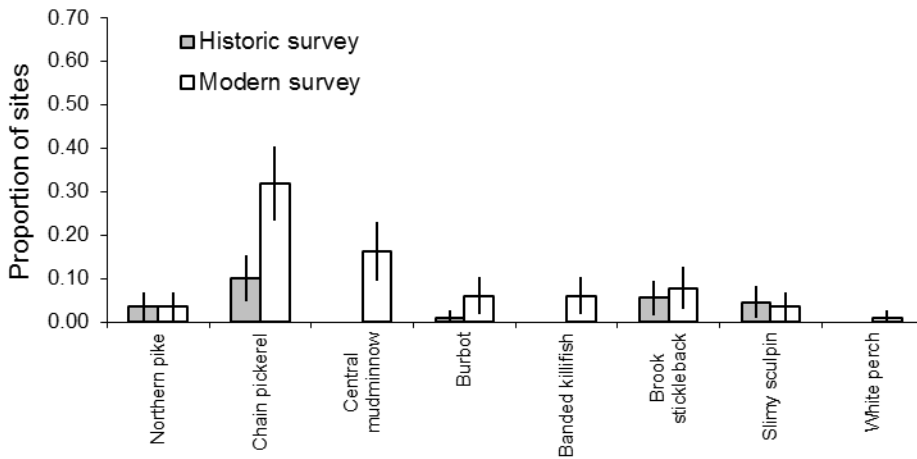


Figure A2-5. Catches (proportion of sites where detected) of fish species in the Black River Watershed from historic and modern stream surveys. Families Esocidae, Gadidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

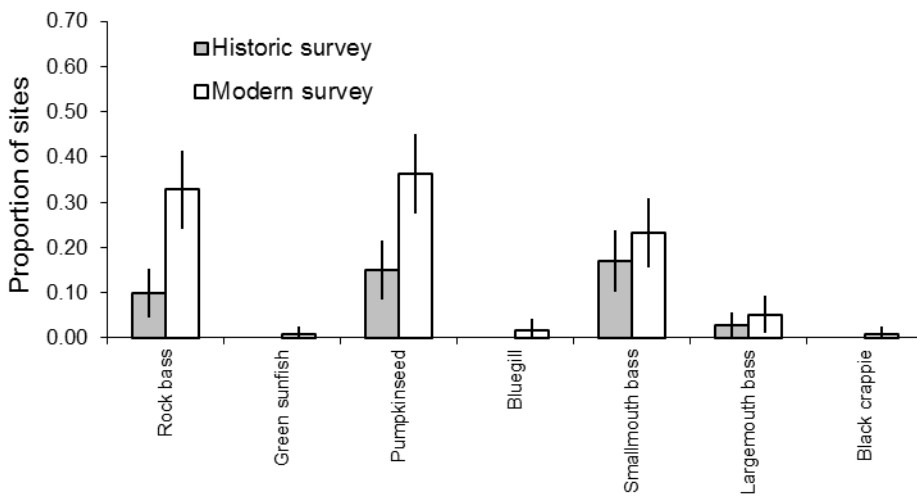


Figure A2-6. Catches (proportion of sites where detected) of fish species in the Black River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

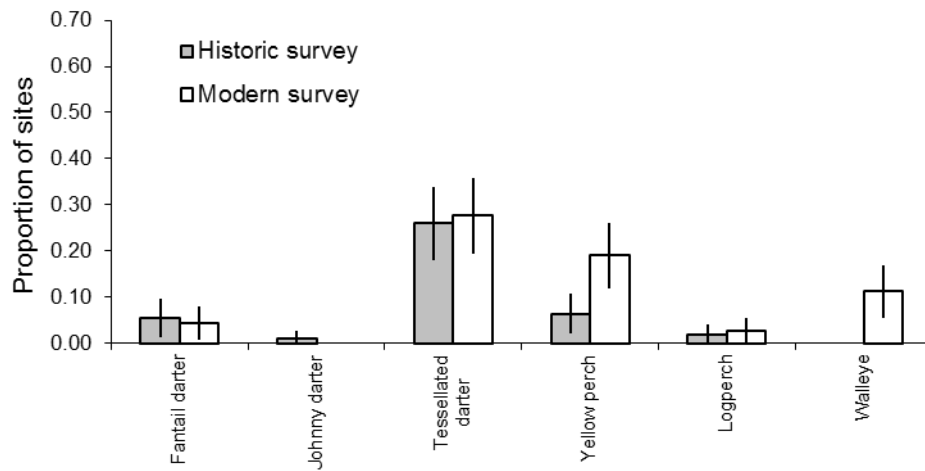


Figure A2-7. Catches (proportion of sites where detected) of fish species in the Black River Watershed from historic and modern stream surveys. Family Percidae. Error bars represent 95% confidence intervals.

CHEMUNG RIVER WATERSHED



Table A3. Catches (proportion of sites where detected) of fish species in the Chemung River watershed from historic and modern stream surveys, and results of Fisher's Exact Test for differences (total number of species represented: 61, Bonferroni inequality correction for significance: $0.05/61 = 0.0008$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=197)	Proportion of sites – Modern (n=41)	Direction of change	Fisher's exact test <i>p</i> -value
Family Anguillidae				
American eel	0.010	0.000		1.000
Family Clupeidae				
Gizzard shad	0.000	0.024		0.172
Family Cyprinidae				
Central stoneroller	0.558	0.732		0.054
Redside dace	0.142	0.000		0.006
Satinfin shiner	0.107	0.000		0.030
Spotfin shiner	0.107	0.342	+	0.0004
Common carp	0.091	0.073		1.000
Cutlip minnow	0.376	0.537		0.079
Common shiner	0.695	0.439		0.004
Pearl dace	0.132	0.146		0.803
River chub	0.178	0.146		0.821
Golden shiner	0.071	0.098		0.523
Comely shiner	0.102	0.000		0.029
Bridle shiner	0.020	0.000		1.000
Bigmouth shiner	0.000	0.049		0.029
Blacknose shiner	0.010	0.000		1.000
Spottail shiner	0.208	0.293		0.301
Swallowtail shiner	0.056	0.049		1.000
Rosyface shiner	0.086	0.122		0.551
Sand shiner	0.000	0.024		0.172
Mimic shiner	0.000	0.293	+	<0.0001
Bluntnose minnow	0.102	0.683	+	<0.0001
Fathead minnow	0.056	0.098		0.300
Eastern blacknose dace	0.655	0.584		0.474
Longnose dace	0.538	0.585		0.609
Creek chub	0.604	0.463		0.118
Fallfish	0.366	0.366		1.000
Family Catastomidae				
Quillback	0.005	0.024		0.316
White sucker	0.772	0.537		0.003
Eastern creek chubsucker	0.051	0.024		0.695
Northern hog sucker	0.310	0.390		0.360
Family Ictaluridae				
Yellow bullhead	0.000	0.146	+	<0.0001
Brown bullhead	0.086	0.024		0.326
Margined madtom	0.178	0.415		0.002
Family Salmonidae				
Rainbow trout	0.020	0.000		1.000
Brown trout	0.142	0.195		0.471
Brook trout	0.041	0.049		0.684

Species	Proportion of sites – Historic (n=197)	Proportion of sites – Modern (n=41)	Direction of change	Fisher's exact test <i>p</i> -value
Family Esocidae				
Northern pike	0.005	0.049		0.078
Chain pickerel	0.254	0.098		0.039
Central mudminnow	0.000	0.073		0.005
Family Fundulidae				
Banded killifish	0.046	0.195		0.003
Family Gasterosteidae				
Brook stickleback	0.000	0.049		0.029
Family Cottidae				
Mottled sculpin	0.305	0.488		0.029
Slimy sculpin	0.005	0.024		0.316
Family Centrarchidae				
Rock bass	0.223	0.537	+	0.0002
Redbreast sunfish	0.112	0.171		0.298
Green sunfish	0.005	0.146	+	0.0001
Pumpkinseed	0.198	0.293		0.209
Bluegill	0.025	0.171		0.001
Smallmouth bass	0.345	0.415		0.474
Largemouth bass	0.031	0.342	+	<0.0001
White crappie	0.000	0.024		0.172
Black crappie	0.000	0.049		0.029
Family Percidae				
Greenside darter	0.000	0.049		0.029
Fantail darter	0.056	0.146		0.087
Johnny darter	0.005	0.024		0.316
Tessellated darter	0.528	0.683		0.084
Banded darter	0.000	0.537	+	<0.0001
Yellow perch	0.102	0.098		1.000
Shield darter	0.112	0.293		0.006
Walleye	0.015	0.049		0.206

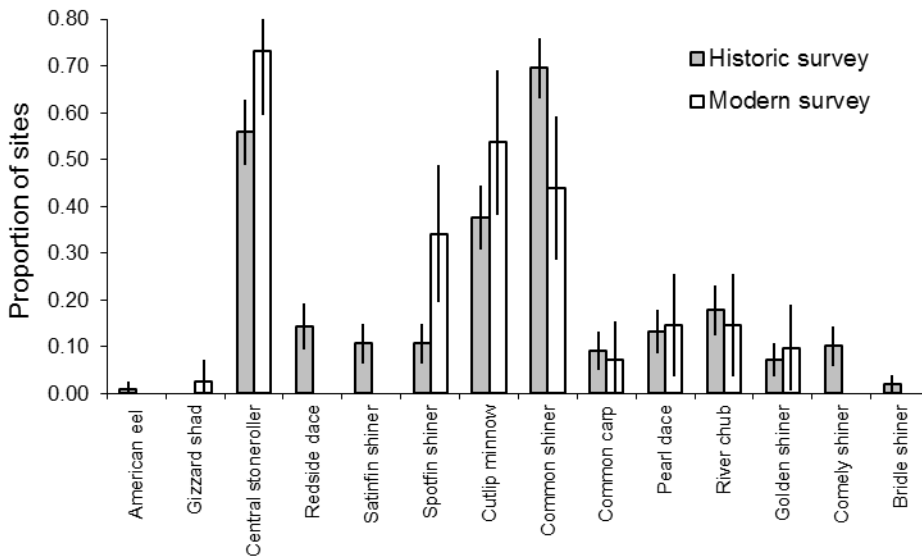


Figure A3-1. Catches (proportion of sites where detected) of fish species in the Chemung River Watershed from historic and modern stream surveys. Families Petromyzontidae, Anguillidae, Clupeidae, and Cyprinidae. Error bars represent 95% confidence intervals.

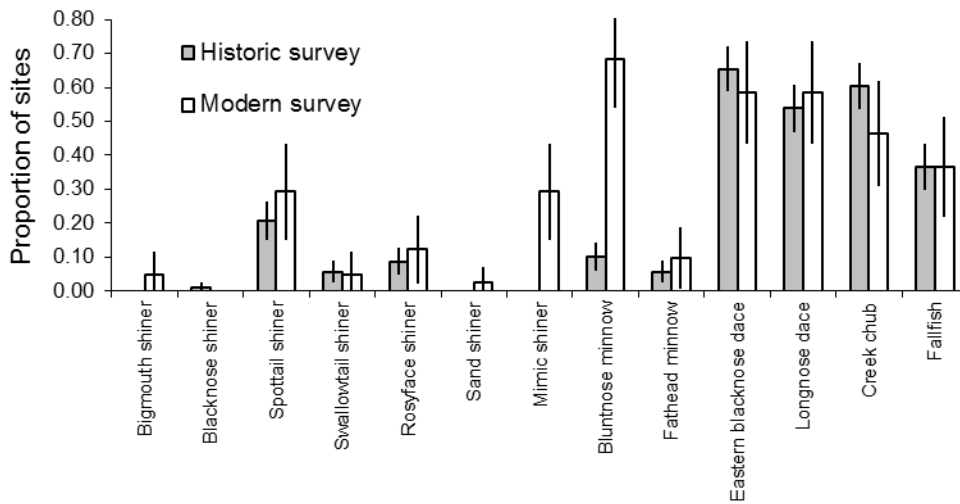


Figure A3-2. Catches (proportion of sites where detected) of fish species in the Chemung River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

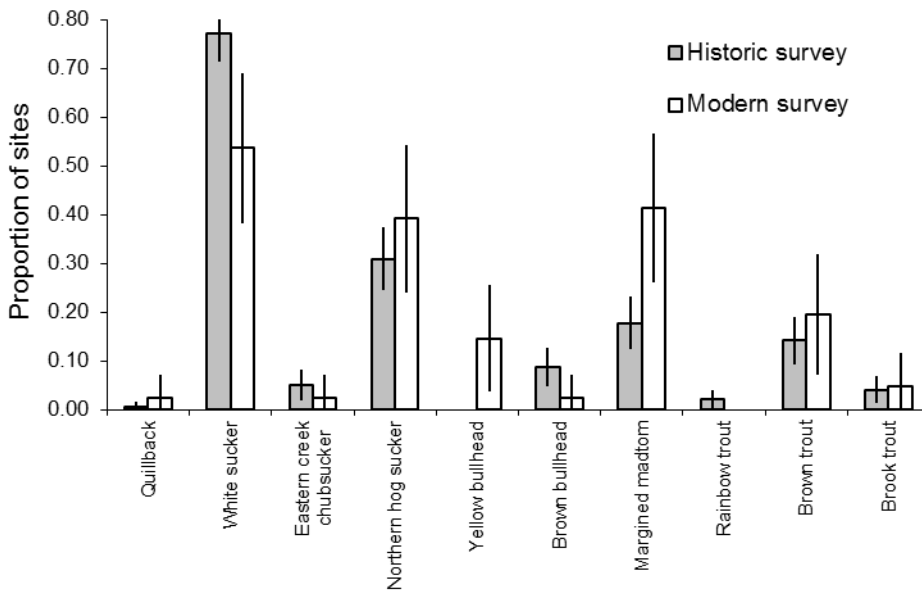


Figure A3-3. Catches (proportion of sites where detected) of fish species in the Chemung River Watershed from historic and modern stream surveys. Families Catastomidae, Ictaluridae, and Salmonidae. Error bars represent 95% confidence intervals.

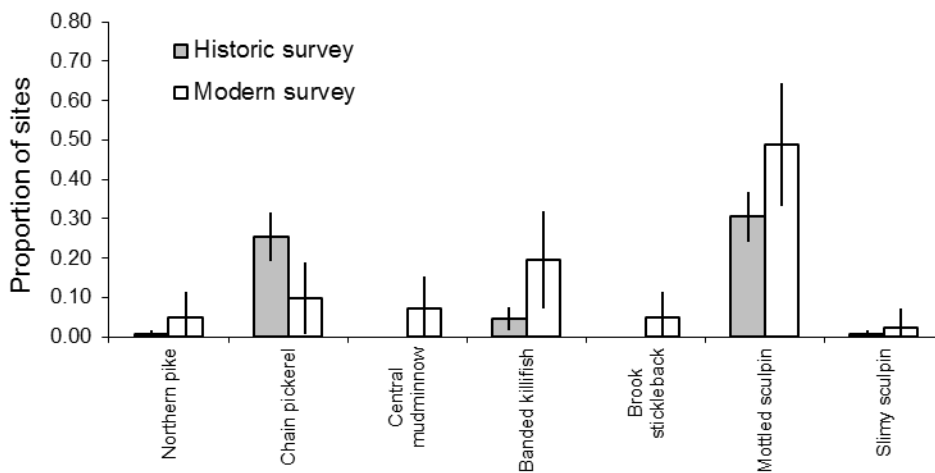


Figure A3-4. Catches (proportion of sites where detected) of fish species in the Chemung River Watershed from historic and modern stream surveys. Families Esocidae, Fundulidae, Gasterosteidae, and Cottidae. Error bars represent 95% confidence intervals.

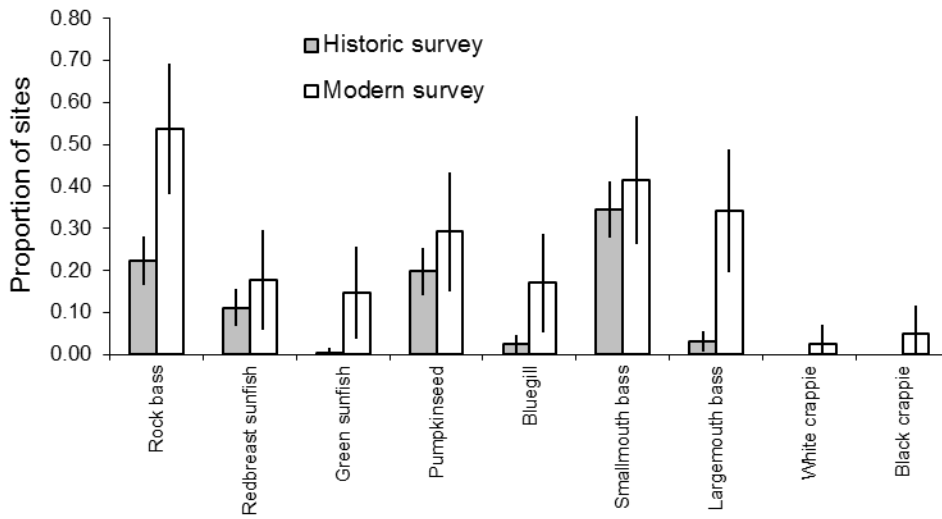


Figure A3-5. Catches (proportion of sites where detected) of fish species in the Chemung River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

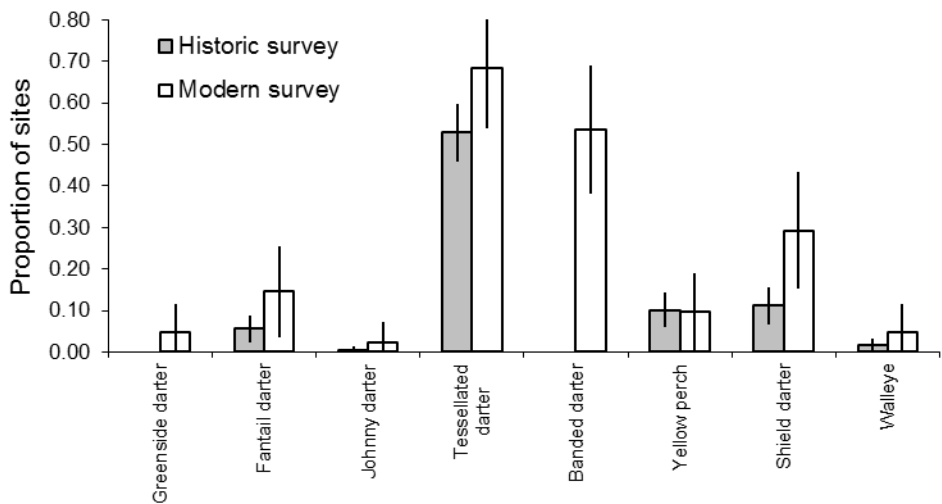


Figure A3-6. Catches (proportion of sites where detected) of fish species in the Chemung River Watershed from historic and modern stream surveys. Family Percidae. Error bars represent 95% confidence intervals.

DELAWARE RIVER WATERSHED



Table A4. Catches (proportion of sites where detected) of fish species in the Delaware River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 58, Bonferroni inequality correction for significance: $0.05/58 = 0.0009$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=336)	Proportion of sites – Modern (n=188)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
Sea lamprey	0.030	0.096		0.002
Family Amiidae				
Bowfin	0.000	0.016		0.046
Family Anguillidae				
American eel	0.039	0.325	+	<0.0001
Family Clupeidae				
Alewife	0.000	0.005		0.359
American shad	0.009	0.027		0.143
Gizzard shad	0.000	0.016		0.046
Family Cyprinidae				
Central stoneroller	0.000	0.064	+	<0.0001
Goldfish	0.000	0.005		0.359
Lake chub	0.015	0.000		0.165
Satinfin shiner	0.155	0.043	-	<0.0001
Spotfin shiner	0.000	0.027		0.006
Common carp	0.006	0.053	+	0.0009
Cutlip minnow	0.015	0.367	+	<0.0001
Eastern silvery minnow	0.003	0.000		1.000
Common shiner	0.435	0.351		0.064
Golden shiner	0.188	0.122		0.065
Comely shiner	0.066	0.037		0.232
Emerald shiner	0.000	0.011		0.128
Bridle shiner	0.057	0.043		0.543
Ironcolor shiner	0.009	0.016		0.672
Spottail shiner	0.101	0.085		0.643
Swallowtail shiner	0.015	0.043		0.075
Mimic shiner	0.000	0.011		0.128
Bluntnose minnow	0.006	0.032		0.023
Fathead minnow	0.000	0.016		0.046
Eastern blacknose dace	0.455	0.468		0.785
Longnose dace	0.235	0.383	+	0.0004
Creek chub	0.247	0.101	-	<0.0001
Fallfish	0.449	0.378		0.118
Family Catostomidae				
Longnose sucker	0.039	0.005		0.023
White sucker	0.521	0.543		0.649
Eastern creek chubsucker	0.042	0.027		0.470
Northern hog sucker	0.003	0.064	+	<0.0001
Family Ictaluridae				
Yellow bullhead	0.000	0.016		0.046
Brown bullhead	0.083	0.112		0.348
Tadpole madtom	0.009	0.011		1.000
Margined madtom	0.134	0.229		0.007

Species	Proportion of sites – Historic (n=336)	Proportion of sites – Modern (n=188)	Direction of change	Fisher's exact test <i>p</i> -value
Family Salmonidae				
Rainbow trout	0.027	0.037		0.598
Brown trout	0.226	0.372	+	0.0005
Brook trout	0.283	0.261		0.611
Family Esocidae				
Redfin pickerel	0.012	0.037		0.062
Chain pickerel	0.158	0.186		0.465
Family Fundulidae				
Banded killifish	0.021	0.023		0.763
Family Cottidae				
Mottled sculpin	0.000	0.015		0.046
Slimy sculpin	0.063	0.176	+	<0.0001
Family Centrarchidae				
Rock bass	0.080	0.128		0.091
Bluespotted sunfish	0.009	0.053		0.003
Redbreast sunfish	0.083	0.128		0.127
Green sunfish	0.000	0.032		0.002
Pumpkinseed	0.131	0.250	+	0.0007
Bluegill	0.006	0.101	+	<0.0001
Smallmouth bass	0.271	0.282		0.838
Largemouth bass	0.003	0.170	+	<0.0001
Black crappie	0.003	0.011		0.293
Family Percidae				
Tessellated darter	0.348	0.468		0.009
Yellow perch	0.063	0.122		0.022
Shield darter	0.095	0.213	+	0.0003
Walleye	0.018	0.016		1.000

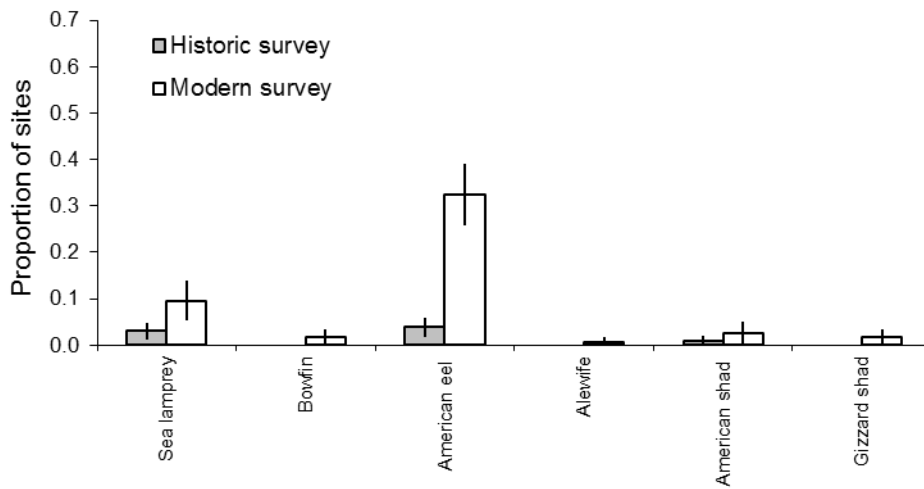


Figure A4-1. Catches (proportion of sites where detected) of fish species in the Delaware River Watershed from historic and modern stream surveys. Families Petromyzontidae, Amiidae, Anguillidae, and Clupeidae. Error bars represent 95% confidence intervals.

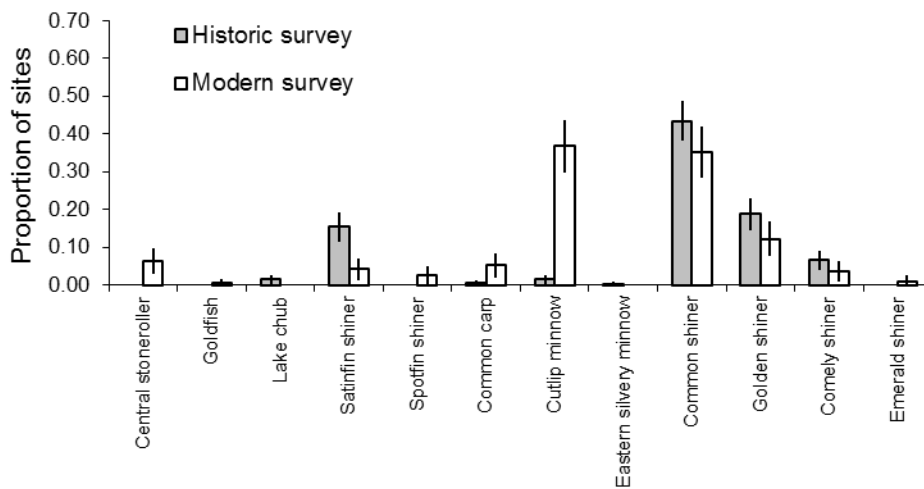


Figure A4-2. Catches (proportion of sites where detected) of fish species in the Delaware River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

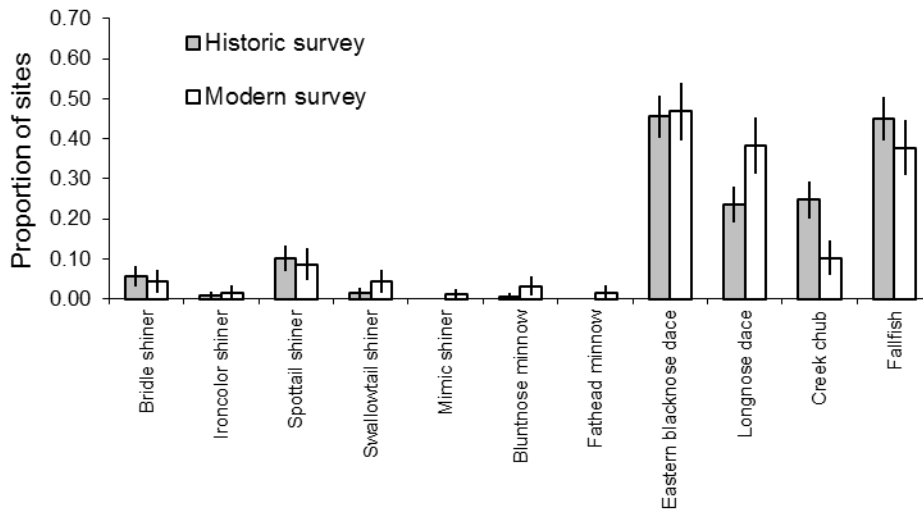


Figure A4-3. Catches (proportion of sites where detected) of fish species in the Delaware River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

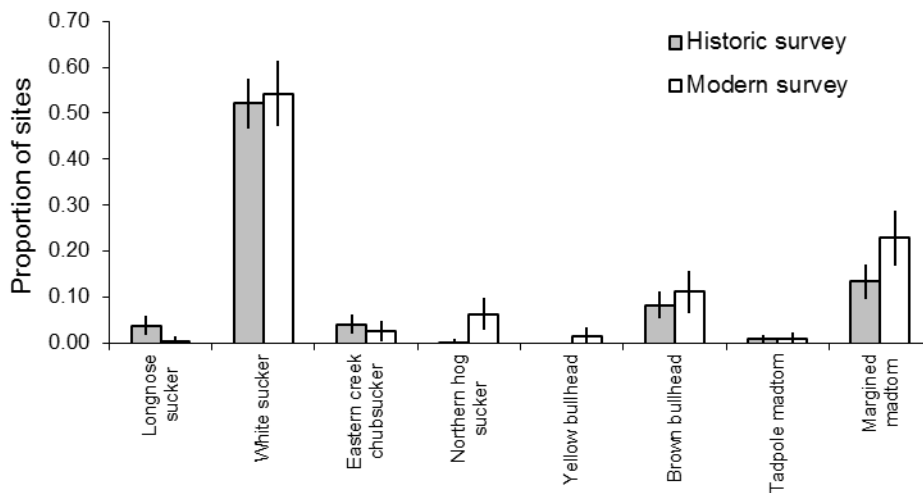


Figure A4-4. Catches (proportion of sites where detected) of fish species in the Delaware River Watershed from historic and modern stream surveys. Families Catastomidae and Ictaluridae. Error bars represent 95% confidence intervals.

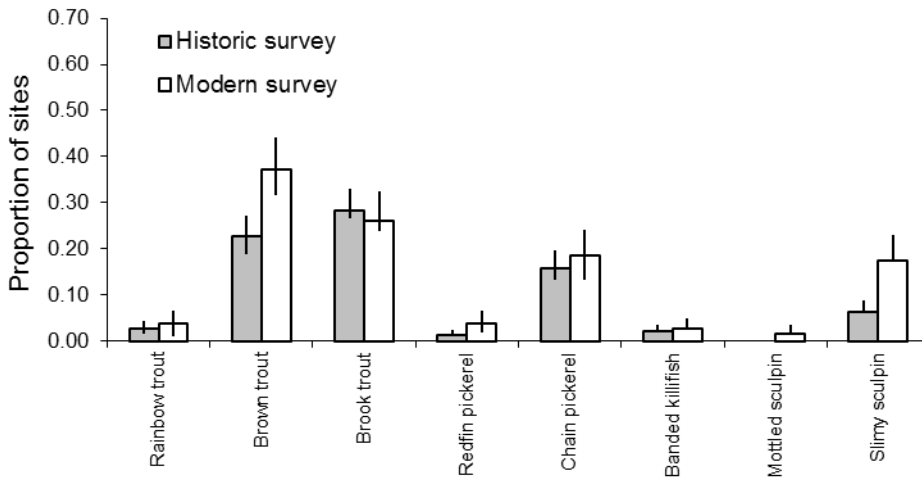


Figure A4-5. Catches (proportion of sites where detected) of fish species in the Delaware River Watershed from historic and modern stream surveys. Families Salmonidae, Esocidae, Fundulidae, and Cottidae. Error bars represent 95% confidence intervals.

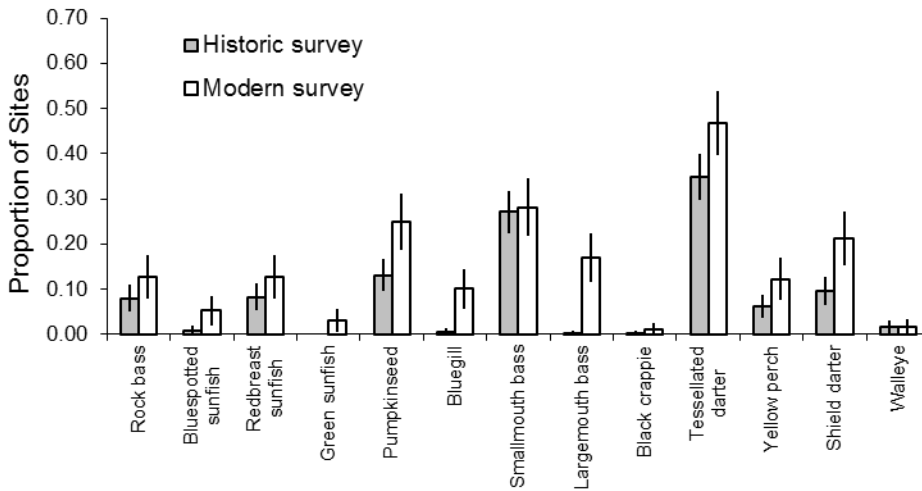


Figure A4-6. Catches (proportion of sites where detected) of fish species in the Delaware River Watershed from historic and modern stream surveys. Families Centrarchidae and Percidae. Error bars represent 95% confidence intervals.

GENESEE RIVER WATERSHED



Table A5. Catches (proportion of sites where detected) of fish species in the Genesee River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 73, Bonferroni inequality correction for significance: $0.05/73 = 0.0007$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=148)	Proportion of sites – Modern (n=54)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
American brook lamprey	0.000	0.167	+	<0.0001
Family Lepisosteidae				
Longnose gar	0.000	0.019		0.267
Family Amiidae				
Bowfin	0.000	0.019		0.267
Family Clupeidae				
Alewife	0.007	0.037		0.175
Gizzard shad	0.000	0.037		0.071
Family Cyprinidae				
Central stoneroller	0.331	0.537		0.009
Redside dace	0.095	0.037		0.245
Spotfin shiner	0.020	0.296	+	<0.0001
Common carp	0.000	0.093		0.001
Tonguetied minnow	0.014	0.019		1.000
Cutlip minnow	0.068	0.074		1.000
Brassy minnow	0.007	0.000		1.000
Eastern silvery minnow	0.007	0.000		1.000
Striped shiner	0.041	0.130		0.045
Common shiner	0.297	0.333		0.611
Pearl dace	0.068	0.037		0.521
Hornyhead chub	0.020	0.056		0.195
Golden shiner	0.027	0.185	+	0.0004
Emerald shiner	0.027	0.000		0.575
Bridle shiner	0.000	0.019		0.267
Bigmouth shiner	0.101	0.093		1.000
Blackchin shiner	0.007	0.019		0.464
Blacknose shiner	0.007	0.000		1.000
Spottail shiner	0.014	0.074		0.045
Rosyface shiner	0.108	0.056		0.413
Sand shiner	0.142	0.148		1.000
Mimic shiner	0.007	0.222	+	<0.0001
Bluntnose minnow	0.169	0.630	+	<0.0001
Fathead minnow	0.034	0.241	+	<0.0001
Longnose dace	0.189	0.315		0.084
Western blacknose dace	0.142	0.426	+	<0.0001
Rudd	0.000	0.019		0.267
Creek chub	0.338	0.537		0.014
Family Catostomidae				
Longnose sucker	0.000	0.037	+	0.071
White sucker	0.257	0.722	+	<0.0001
Northern hog sucker	0.182	0.315		0.054
Silver redhorse	0.007	0.019		0.464
Black redhorse	0.014	0.000		1.000
Golden redhorse	0.007	0.148	+	<0.0001

Species	Proportion of sites – Historic (n=148)	Proportion of sites – Modern (n=54)	Direction of change	Fisher's exact test p-value
Shorthead redhorse	0.041	0.037		0.636
Greater redhorse	0.000	0.037		0.071
Family Ictaluridae				
Black bullhead	0.007	0.000		1.000
Brown bullhead	0.047	0.093		0.310
Channel catfish	0.000	0.019		0.267
Stonecat	0.034	0.111		0.072
Family Salmonidae				
Rainbow trout	0.061	0.000		0.116
Brown trout	0.182	0.130		0.524
Brook trout	0.142	0.000		0.001
Family Esocidae				
Northern pike	0.020	0.167	+	0.0004
Chain pickerel	0.020	0.056		0.195
Central mudminnow	0.020	0.093		0.033
Family Percopsidae				
Trout-perch	0.061	0.037		0.731
Family Atherinopsidae				
Brook silverside	0.000	0.130	+	<0.0001
Family Fundulidae				
Banded killifish	0.014	0.056		0.120
Family Gasterosteidae				
Brook stickleback	0.020	0.037		0.611
Threespine stickleback	0.007	0.000		1.000
Family Cottidae				
Mottled sculpin	0.014	0.204	+	<0.0001
Family Centrarchidae				
Rock bass	0.081	0.352	+	<0.0001
Green sunfish	0.000	0.111	+	0.0003
Pumpkinseed	0.034	0.389	+	<0.0001
Bluegill	0.000	0.389	+	<0.0001
Smallmouth bass	0.095	0.315	+	0.0003
Largemouth bass	0.041	0.259	+	<0.0001
Black crappie	0.000	0.074		0.005
Family Percidae				
Greenside darter	0.068	0.389	+	<0.0001
Rainbow darter	0.000	0.278	+	<0.0001
Iowa darter	0.007	0.000		1.000
Fantail darter	0.122	0.519	+	<0.0001
Johnny darter	0.074	0.426	+	<0.0001
Tessellated darter	0.000	0.130	+	<0.0001
Yellow perch	0.047	0.074		0.489
Logperch	0.034	0.222	+	<0.0001
Blackside darter	0.054	0.167		0.019
Walleye	0.020	0.000	-	0.566

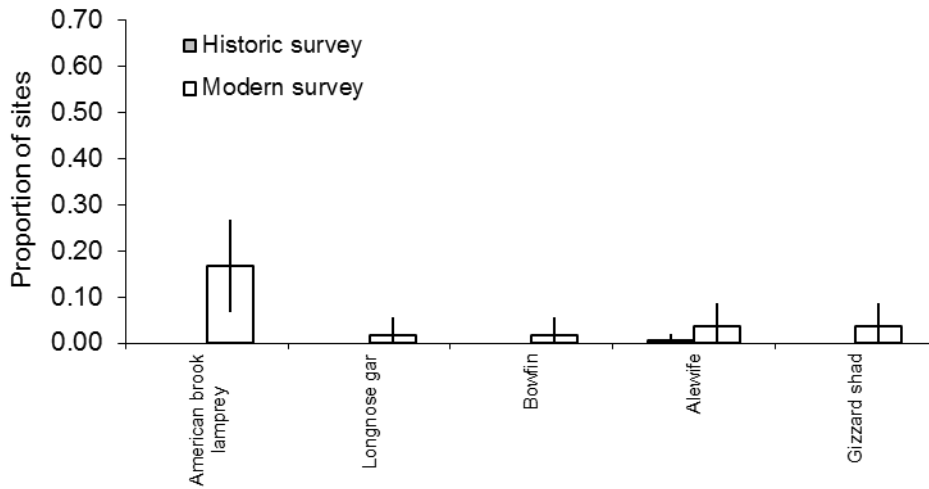


Figure A5-1. Catches (proportion of sites where detected) of fish species in the Genesee River Watershed from historic and modern stream surveys. Families Petromyzontidae, Lepisosteidae, Amiidae, and Clupeidae. Error bars represent 95% confidence intervals.

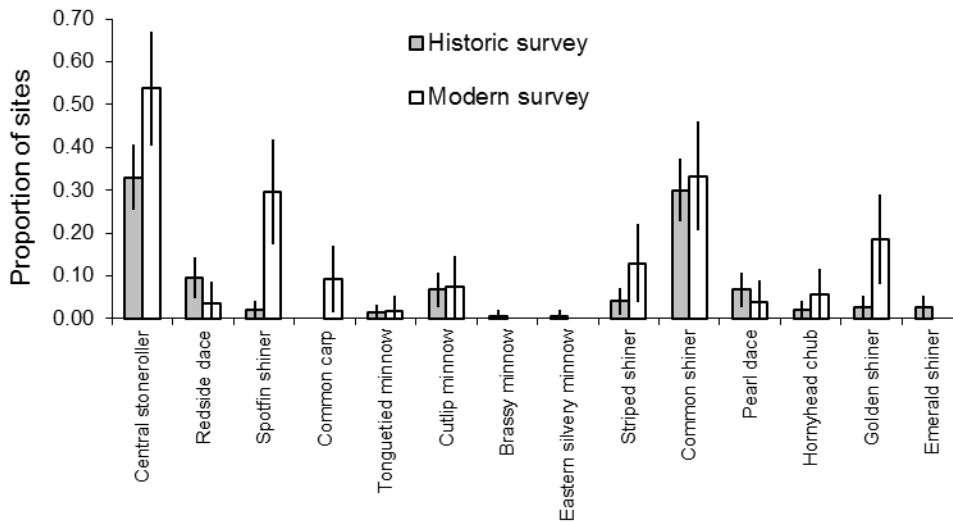


Figure A5-2. Catches (proportion of sites where detected) of fish species in the Genesee River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

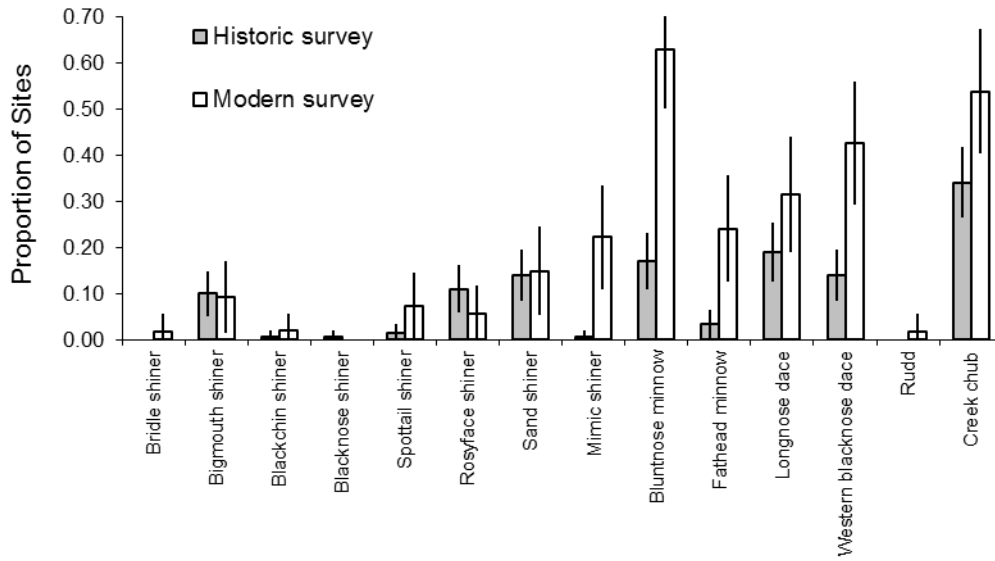


Figure A5-3. Catches (proportion of sites where detected) of fish species in the Genesee River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

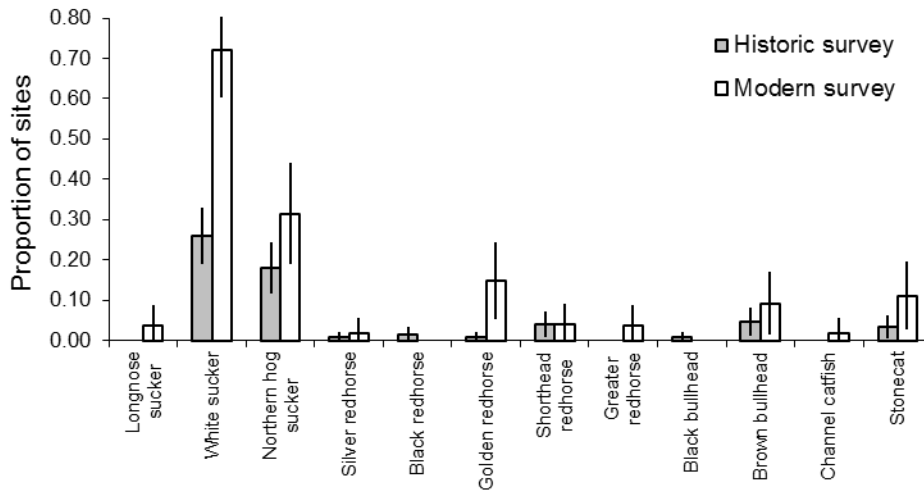


Figure A5-4. Catches (proportion of sites where detected) of fish species in the Genesee River Watershed from historic and modern stream surveys. Families Catostomidae and Ictaluridae. Error bars represent 95% confidence intervals.

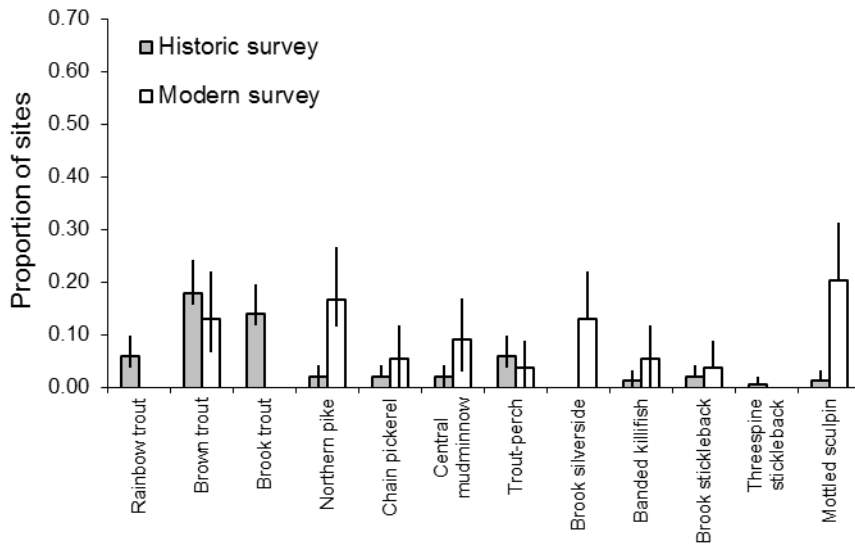


Figure A5-5. Catches (proportion of sites where detected) of fish species in the Genesee River Watershed from historic and modern stream surveys. Families Salmonidae, Esocidae, Percopsidae, Atherinopsidae, Fundulidae, Gasterosteidae, and Cottidae. Error bars represent 95% confidence intervals.

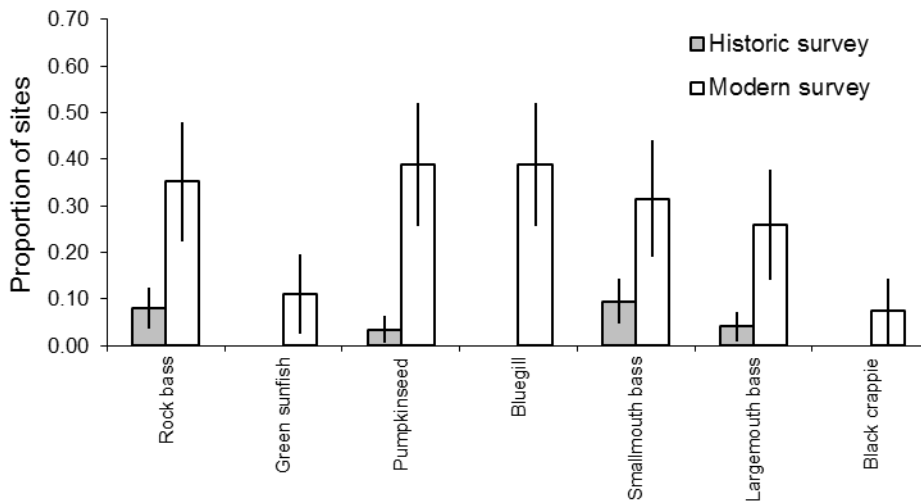


Figure A5-6. Catches (proportion of sites where detected) of fish species in the Genesee River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

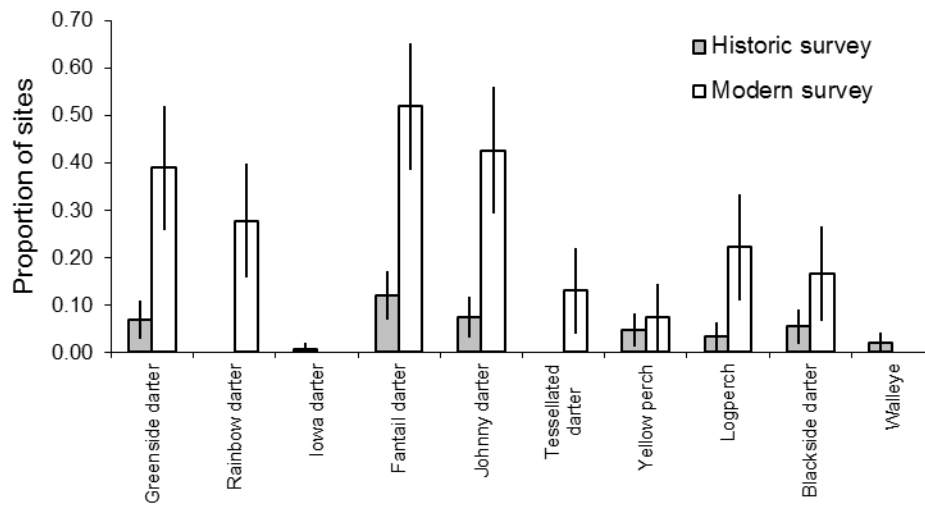


Figure A5-7. Catches (proportion of sites where detected) of fish species in the Genesee River Watershed from historic and modern stream surveys. Family Percidae. Error bars represent 95% confidence intervals.

LAKE CHAMPLAIN WATERSHED



Table A6. Catches (proportion of sites where detected) of fish species in the Lake Champlain watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 76, Bonferroni inequality correction for significance: $0.05/76 = 0.0007$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=106)	Proportion of sites – Modern (n=110)	Direction of change	Fisher's exact test <i>p</i> -value
Family				
Petromyzontidae				
Silver lamprey	0.038	0.000		0.056
American brook lamprey	0.009	0.009		1.000
Sea lamprey	0.000	0.009		1.000
Family Lepisosteidae				
Longnose gar	0.038	0.009		0.206
Family Clupeidae				
Blueback herring	0.000	0.036		0.122
Gizzard shad	0.000	0.009		1.000
Family Cyprinidae				
Northern redbelly dace	0.076	0.146		0.130
Finescale dace	0.019	0.000		0.240
Lake chub	0.038	0.027		0.718
Spotfin shiner	0.066	0.118		0.242
Common carp	0.000	0.036		0.122
Cutlip minnow	0.151	0.318		0.004
Brassy minnow	0.028	0.000		0.117
Eastern silvery minnow	0.142	0.136		1.000
Common shiner	0.396	0.509		0.103
Pearl dace	0.066	0.018		0.097
Golden shiner	0.189	0.191		1.000
Emerald shiner	0.076	0.027		0.130
Bridle shiner	0.094	0.027		0.047
Blackchin shiner	0.047	0.018		0.273
Blacknose shiner	0.028	0.018		0.679
Spottail shiner	0.142	0.018	-	0.0007
Rosyface shiner	0.104	0.246		0.007
Sand shiner	0.057	0.036		0.533
Mimic shiner	0.151	0.173		0.714
Bluntnose minnow	0.302	0.518		0.002
Fathead minnow	0.057	0.182		0.006
Eastern blacknose dace	0.283	0.391		0.114
Longnose dace	0.123	0.264		0.010
Creek chub	0.302	0.491		0.005
Fallfish	0.142	0.236		0.085
Family Catostomidae				
Longnose sucker	0.028	0.009		0.362
White sucker	0.396	0.564		0.015
Silver redhorse	0.038	0.018		0.439
Shorthead redhorse	0.009	0.009		1.000
Greater redhorse	0.019	0.036		0.683
Family Ictaluridae				
Black bullhead	0.000	0.018		0.498

Species	Proportion of sites – Historic (n=106)	Proportion of sites – Modern (n=110)	Direction of change	Fisher's exact test <i>p</i> -value
Yellow bullhead	0.000	0.046		0.060
Brown bullhead	0.170	0.155		0.854
Channel catfish	0.019	0.019		1.000
Stonecat	0.009	0.009		1.000
Family Salmonidae				
Rainbow trout	0.038	0.036		1.000
Atlantic salmon	0.019	0.036		0.683
Brown trout	0.047	0.127		0.053
Brook trout	0.113	0.127		0.836
Family Esocidae				
Redfin pickerel	0.104	0.035		0.063
Northern pike	0.151	0.055		0.024
Muskellunge	0.019	0.009		0.616
Chain pickerel	0.028	0.082		0.136
Central mudminnow	0.019	0.191	+	<0.0001
Family Percopsidae				
Trout-perch	0.028	0.009		0.362
Family Gadidae				
Burbot	0.009	0.000		0.491
Family Atherinopsidae				
Brook silverside	0.000	0.091		0.002
Family Fundulidae				
Banded killifish	0.142	0.064		0.073
Family Gasterosteidae				
Brook stickleback	0.038	0.046		1.000
Family Cottidae				
Mottled sculpin	0.000	0.009		1.000
Slimy sculpin	0.076	0.109		0.484
Family Moronidae				
White perch	0.000	0.018		0.498
Family Centrarchidae				
Rock bass	0.189	0.327		0.029
Redbreast sunfish	0.028	0.009		0.362
Pumpkinseed	0.236	0.491	+	0.0001
Bluegill	0.000	0.173	+	<0.0001
Smallmouth bass	0.160	0.355		0.002
Largemouth bass	0.009	0.200	+	<0.0001
White crappie	0.000	0.009		1.000
Black crappie	0.009	0.064		0.066
Family Percidae				
Eastern sand darter	0.000	0.055		0.029
Iowa darter	0.009	0.009		1.000
Fantail darter	0.038	0.082		0.253
Tessellated darter	0.330	0.518		0.006
Yellow perch	0.236	0.291		0.440
Logperch	0.132	0.282		0.008
Channel darter	0.009	0.000		0.491

Species	Proportion of sites – Historic (n=106)	Proportion of sites – Modern (n=110)	Direction of change	Fisher's exact test <i>p</i> -value
Sauger	0.009	0.000		0.491
Walleye	0.028	0.000		0.117
Family Scianidae				
Freshwater drum	0.019	0.009		0.616

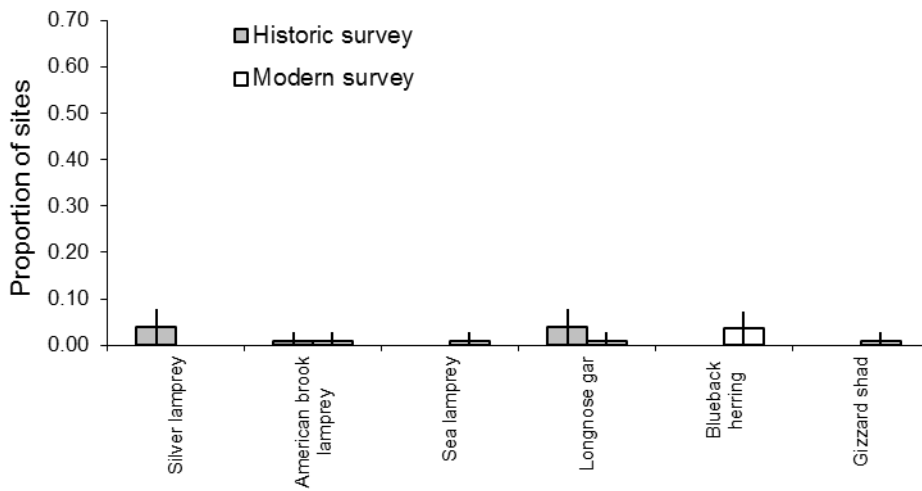


Figure A6-1. Catches (proportion of sites where detected) of fish species in the Lake Champlain Watershed from historic and modern stream surveys. Families Petromyzontidae, Lepisosteidae, and Clupeidae. Error bars represent 95% confidence intervals.

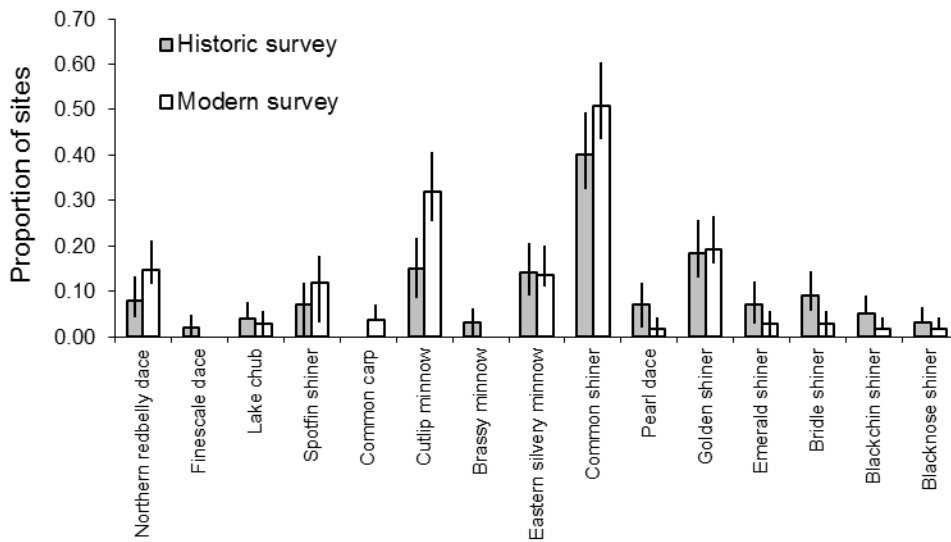


Figure A6-2. Catches (proportion of sites where detected) of fish species in the Lake Champlain Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

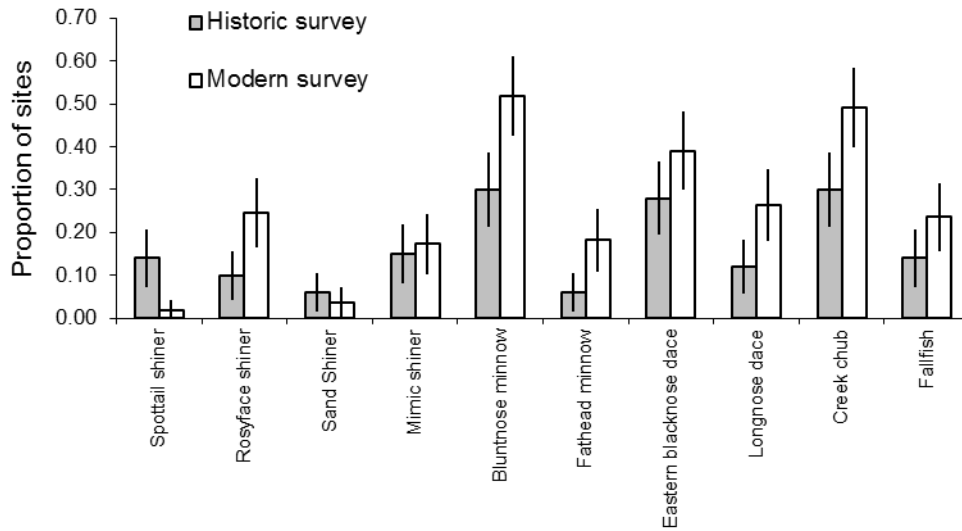


Figure A6-3. Catches (proportion of sites where detected) of fish species in the Lake Champlain Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

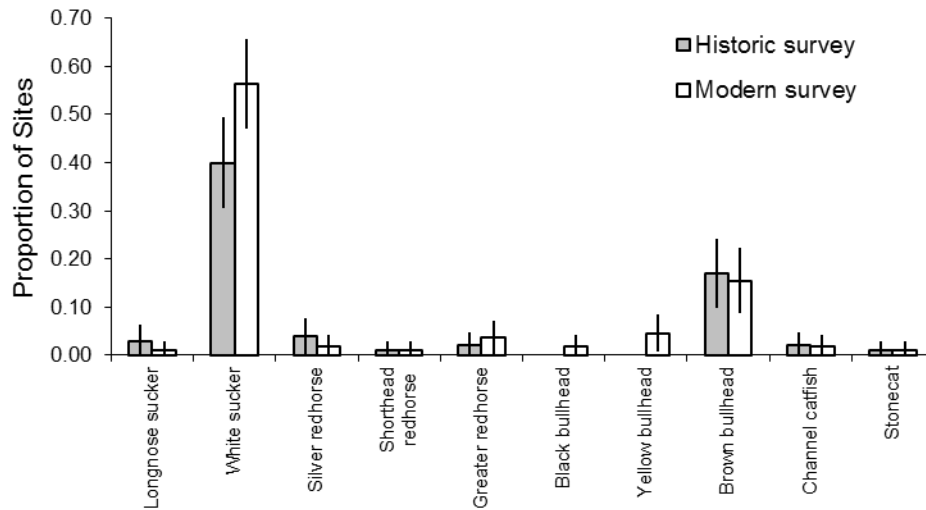


Figure A6-4. Catches (proportion of sites where detected) of fish species in the Lake Champlain Watershed from historic and modern stream surveys. Families Catastomidae and Ictaluridae. Error bars represent 95% confidence intervals.

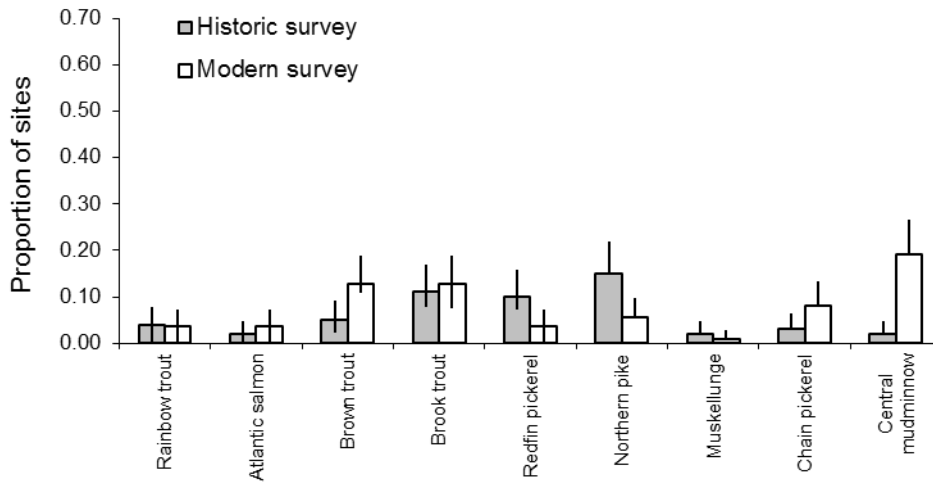


Figure A6-5. Catches (proportion of sites where detected) of fish species in the Lake Champlain Watershed from historic and modern stream surveys. Families Salmonidae and Esocidae. Error bars represent 95% confidence intervals.

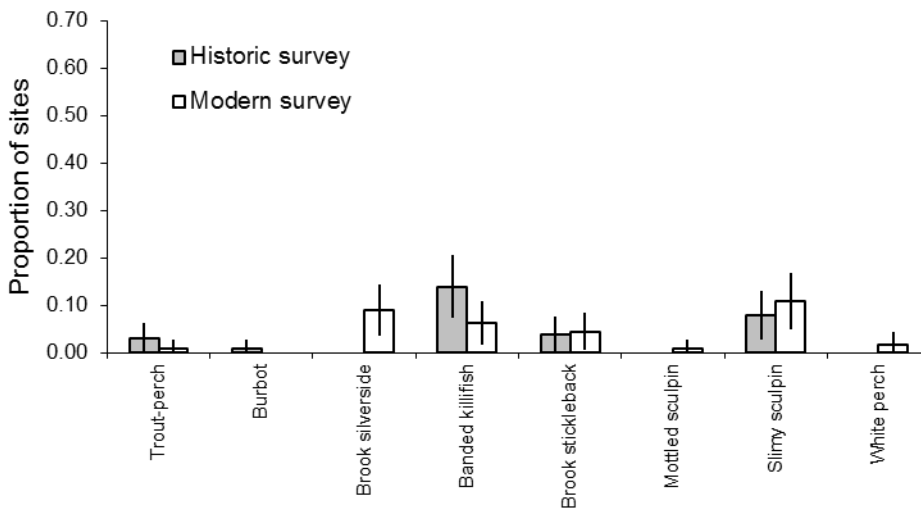


Figure A6-6. Catches (proportion of sites where detected) of fish species in the Lake Champlain Watershed from historic and modern stream surveys. Families Percopsidae, Gadidae, Atherinopsidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

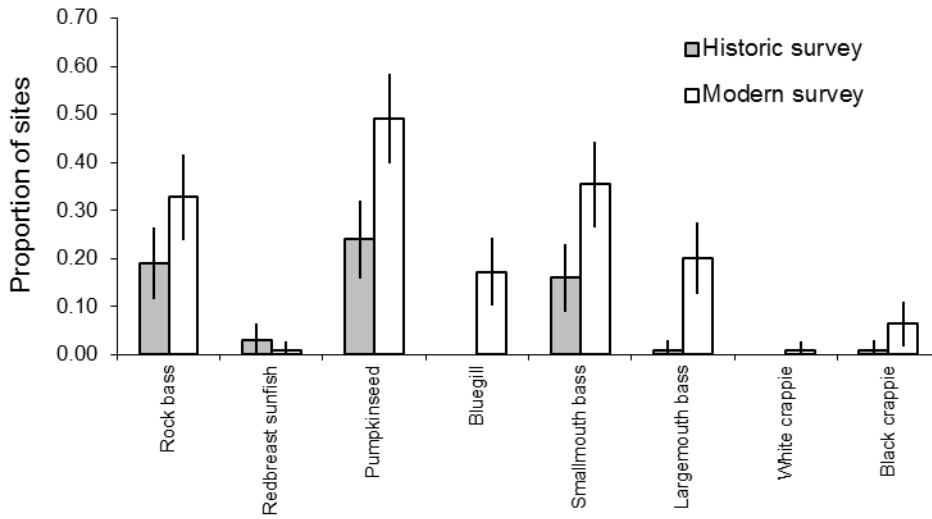


Figure A6-7. Catches (proportion of sites where detected) of fish species in the Lake Champlain Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

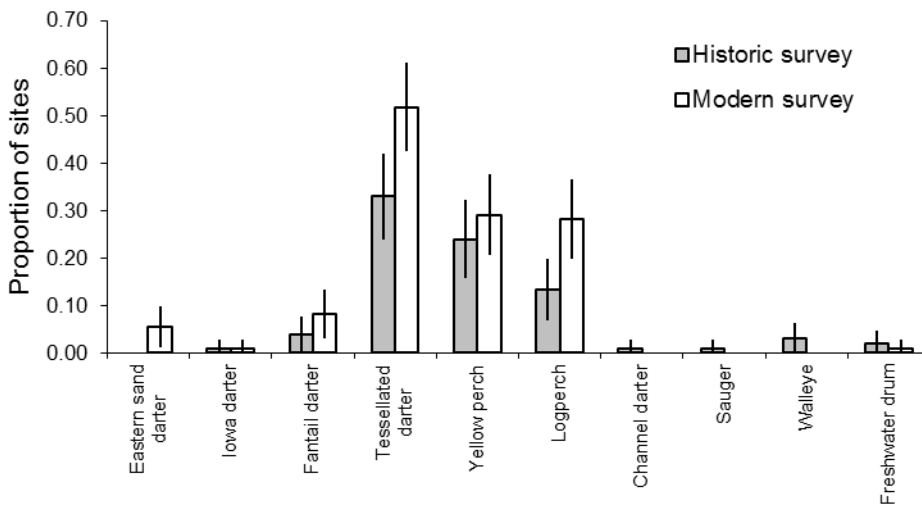


Figure A6-8. Catches (proportion of sites where detected) of fish species in the Lake Champlain Watershed from historic and modern stream surveys. Families Percidae and Scianidae. Error bars represent 95% confidence intervals.

LAKE ERIE-NIAGARA RIVER WATERSHED



Table A7. Catches (proportion of sites where detected) of fish species in the Lake Erie-Niagara River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 89, Bonferroni inequality correction for significance: $0.05/89 = 0.0006$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=161)	Proportion of sites – Modern (n=148)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
Northern brook lamprey	0.006	0.027		0.198
American brook lamprey	0.012	0.061		0.030
Sea lamprey	0.000	0.007		0.479
Family Lepisosteidae				
Longnose gar	0.019	0.007		0.624
Family Hiodontidae				
Mooneye	0.037	0.000		0.031
Family Clupeidae				
Gizzard shad	0.000	0.115	+	<0.0001
Family Cyprinidae				
Central stoneroller	0.211	0.358		0.005
Goldfish	0.019	0.027		0.714
Northern redbelly dace	0.006	0.000		1.000
Redside dace	0.019	0.027		0.714
Spotfin shiner	0.093	0.162		0.086
Common carp	0.050	0.128		0.016
Bigeye chub	0.006	0.047		0.030
Striped shiner	0.056	0.277	+	<0.0001
Common shiner	0.342	0.385		0.478
Redfin shiner	0.031	0.027		1.000
Silver chub	0.025	0.000		0.124
Hornyhead chub	0.019	0.074		0.026
River chub	0.124	0.169		0.333
Golden shiner	0.050	0.149		0.004
Emerald shiner	0.137	0.243		0.020
Bigmouth shiner	0.031	0.061		0.276
Blacknose shiner	0.062	0.007		0.011
Spottail shiner	0.062	0.108		0.157
Rosyface shiner	0.025	0.162	+	<0.0001
Sand shiner	0.230	0.237		0.894
Mimic shiner	0.050	0.122		0.025
Bluntnose minnow	0.311	0.628	+	<0.0001
Fathead minnow	0.081	0.243	+	<0.0001
Longnose dace	0.186	0.203		0.774
Western blacknose dace	0.385	0.203	-	0.0005
Rudd	0.000	0.020		0.109
Creek chub	0.130	0.338	+	<0.0001
Fallfish	0.006	0.020		0.353
Family Catostomidae				
Quillback	0.019	0.061		0.076
White sucker	0.280	0.676	+	<0.0001
Lake chubsucker	0.006	0.000		1.000
Northern hog sucker	0.118	0.473	+	<0.0001
Spotted sucker	0.000	0.007		0.479

Species	Proportion of sites – Historic (n=161)	Proportion of sites – Modern (n=148)	Direction of change	Fisher's exact test <i>p</i> -value
Silver redhorse	0.044	0.054		0.793
Black redhorse	0.019	0.041		0.320
Golden redhorse	0.012	0.223	+	<0.0001
Shorthead redhorse	0.056	0.061		1.000
Greater redhorse	0.000	0.020		0.109
Family Ictaluridae				
Yellow bullhead	0.012	0.007		1.000
Brown bullhead	0.106	0.014	-	0.0006
Channel catfish	0.012	0.007		1.000
Stonecat	0.012	0.149	+	<0.0001
Tadpole madtom	0.006	0.020		0.353
Brindled madtom	0.000	0.014		0.229
Family Osmeridae				
Rainbow smelt	0.000	0.007		0.479
Family Salmonidae				
Rainbow trout	0.006	0.155	+	<0.0001
Brown trout	0.012	0.122	+	<0.0001
Brook trout	0.025	0.007		0.373
Family Esocidae				
Grass pickerel	0.006	0.027		0.198
Northern pike	0.044	0.101		0.075
Muskellunge	0.006	0.007		1.000
Chain pickerel	0.000	0.007		0.479
Central mudminnow	0.044	0.101		0.075
Family Percopsidae				
Trout-perch	0.062	0.007		0.011
Family Aphredoderidae				
Pirate perch	0.012	0.000		0.499
Family Atherinopsidae				
Brook silverside	0.006	0.054		0.016
Family Fundulidae				
Banded killifish	0.000	0.054		0.003
Family Gasterosteidae				
Brook stickleback	0.025	0.027		1.000
Family Cottidae				
Mottled sculpin	0.006	0.054		0.016
Family Moronidae				
White perch	0.000	0.007		0.479
White bass	0.044	0.014		0.177
Family Centrarchidae				
Rock bass	0.044	0.392	+	<0.0001
Green sunfish	0.000	0.216	+	<0.0001
Pumpkinseed	0.037	0.358	+	<0.0001
Bluegill	0.000	0.284	+	<0.0001
Northern sunfish	0.000	0.020		0.109
Smallmouth bass	0.000	0.399	+	<0.0001
Largemouth bass	0.000	0.203	+	<0.0001

Species	Proportion of sites – Historic (n=161)	Proportion of sites – Modern (n=148)	Direction of change	Fisher's exact test <i>p</i> -value
White crappie	0.025	0.007		0.373
Black crappie	0.000	0.054		0.003
Family Percidae				
Greenside darter	0.006	0.108	+	<0.0001
Rainbow darter	0.174	0.446	+	<0.0001
Fantail darter	0.012	0.196	+	<0.0001
Johnny darter	0.025	0.446	+	<0.0001
Yellow perch	0.056	0.088		0.376
Logperch	0.087	0.142		0.152
Channel darter	0.019	0.014		1.000
Blackside darter	0.019	0.095		0.005
Sauger	0.006	0.000		1.000
Walleye	0.037	0.027		0.752
Blue pike	0.019	0.000		0.249
Family Scianidae				
Freshwater drum	0.037	0.007		0.123
Family Gobiidae				
Round goby	0.000	0.115	+	<0.0001

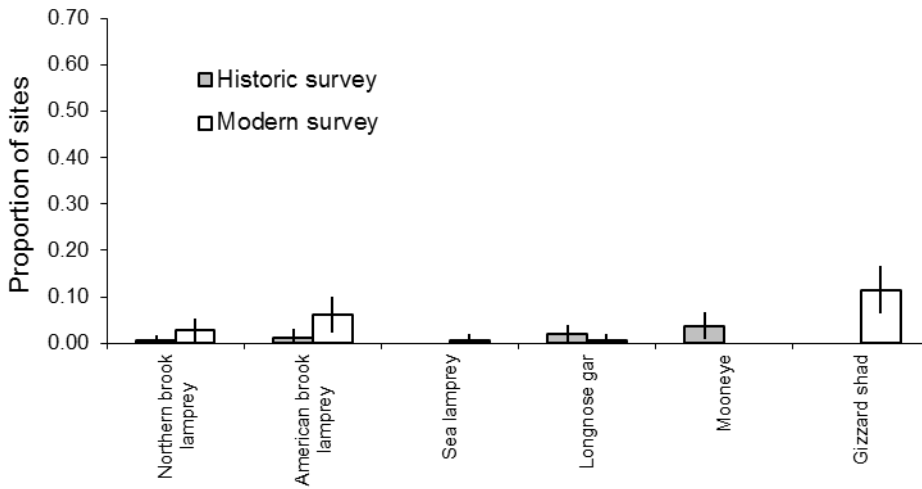


Figure A7-1. Catches (proportion of sites where detected) of fish species in the Lake Erie-Niagara River Watershed from historic and modern stream surveys. Families Petromyzontidae, Lepisosteidae, Hiodontidae, and Clupeidae. Error bars represent 95% confidence intervals.

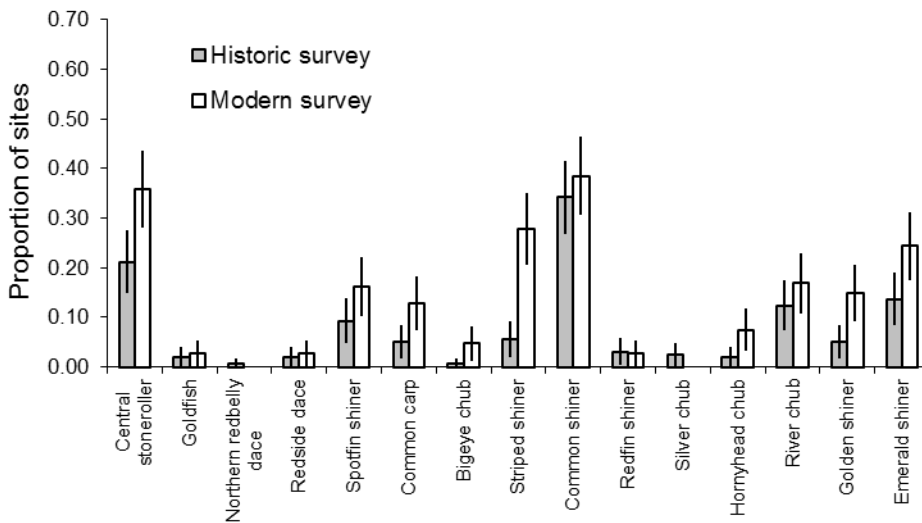


Figure A7-2. Catches (proportion of sites where detected) of fish species in the Lake Erie-Niagara River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

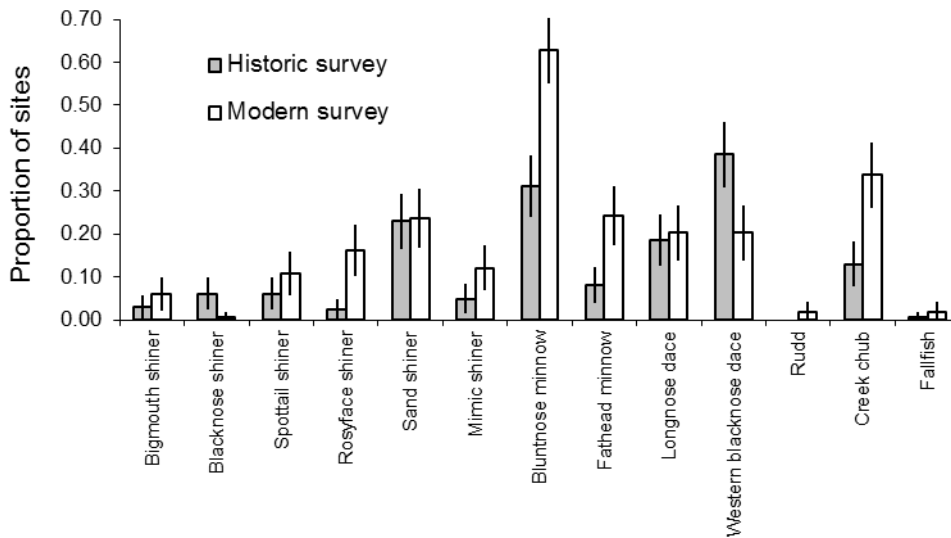


Figure A7-3. Catches (proportion of sites where detected) of fish species in the Lake Erie-Niagara River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

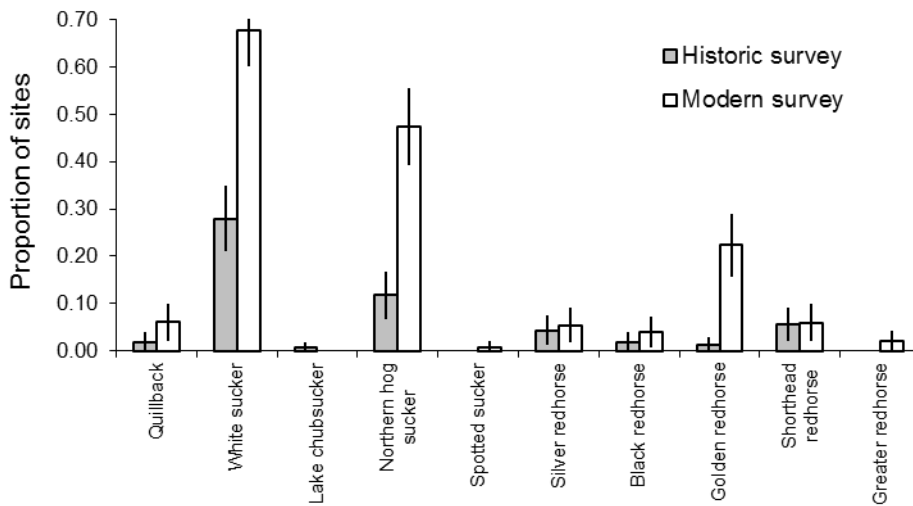


Figure A7-4. Catches (proportion of sites where detected) of fish species in the Lake Erie-Niagara River Watershed from historic and modern stream surveys. Family Catostomidae. Error bars represent 95% confidence intervals.

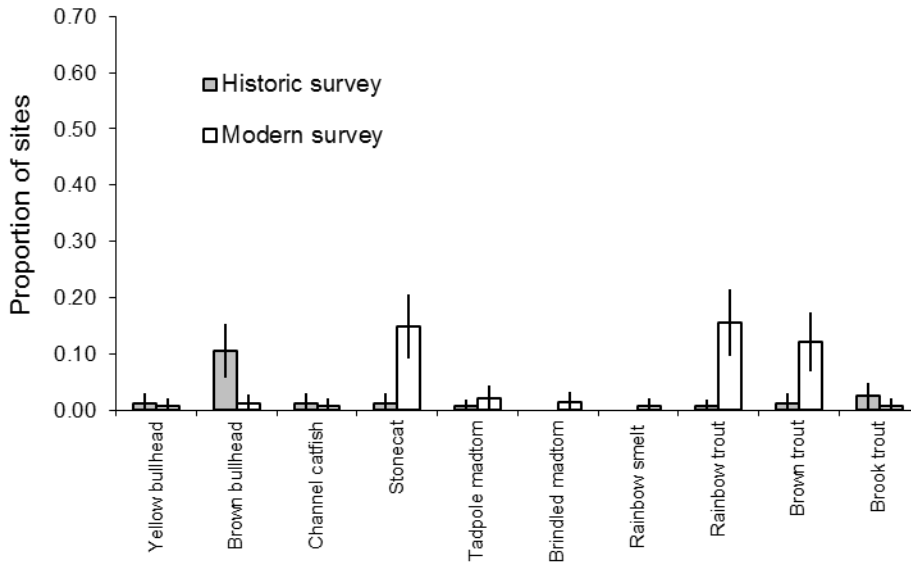


Figure A7-5. Catches (proportion of sites where detected) of fish species in the Lake Erie-Niagara River Watershed from historic and modern stream surveys. Families Ictaluridae, Osmeridae, and Salmonidae. Error bars represent 95% confidence intervals.

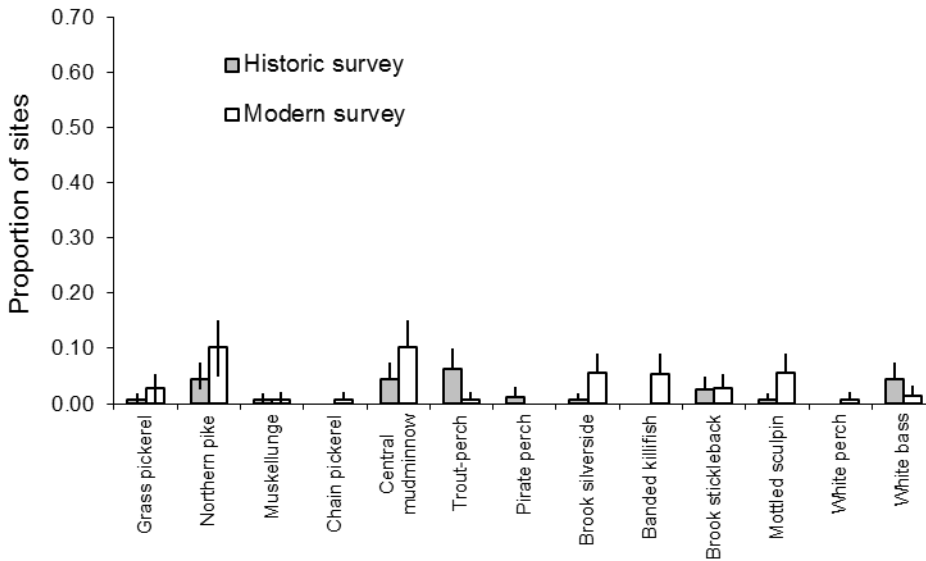


Figure A7-6. Catches (proportion of sites where detected) of fish species in the Lake Erie-Niagara River Watershed from historic and modern stream surveys. Families Esocidae, Percopsidae, Aphredoderidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

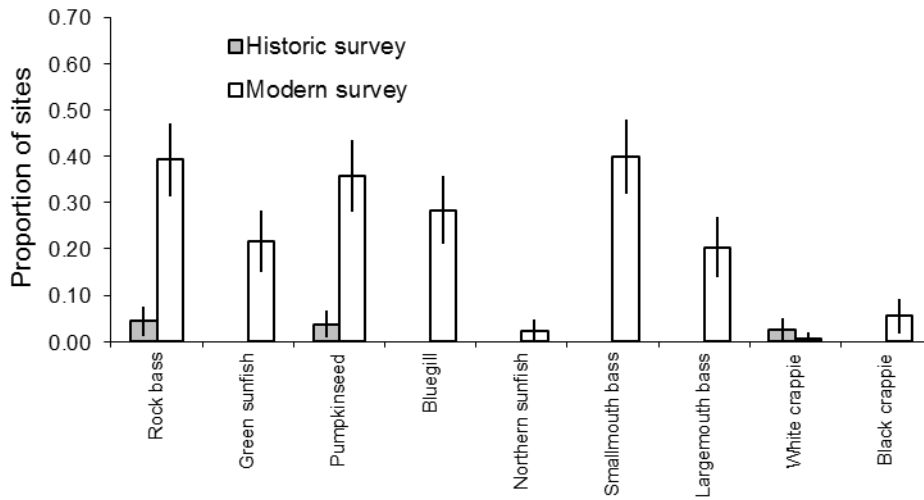


Figure A7-7. Catches (proportion of sites where detected) of fish species in the Lake Erie-Niagara River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

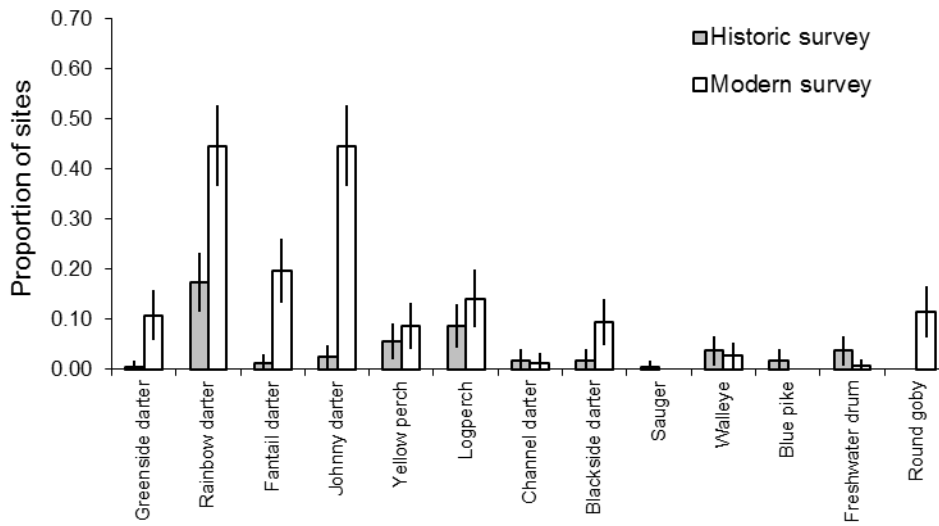


Figure A7-8. Catches (proportion of sites where detected) of fish species in the Lake Erie-Niagara River Watershed from historic and modern stream surveys. Families Percidae, Scianidae, and Gobiidae. Error bars represent 95% confidence intervals.

LAKE ONTARIO WATERSHED



Table A8. Catches (proportion of sites where detected) of fish species in the Lake Ontario watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 102, Bonferroni inequality correction for significance: $0.05/102 = 0.0005$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=364)	Proportion of sites – Modern (n=346)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
American brook lamprey	0.000	0.006		0.237
Sea lamprey	0.006	0.006		1.000
Family Lepisosteidae				
Longnose gar	0.000	0.029		0.0007
Family Amiidae				
Bowfin	0.006	0.087	+	<0.0001
Family Anguillidae				
American eel	0.008	0.020		0.213
Family Clupeidae				
Alewife	0.050	0.052		1.000
Gizzard shad	0.006	0.020		0.099
Family Cyprinidae				
Central stoneroller	0.132	0.124		0.823
Goldfish	0.006	0.009		0.679
Northern redbelly dace	0.006	0.020		0.099
Finescale dace	0.006	0.000		0.500
Redside dace	0.071	0.029		0.010
Lake chub	0.022	0.000		0.008
Spotfin shiner	0.041	0.078		0.040
Common carp	0.050	0.110		0.003
Cutlip minnow	0.168	0.119		0.069
Brassy minnow	0.017	0.000		0.031
Eastern silvery minnow	0.017	0.052		0.012
Bigeye chub	0.008	0.000		0.249
Striped shiner	0.124	0.069		0.016
Common shiner	0.316	0.208		0.001
Redfin shiner	0.014	0.012		1.000
Pearl dace	0.014	0.017		0.768
Hornyhead chub	0.096	0.032		0.0006
River chub	0.022	0.003		0.038
Golden shiner	0.137	0.292	+	<0.0001
Emerald shiner	0.058	0.061		0.875
Bridle shiner	0.077	0.058		0.370
Blackchin shiner	0.011	0.009		1.000
Blacknose shiner	0.071	0.020		0.001
Spottail shiner	0.052	0.078		0.173
Rosyface shiner	0.082	0.020	-	0.0002
Sand shiner	0.022	0.026		0.809
Mimic shiner	0.044	0.078		0.061
Bluntnose minnow	0.294	0.393		0.006
Fathead minnow	0.058	0.162	+	<0.0001
Eastern blacknose dace	0.165	0.145		0.469
Longnose dace	0.063	0.081		0.386
Western blacknose dace	0.033	0.032		1.000

Species	Proportion of sites – Historic (n=364)	Proportion of sites – Modern (n=346)	Direction of change	Fisher's exact test <i>p</i> -value
Rudd	0.000	0.003		0.487
Creek chub	0.360	0.260		0.005
Fallfish	0.132	0.029	-	<0.0001
Family Catostomidae				
Longnose sucker	0.003	0.000		1.000
White sucker	0.434	0.410		0.544
Eastern creek chubsucker	0.047	0.020		0.062
Lake chubsucker	0.017	0.000		0.031
Northern hog sucker	0.039	0.043		0.850
Silver redhorse	0.006	0.020		0.099
Shorthead redhorse	0.014	0.026		0.287
Golden redhorse	0.025	0.023		1.000
Greater redhorse	0.003	0.003		1.000
Family Ictaluridae				
Black bullhead	0.006	0.006		1.000
Yellow bullhead	0.008	0.015		0.495
Brown bullhead	0.187	0.286		0.002
Channel catfish	0.000	0.003		0.487
Stonecat	0.025	0.041		0.291
Tadpole madtom	0.063	0.078		0.466
Margined madtom	0.006	0.000		0.500
Brindled madtom	0.008	0.012		0.719
Family Osmeridae				
Rainbow smelt	0.000	0.009		0.115
Family Salmonidae				
Coho salmon	0.000	0.003		0.487
Rainbow trout	0.033	0.046		0.442
Chinook salmon	0.000	0.035	+	0.0002
Atlantic salmon	0.000	0.003		0.487
Brown trout	0.030	0.012		0.115
Brook trout	0.110	0.017	-	<0.0001
Family Esocidae				
Grass pickerel	0.091	0.049		0.039
Northern pike	0.085	0.188	+	<0.0001
Chain pickerel	0.014	0.043		0.022
Central mudminnow	0.041	0.168	+	<0.0001
Family Percopsidae				
Trout-perch	0.006	0.012		0.440
Family Aphredoderidae				
Pirate perch	0.017	0.020		0.784
Family Atherinopsidae				
Brook silverside	0.025	0.067		0.010
Family Fundulidae				
Banded killifish	0.050	0.153	+	<0.0001
Family Gasterosteidae				
Brook stickleback	0.060	0.069		0.650
Threespine stickleback	0.022	0.012		0.386
Family Cottidae				

Species	Proportion of sites – Historic (n=364)	Proportion of sites – Modern (n=346)	Direction of change	Fisher's exact test <i>p</i> -value
Mottled sculpin	0.008	0.003		0.624
Slimy sculpin	0.019	0.012		0.547
Family Moronidae				
White perch	0.000	0.015		0.027
White bass	0.011	0.000		0.124
Family Centrarchidae				
Rock bass	0.297	0.384		0.014
Green sunfish	0.000	0.093	+	<0.0001
Pumpkinseed	0.245	0.552	+	<0.0001
Bluegill	0.014	0.254	+	<0.0001
Northern sunfish	0.028	0.003		0.011
Smallmouth bass	0.203	0.214		0.782
Largemouth bass	0.115	0.341	+	<0.0001
White crappie	0.014	0.006		0.452
Black crappie	0.028	0.098	+	<0.0001
Family Percidae				
Greenside darter	0.028	0.020		0.627
Rainbow darter	0.041	0.043		1.000
Iowa darter	0.014	0.023		0.410
Fantail darter	0.272	0.165		0.0006
Johnny darter	0.236	0.139		0.001
Tessellated darter	0.019	0.298	+	<0.0001
Yellow perch	0.129	0.448	+	<0.0001
Logperch	0.082	0.104		0.366
Blackside darter	0.025	0.017		0.605
Walleye	0.006	0.006		1.000
Blue pike	0.003	0.000		1.000
Family Scianidae				
Freshwater drum	0.003	0.003		1.000
Family Gobiidae				
Round goby	0.000	0.035	+	0.0002

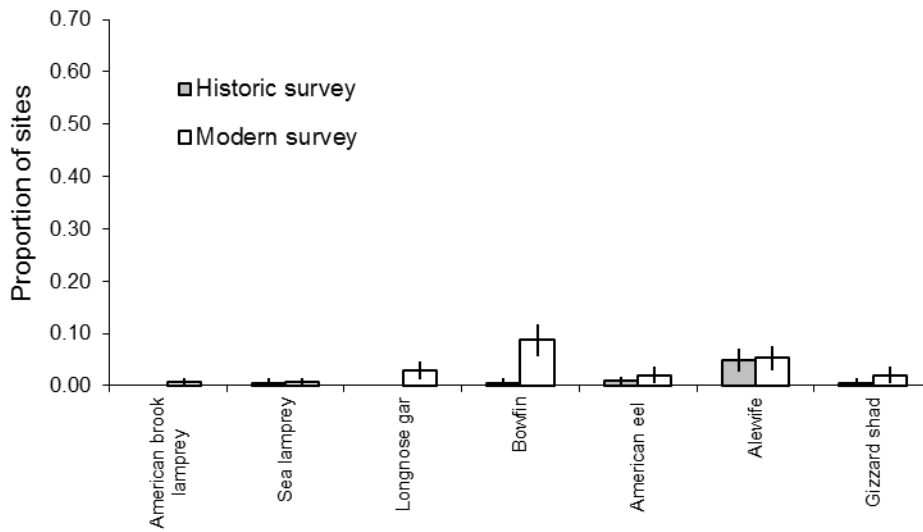


Figure A8-1. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Families Petromyzontidae, Lepisosteidae, Amiidae, Anguillidae, and Clupeidae. Error bars represent 95% confidence intervals.

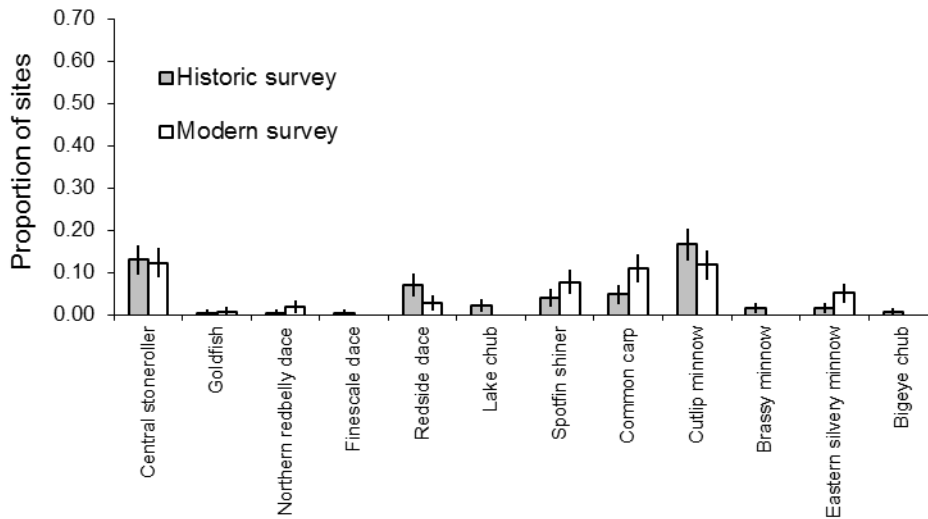


Figure A8-2. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

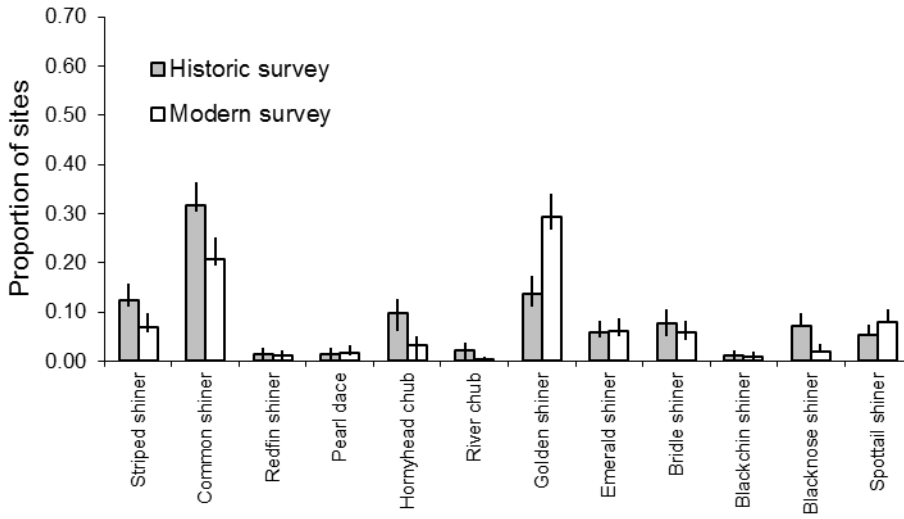


Figure A8-3. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

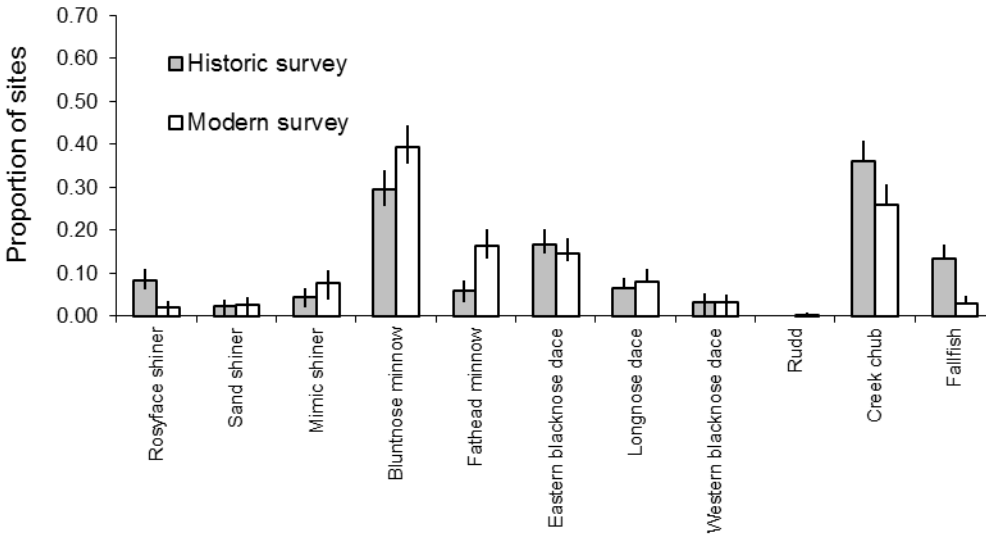


Figure A8-4. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

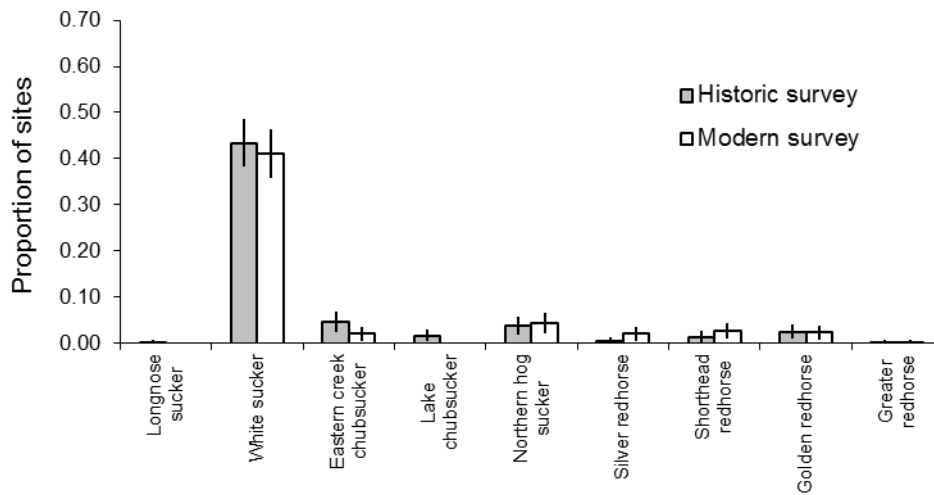


Figure A8-5. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Family Catastomidae. Error bars represent 95% confidence intervals.

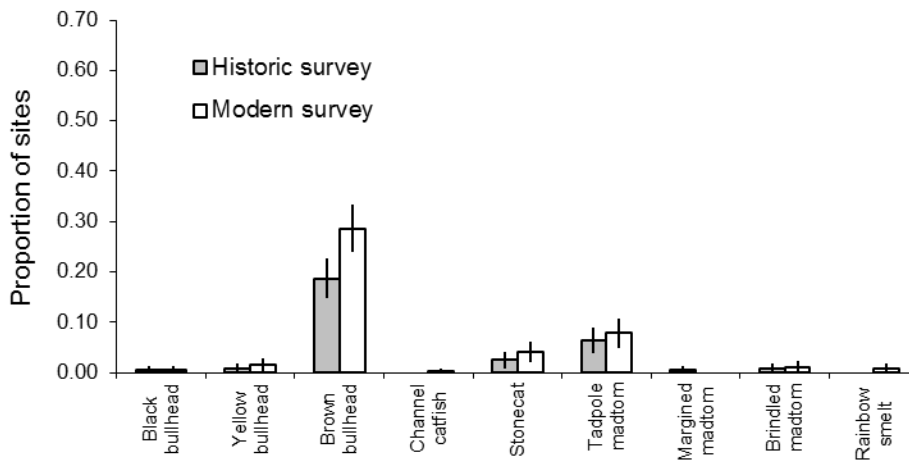


Figure A8-6. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Families Ictaluridae and Osmeridae. Error bars represent 95% confidence intervals.

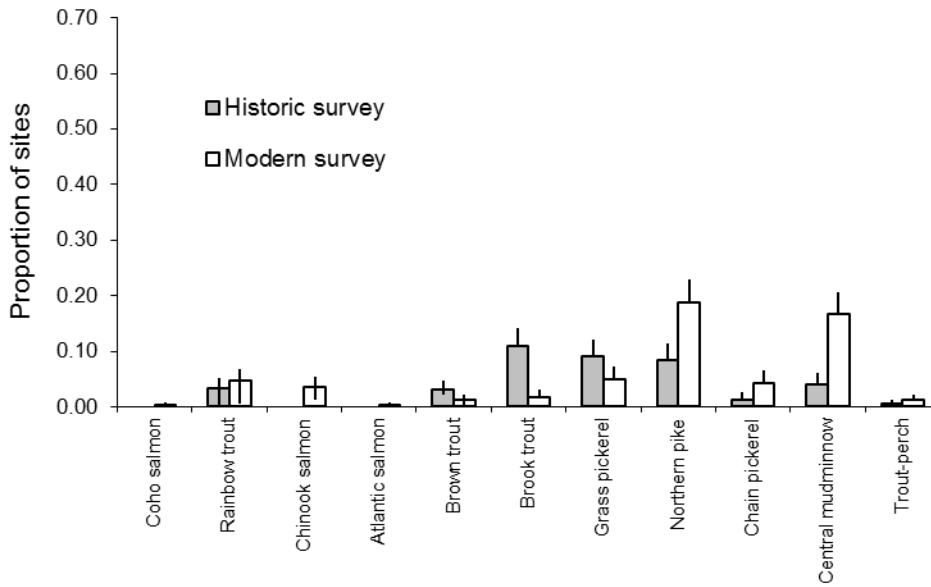


Figure A8-7. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Families Salmonidae, Esocidae, and Percopsidae. Error bars represent 95% confidence intervals.

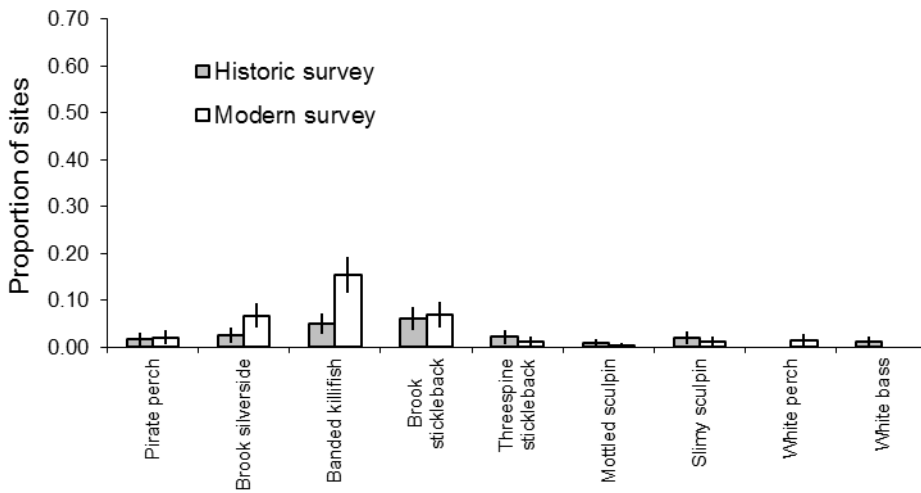


Figure A8-8. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Families Aphredoderidae, Atherinopsidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

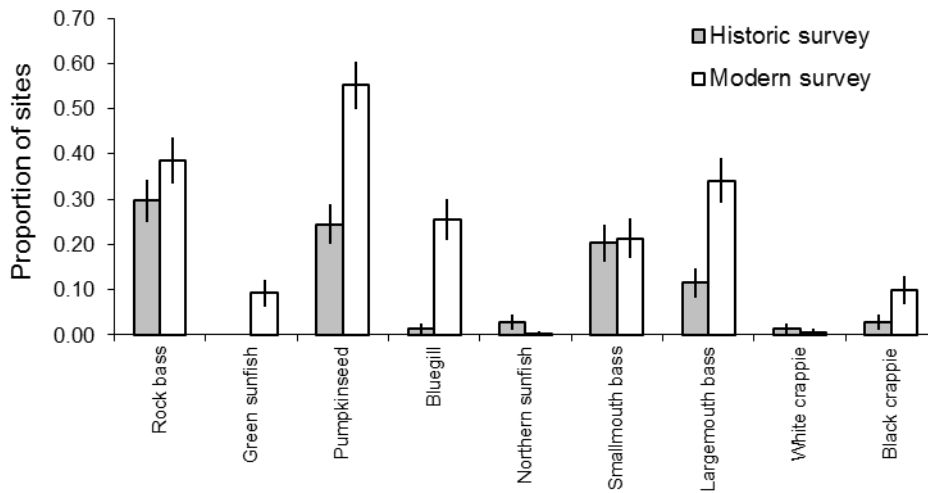


Figure A8-9. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

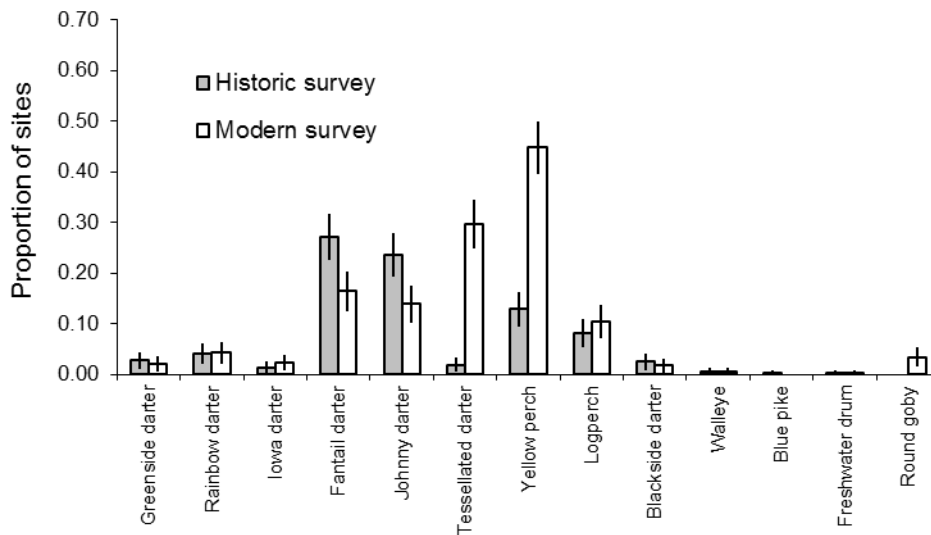


Figure A8-10. Catches (proportion of sites where detected) of fish species in the Lake Ontario Watershed from historic and modern stream surveys. Families Percidae, Scianidae, and Gobiidae. Error bars represent 95% confidence intervals.

LONG ISLAND WATERSHED



Table A9. Catches (proportion of sites where detected) of fish species in the Long Island watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 51, Bonferroni inequality correction for significance: $0.05/51 = 0.001$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=133)	Proportion of sites – Modern (n=94)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
American brook lamprey	0.000	0.064		0.005
Sea lamprey	0.015	0.011		1.000
Family Anguillidae				
American eel	0.549	0.447		0.140
Family Clupeidae				
Blueback herring	0.008	0.000		1.000
Alewife	0.075	0.000		0.006
American shad	0.015	0.000		0.513
Gizzard shad	0.008	0.043		0.163
Family Cyprinidae				
Goldfish	0.015	0.043		0.235
Common carp	0.008	0.043		0.163
Common shiner	0.030	0.000		0.144
Golden shiner	0.105	0.234		0.010
Bridle shiner	0.008	0.000		1.000
Fathead minnow	0.008	0.011		1.000
Eastern blacknose dace	0.023	0.075		0.097
Longnose dace	0.000	0.011		0.414
Creek chub	0.023	0.032		0.694
Fallfish	0.000	0.011		0.414
Family Catostomidae				
White sucker	0.053	0.075		0.580
Creek chubsucker	0.023	0.053		0.281
Family Ictaluridae				
Brown bullhead	0.105	0.351	+	<0.0001
Channel catfish	0.000	0.011		0.414
Family Osmeridae				
Rainbow smelt	0.008	0.000		1.000
Family Salmonidae				
Rainbow trout	0.030	0.032		1.000
Brown trout	0.060	0.149		0.039
Brook trout	0.128	0.234		0.049
Family Esocidae				
Redfin pickerel	0.045	0.287	+	<0.0001
Chain pickerel	0.075	0.170		0.034
Eastern mudminnow	0.165	0.213		0.389
Family Aphredoderidae				
Pirate perch	0.105	0.170		0.168

Species	Proportion of sites – Historic (n=133)	Proportion of sites – Modern (n=94)	Direction of change	Fisher's exact test <i>p</i> -value
Family Gadidae				
Atlantic tomcod	0.045	0.000		0.043
Family Fundulidae				
Banded killifish	0.128	0.149		0.697
Mummichog	0.346	0.043	-	<0.0001
Family Poeciliidae				
Western mosquitofish	0.000	0.032		0.070
Family Gasterosteidae				
Fourspine stickleback	0.158	0.138		0.711
Threespine stickleback	0.008	0.011		1.000
Ninespine stickleback	0.083	0.064		0.799
Family Moronidae				
White perch	0.015	0.064		0.069
Striped bass	0.008	0.032		0.309
Family Centrarchidae				
Rock bass	0.000	0.021		0.170
Banded sunfish	0.008	0.021		0.571
Redbreast sunfish	0.030	0.085		0.078
Green sunfish	0.000	0.011		0.414
Pumpkinseed	0.158	0.532	+	<0.0001
Bluegill	0.023	0.309	+	<0.0001
Smallmouth bass	0.023	0.011		0.644
Largemouth bass	0.068	0.436	+	<0.0001
Black crappie	0.000	0.043		0.028
Family Percidae				
Swamp darter	0.008	0.021		0.571
Tessellated darter	0.075	0.372	+	<0.0001
Yellow perch	0.008	0.096		0.002
Walleye	0.000	0.011		0.414

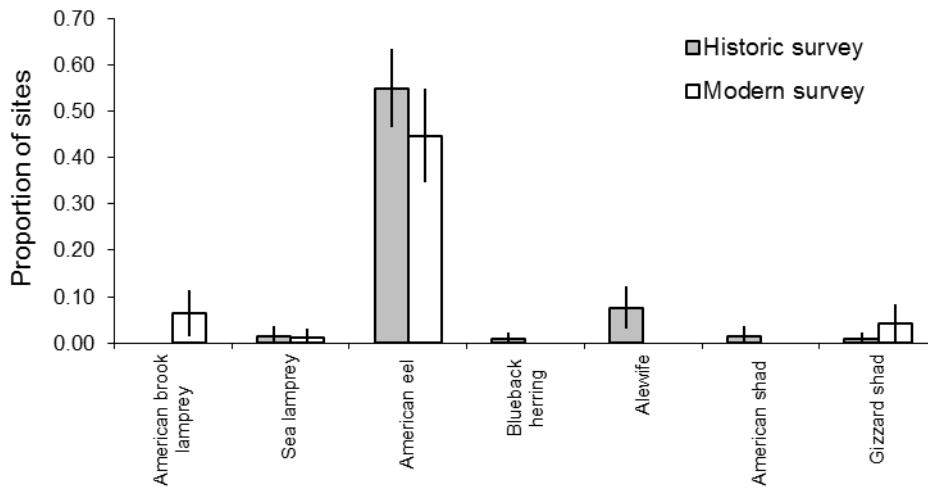


Figure A9-1. Catches (proportion of sites where detected) of fish species in the Long Island Watershed from historic and modern stream surveys. Families Petromyzontidae, Anguillidae, and Clupeidae. Error bars represent 95% confidence intervals.

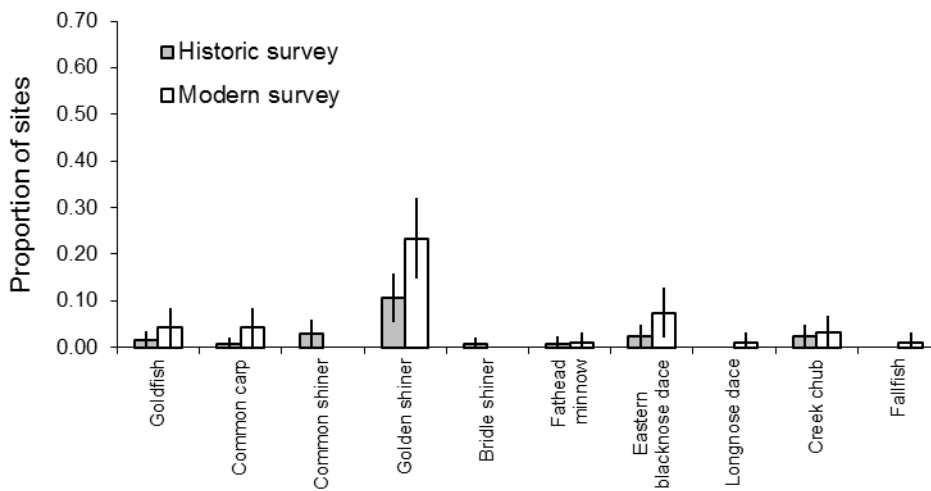


Figure A9-2. Catches (proportion of sites where detected) of fish species in the Long Island Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

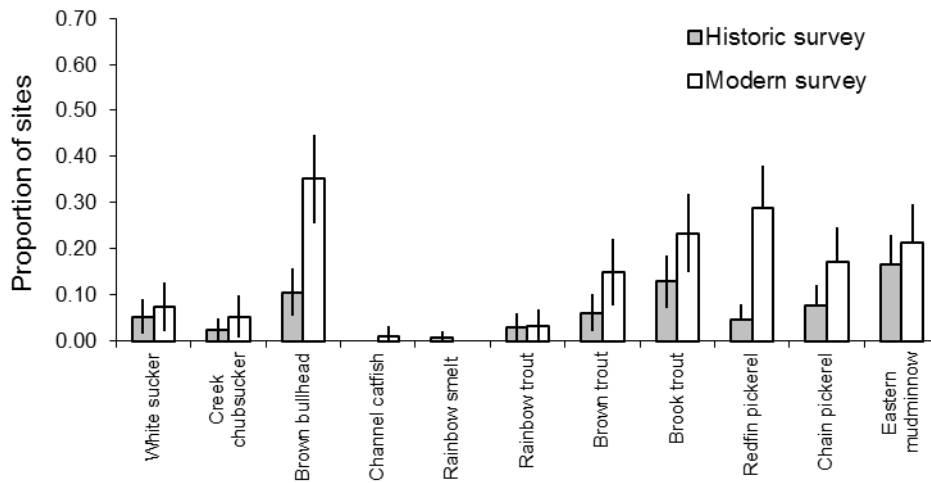


Figure A9-3. Catches (proportion of sites where detected) of fish species in the Long Island Watershed from historic and modern stream surveys. Families Catostomidae, Ictaluridae, Osmeridae, Salmonidae, and Esocidae. Error bars represent 95% confidence intervals.

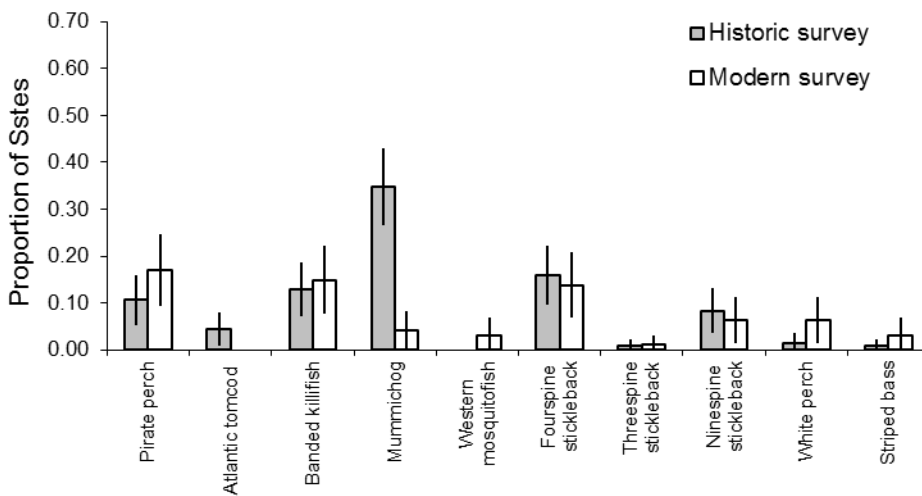


Figure A9-4. Catches (proportion of sites where detected) of fish species in the Long Island Watershed from historic and modern stream surveys. Families Aphredoderidae, Gadidae, Fundulidae, Poeciliidae, Gasterosteidae, and Moronidae. Error bars represent 95% confidence intervals.

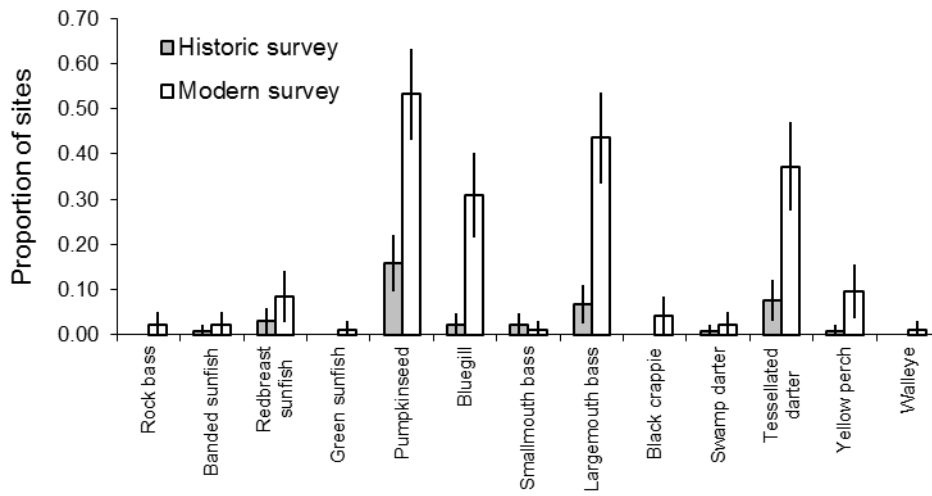


Figure A9-5. Catches (proportion of sites where detected) of fish species in the Long Island Watershed from historic and modern stream surveys. Families Centrarchidae and Percidae. Error bars represent 95% confidence intervals.

LOWER HUDSON RIVER WATERSHED



Table A10. Catches (proportion of sites where detected) of fish species in the Lower Hudson River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 76, Bonferroni inequality correction for significance: $0.05/76 = 0.0007$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=463)	Proportion of sites – Modern (n=224)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
Sea lamprey	0.007	0.005		1.000
Family Anguillidae				
American eel	0.136	0.304	+	<0.0001
Family Clupeidae				
Blueback herring	0.013	0.018		0.736
Alewife	0.013	0.018		0.736
American shad	0.007	0.000		0.555
Family Cyprinidae				
Goldfish	0.022	0.009		0.355
Northern redbelly dace	0.002	0.005		0.546
Lake chub	0.002	0.000		1.000
Satinfin shiner	0.063	0.036		0.154
Spotfin shiner	0.082	0.076		0.881
Common carp	0.015	0.040		0.057
Cutlip minnow	0.324	0.366		0.302
Brassy minnow	0.007	0.005		1.000
Eastern silvery minnow	0.037	0.005		0.010
Common shiner	0.534	0.335	-	<0.0001
Pearl dace	0.004	0.009		0.600
Golden shiner	0.294	0.196		0.007
Comely shiner	0.024	0.005		0.116
Emerald shiner	0.000	0.005		0.326
Bridle shiner	0.082	0.000	-	<0.0001
Spottail shiner	0.093	0.134		0.113
Rosyface shiner	0.013	0.009		1.000
Sand shiner	0.000	0.013		0.034
Bluntnose minnow	0.011	0.102	+	<0.0001
Fathead minnow	0.002	0.085	+	<0.0001
Eastern blacknose dace	0.467	0.531		0.122
Longnose dace	0.225	0.424	+	<0.0001
Bitterling	0.009	0.000		0.310
Rudd	0.009	0.018		0.285
Creek chub	0.328	0.446		0.003
Fallfish	0.289	0.152	-	<0.0001
Family Catostomidae				
Longnose sucker	0.015	0.027		0.370
White sucker	0.648	0.763		0.002
Eastern creek chubsucker	0.123	0.085		0.154
Northern hog sucker	0.007	0.000		0.555
Family Cobitidae				
Oriental weatherfish	0.000	0.009		0.106
Family Ictaluridae				
White catfish	0.007	0.000		0.555

Species	Proportion of sites – Historic (n=463)	Proportion of sites – Modern (n=224)	Direction of change	Fisher's exact test <i>p</i> -value
Yellow bullhead	0.019	0.201	+	<0.0001
Brown bullhead	0.166	0.152		0.660
Stonecat	0.002	0.000		1.000
Tadpole madtom	0.015	0.005		0.449
Margined madtom	0.015	0.013		1.000
Family Osmeridae				
Rainbow smelt	0.002	0.000		1.000
Family Salmonidae				
Rainbow trout	0.035	0.045		0.527
Brown trout	0.190	0.299		0.002
Brook trout	0.089	0.090		0.887
Family Esocidae				
Redfin pickerel	0.026	0.228	+	<0.0001
Northern pike	0.000	0.009		0.106
Chain pickerel	0.108	0.112		0.897
Central mudminnow	0.000	0.018		0.011
Eastern mudminnow	0.019	0.022		0.779
Family Percopsidae				
Trout-perch	0.015	0.005		0.449
Family Gadidae				
Atlantic tomcod	0.000	0.005		0.326
Family Fundulidae				
Banded killifish	0.108	0.067		0.096
Mummichog	0.026	0.058		0.049
Family Gasterosteidae				
Fourspine stickleback	0.030	0.018		0.449
Brook stickleback	0.007	0.009		0.663
Family Cottidae				
Slimy sculpin	0.050	0.085		0.089
Family Moronidae				
White perch	0.037	0.031		0.827
Striped bass	0.004	0.018		0.092
Family Centrarchidae				
Rock bass	0.166	0.263		0.004
Bluespotted sunfish	0.007	0.005		1.000
Redbreast sunfish	0.298	0.281		0.721
Green sunfish	0.004	0.112	+	<0.0001
Pumpkinseed	0.365	0.478		0.006
Warmouth	0.002	0.009		0.249
Bluegill	0.043	0.455	+	<0.0001
Smallmouth bass	0.169	0.183		0.667
Largemouth bass	0.164	0.402	+	<0.0001
White crappie	0.004	0.005		1.000
Black crappie	0.043	0.054		0.565
Family Percidae				
Tessellated darter	0.343	0.594	+	<0.0001
Yellow perch	0.121	0.125		0.901
Logperch	0.019	0.054		0.019

Species	Proportion of sites – Historic (n=463)	Proportion of sites – Modern (n=224)	Direction of change	Fisher's exact test <i>p</i> -value
Shield darter	0.015	0.022		0.54
Walleye	0.007	0.000		0.555

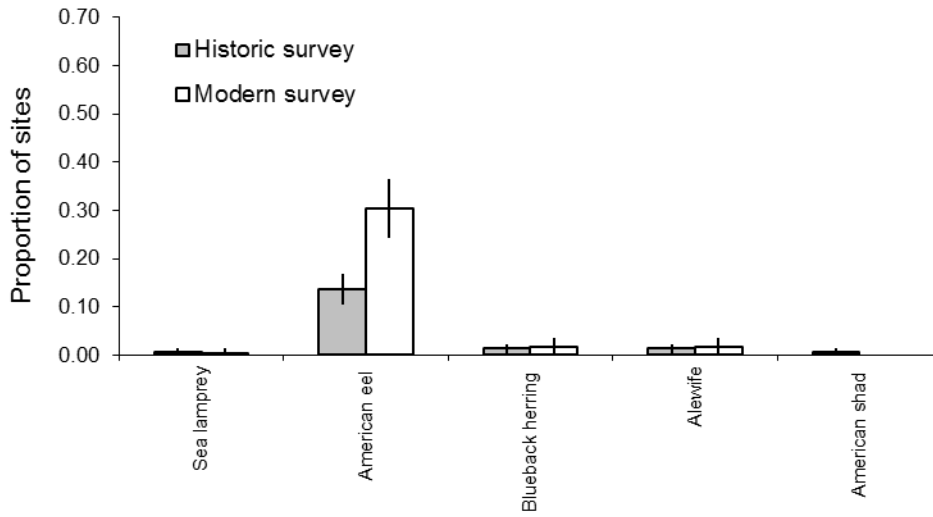


Figure A10-1. Catches (proportion of sites where detected) of fish species in the Lower Hudson River Watershed from historic and modern stream surveys. Families Petromyzontidae, Anguillidae, and Clupeidae. Error bars represent 95% confidence intervals.

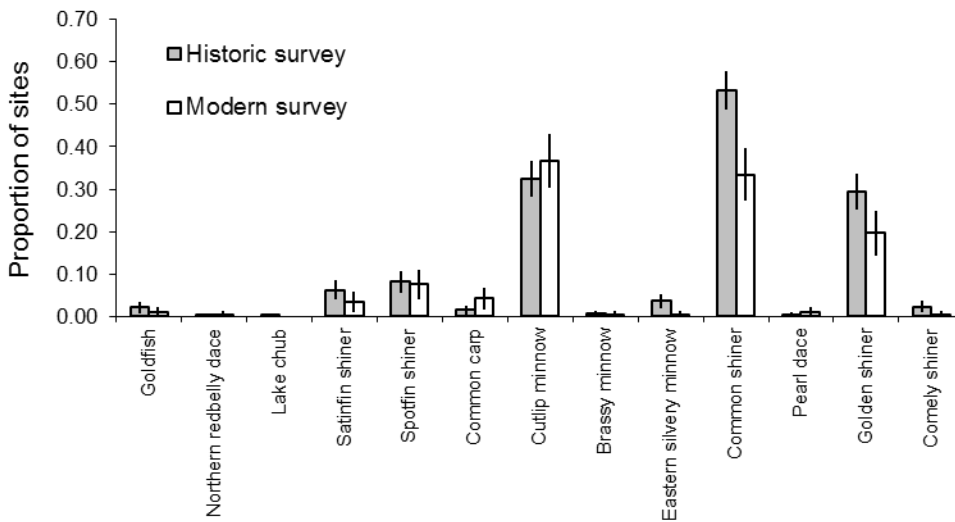


Figure A10-2. Catches (proportion of sites where detected) of fish species in the Lower Hudson River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

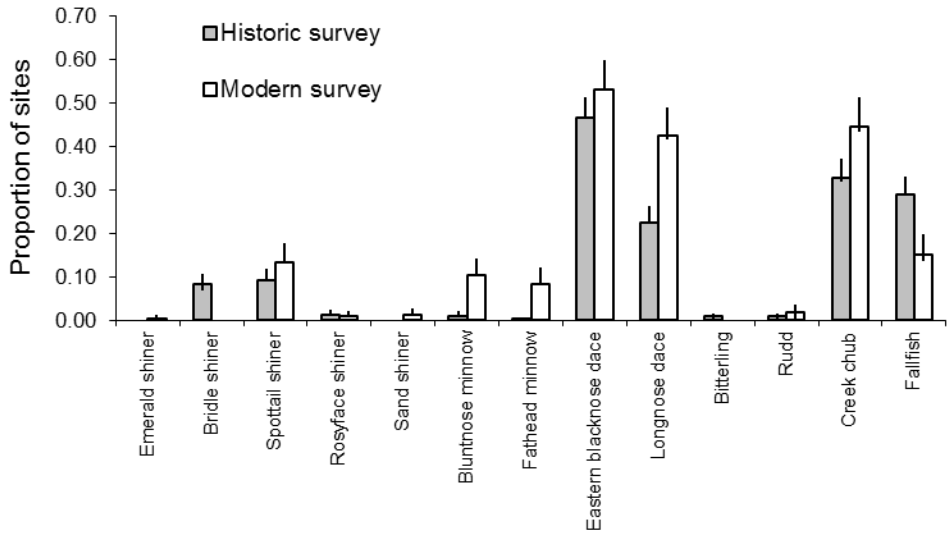


Figure A10-3. Catches (proportion of sites where detected) of fish species in the Lower Hudson River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

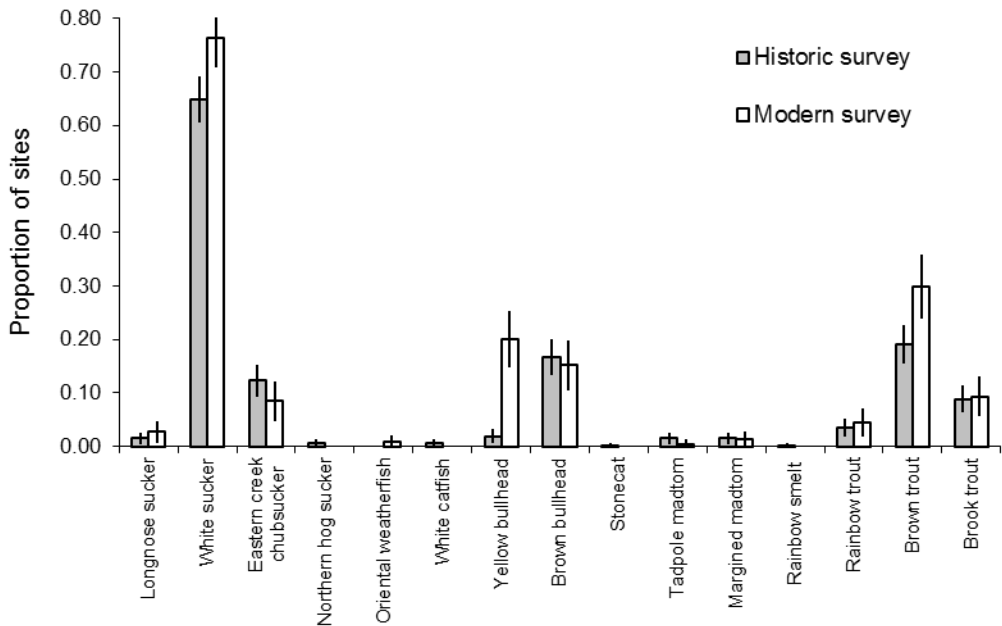


Figure A10-4. Catches (proportion of sites where detected) of fish species in the Lower Hudson River Watershed from historic and modern stream surveys. Families Catastomidae, Cobitidae, Ictaluridae, Osmeridae, and Salmonidae. Error bars represent 95% confidence intervals.

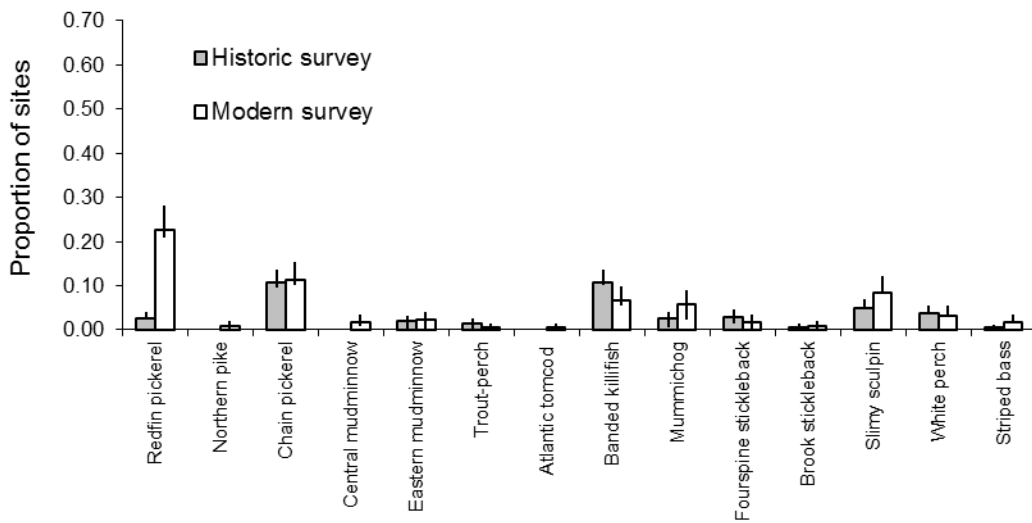


Figure A10-5. Catches (proportion of sites where detected) of fish species in the Lower Hudson River Watershed from historic and modern stream surveys. Families Esocidae, Percopsidae, Gadidae, Atherinopsidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

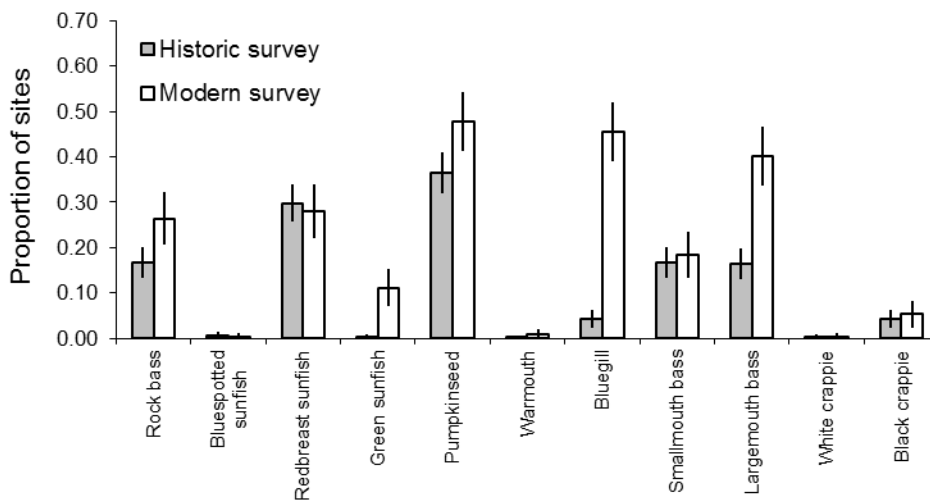


Figure A10-6. Catches (proportion of sites where detected) of fish species in the Lower Hudson River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

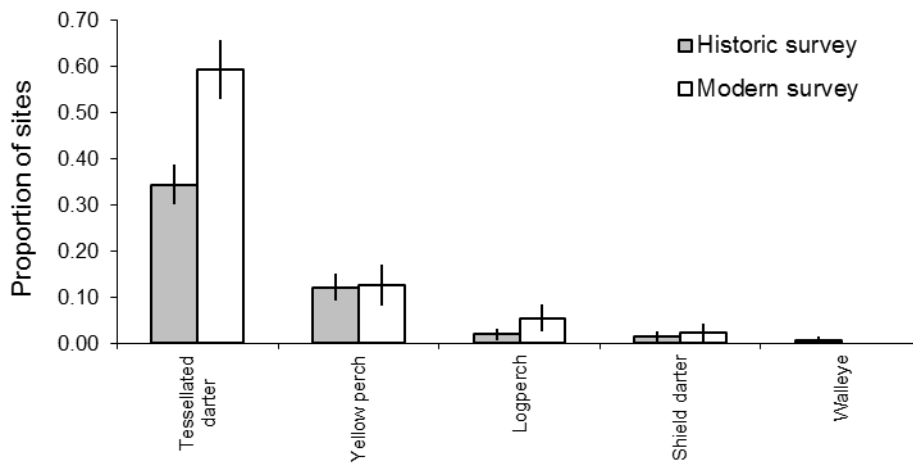


Figure A10-7. Catches (proportion of sites where detected) of fish species in the Lower Hudson River Watershed from historic and modern stream surveys. Family Percidae. Error bars represent 95% confidence intervals.

MOHAWK RIVER WATERSHED



Table A11. Catches (proportion of sites where detected) of fish species in the Mohawk River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 75, Bonferroni inequality correction for significance: $0.05/75 = 0.0007$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=358)	Proportion of sites – Modern (n=178)	Direction of change	Fisher's exact test <i>p</i> -value
Family Anguillidae				
American eel	0.003	0.000		1.000
Family Clupeidae				
Blueback herring	0.034	0.011		0.158
Alewife	0.028	0.000		0.035
Gizzard shad	0.000	0.011		0.110
Family Cyprinidae				
Central stoneroller	0.000	0.320	+	<0.0001
Goldfish	0.008	0.000		0.554
Northern redbelly dace	0.008	0.011		0.669
Redside dace	0.062	0.034		0.218
Lake chub	0.006	0.006		1.000
Satinfin shiner	0.059	0.028		0.139
Spotfin shiner	0.045	0.169	+	<0.0001
Common carp	0.134	0.062		0.012
Cutlip minnow	0.173	0.287		0.003
Brassy minnow	0.003	0.000		1.000
Eastern silvery minnow	0.022	0.017		1.000
Common shiner	0.497	0.478		0.714
Pearl dace	0.003	0.017		0.109
Hornyhead chub	0.022	0.017		1.000
Golden shiner	0.243	0.107	-	0.0001
Comely shiner	0.003	0.000		1.000
Emerald shiner	0.036	0.045		0.641
Bridle shiner	0.006	0.000		1.000
Blacknose shiner	0.008	0.000		0.554
Spottail shiner	0.140	0.056		0.003
Rosyface shiner	0.070	0.118		0.072
Bluntnose minnow	0.388	0.303		0.057
Fathead minnow	0.034	0.258	+	<0.0001
Eastern blacknose dace	0.399	0.534		0.004
Longnose dace	0.187	0.433	+	<0.0001
Creek chub	0.436	0.511		0.118
Fallfish	0.277	0.247		0.534
Family Catostomidae				
Longnose sucker	0.034	0.011		0.158
White sucker	0.668	0.635		0.499
Eastern creek chubsucker	0.008	0.006		1.000
Northern hog sucker	0.134	0.118		0.682
Shorthead redhorse	0.048	0.023		0.236
Family Ictaluridae				
Yellow bullhead	0.003	0.011		0.257
Brown bullhead	0.204	0.146		0.124
Stonecat	0.022	0.034		0.566
Tadpole madtom	0.006	0.000		1.000

Species	Proportion of sites – Historic (n=358)	Proportion of sites – Modern (n=178)	Direction of change	Fisher's exact test p-value
Margined madtom	0.008	0.124	+	<0.0001
Brindled madtom	0.000	0.006		0.332
Family Salmonidae				
Lake whitefish	0.003	0.000		1.000
Rainbow trout	0.045	0.028		0.480
Brown trout	0.059	0.140		0.003
Brook trout	0.095	0.062		0.247
Family Esocidae				
Redfin pickerel	0.006	0.011		0.603
Northern pike	0.000	0.028		0.004
Chain pickerel	0.014	0.034		0.192
Tiger muskellunge	0.000	0.017		0.036
Central mudminnow	0.006	0.023		0.098
Family Percopsidae				
Trout-perch	0.014	0.017		0.725
Family Atherinopsidae				
Brook silverside	0.003	0.028		0.017
Family Fundulidae				
Banded killifish	0.020	0.023		0.759
Family Gasterosteidae				
Brook stickleback	0.034	0.107		0.001
Family Cottidae				
Slimy sculpin	0.017	0.090	+	0.0001
Family Moronidae				
White perch	0.014	0.000		0.176
White bass	0.000	0.006		0.332
Striped bass	0.003	0.000		1.000
Family Centrarchidae				
Rock bass	0.176	0.152		0.540
Redbreast sunfish	0.008	0.006		1.000
Green sunfish	0.000	0.039	+	0.0004
Pumpkinseed	0.249	0.320		0.081
Bluegill	0.000	0.129	+	<0.0001
Smallmouth bass	0.279	0.309		0.481
Largemouth bass	0.176	0.174		1.000
White crappie	0.022	0.000		0.057
Black crappie	0.036	0.011		0.161
Family Percidae				
Greenside darter	0.034	0.135	+	<0.0001
Rainbow darter	0.000	0.006		0.332
Fantail darter	0.025	0.281	+	<0.0001
Tessellated darter	0.369	0.506		0.003
Yellow perch	0.240	0.101	-	0.0001
Logperch	0.103	0.157		0.091
Walleye	0.106	0.011	-	<0.0001

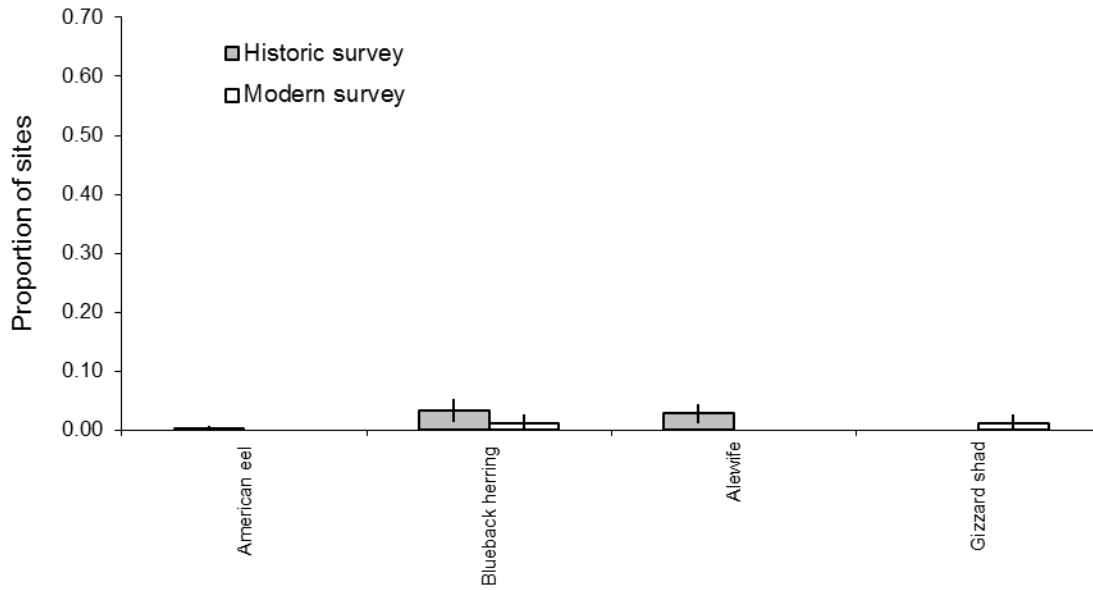


Figure A11-1. Catches (proportion of sites where detected) of fish species in the Mohawk River Watershed from historic and modern stream surveys. Families Anguillidae and Clupeidae. Error bars represent 95% confidence intervals.

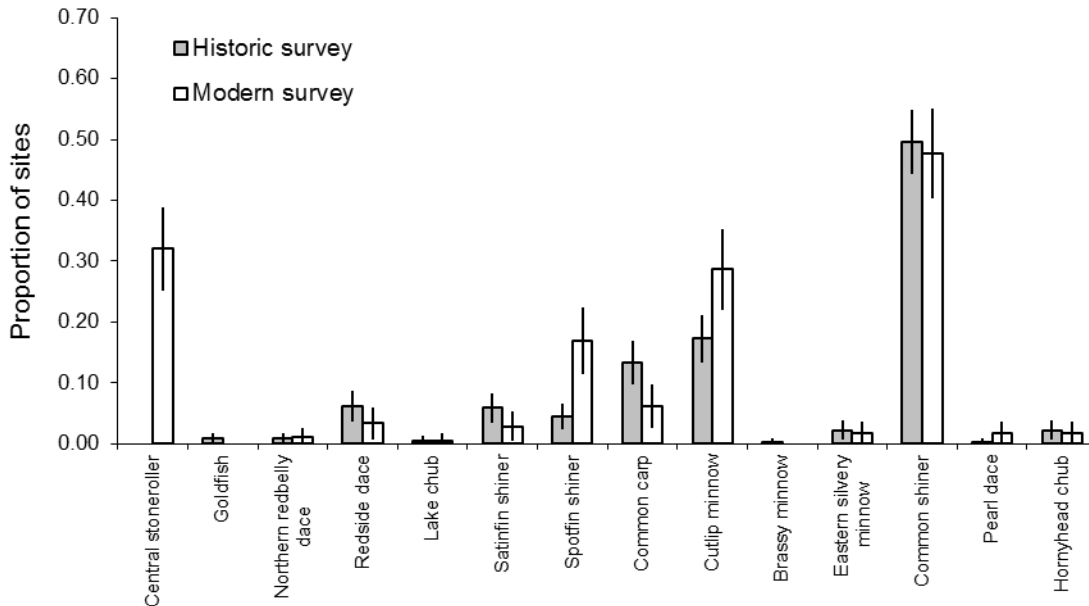


Figure A11-2. Catches (proportion of sites where detected) of fish species in the Mohawk River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

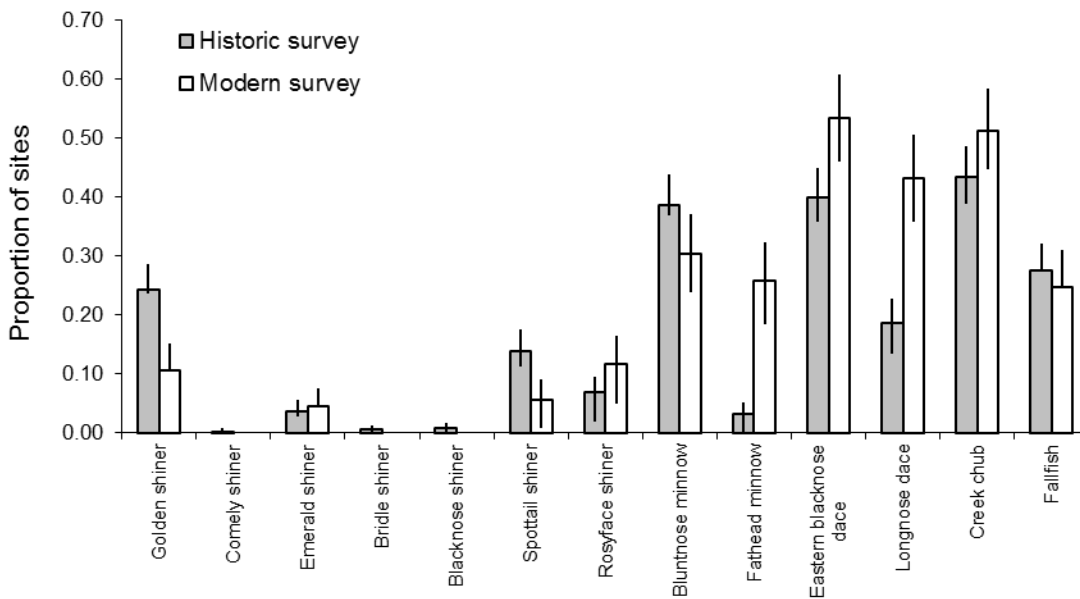


Figure A11-3. Catches (proportion of sites where detected) of fish species in the Mohawk River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

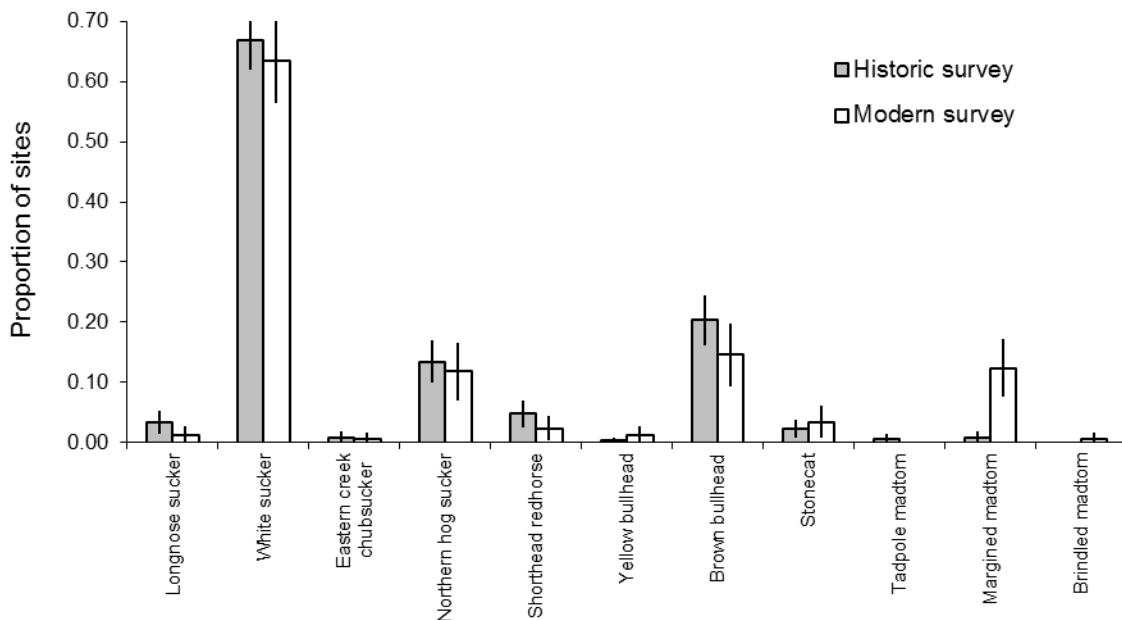


Figure A11-4. Catches (proportion of sites where detected) of fish species in the Mohawk River Watershed from historic and modern stream surveys. Families Catastomidae and Ictaluridae. Error bars represent 95% confidence intervals.

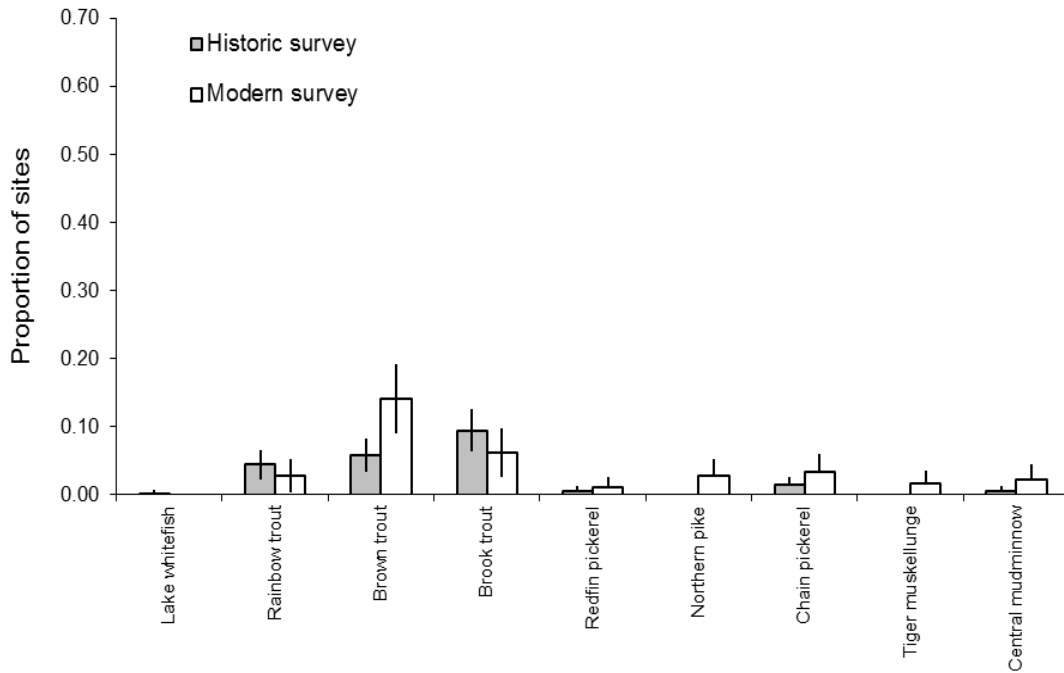


Figure A11-5. Catches (proportion of sites where detected) of fish species in the Mohawk River Watershed from historic and modern stream surveys. Families Salmonidae and Esocidae. Error bars represent 95% confidence intervals.

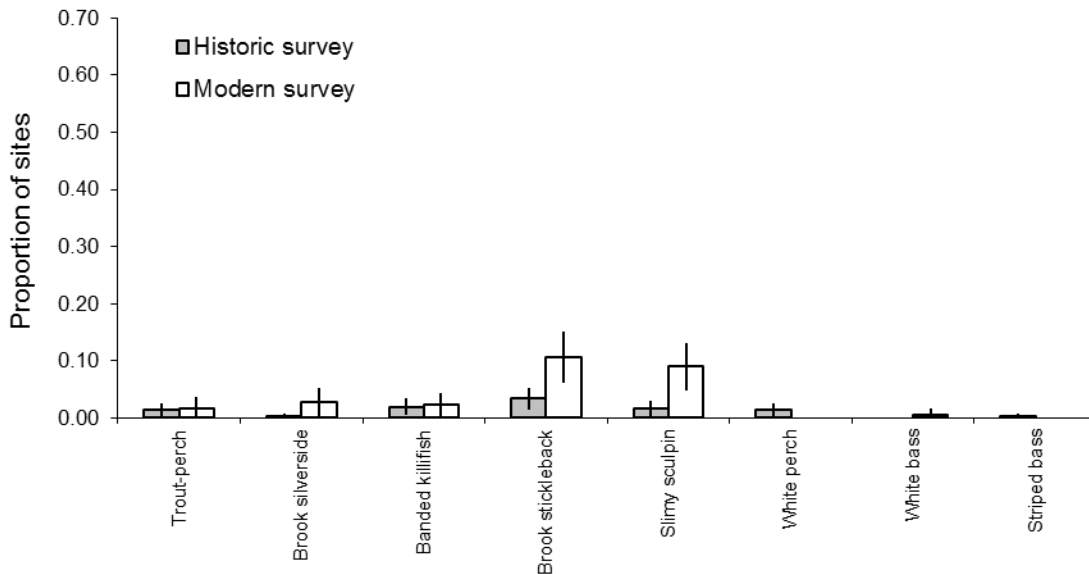


Figure A11-6. Catches (proportion of sites where detected) of fish species in the Mohawk River Watershed from historic and modern stream surveys. Families Percopsidae, Atherinopsidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

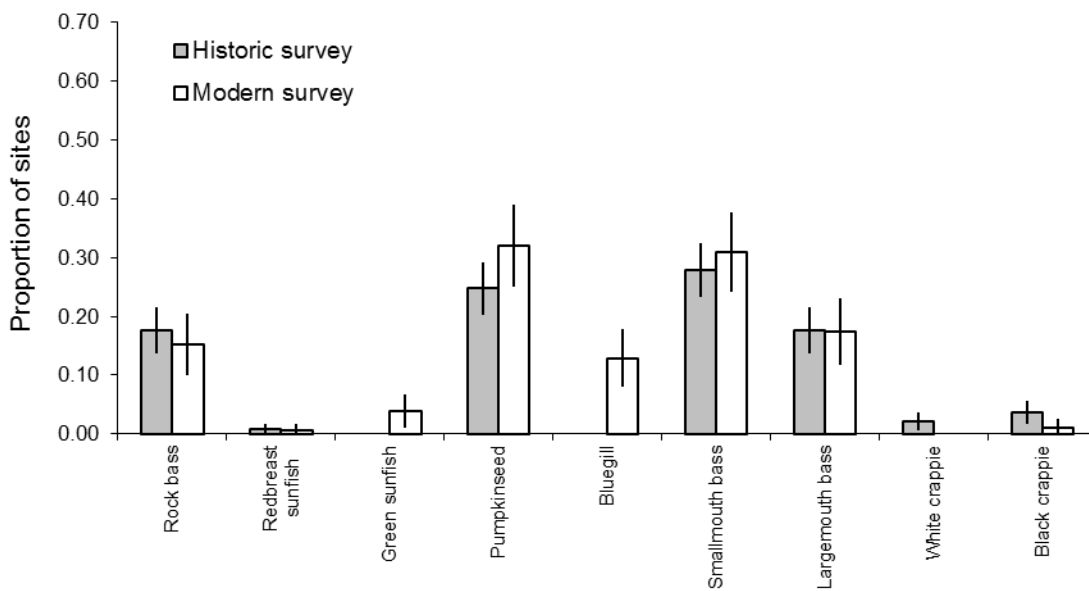


Figure A11-7. Catches (proportion of sites where detected) of fish species in the Mohawk River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

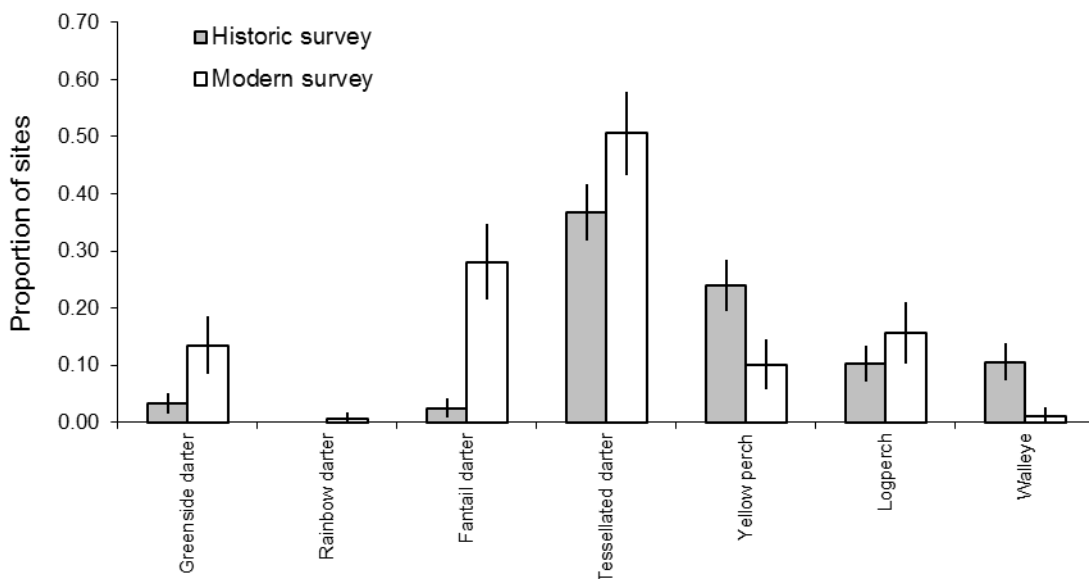


Figure A11-8. Catches (proportion of sites where detected) of fish species in the Mohawk River Watershed from historic and modern stream surveys. Family Percidae. Error bars represent 95% confidence intervals.

NEWARK BAY WATERSHED



Table A12. Catches (proportion of sites where detected) of fish species in the Newark Bay watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 40, Bonferroni inequality correction for significance: $0.05/40 = 0.001$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=36)	Proportion of sites – Modern (n=29)	Direction of change	Fisher's exact test <i>p</i> -value
Family Anguillidae				
American eel	0.056	0.035		1.000
Family Cyprinidae				
Goldfish	0.028	0.000		1.000
Common carp	0.028	0.172		0.081
Cutlip minnow	0.250	0.103		0.200
Common shiner	0.444	0.172		0.032
Golden shiner	0.361	0.103		0.021
Comely shiner	0.028	0.000		1.000
Bridle shiner	0.139	0.000		0.060
Ironcolor shiner	0.083	0.000		0.247
Eastern blacknose dace	0.361	0.379		1.000
Longnose dace	0.056	0.138		0.395
Rudd	0.000	0.035		0.446
Creek chub	0.083	0.241		0.096
Fallfish	0.472	0.138		0.007
Family Catostomidae				
White sucker	0.528	0.483		0.805
Creek chubsucker	0.333	0.035		0.004
Family Ictaluridae				
Yellow bullhead	0.028	0.207		0.039
Brown bullhead	0.222	0.103		0.320
Tadpole madtom	0.111	0.000		0.122
Family Salmonidae				
Rainbow trout	0.028	0.035		1.000
Brown trout	0.139	0.069		0.447
Brook trout	0.167	0.035		0.120
Family Esocidae				
Redfin pickerel	0.361	0.345		1.000
Chain pickerel	0.222	0.069		0.165
Eastern mudminnow	0.167	0.276		0.367
Family Fundulidae				
Banded killifish	0.056	0.035		1.000
Family Cottidae				
Slimy sculpin	0.000	0.035		0.446
Family Moronidae				
White perch	0.000	0.069		0.195
Family Centrarchidae				
Mud sunfish	0.083	0.000		0.247
Rock bass	0.222	0.035		0.036
Bluespotted sunfish	0.139	0.138		1.000

Species	Proportion of sites – Historic (n=36)	Proportion of sites – Modern (n=29)	Direction of change	Fisher's exact test <i>p</i> -value
Redbreast sunfish	0.278	0.276		1.000
Green sunfish	0.000	0.138		0.035
Pumpkinseed	0.417	0.414		1.000
Bluegill	0.194	0.483		0.018
Smallmouth bass	0.194	0.035		0.066
Largemouth bass	0.333	0.310		1.000
Black crappie	0.000	0.241		0.002
Family Percidae				
Tessellated darter	0.361	0.655		0.025
Yellow perch	0.167	0.379		0.087

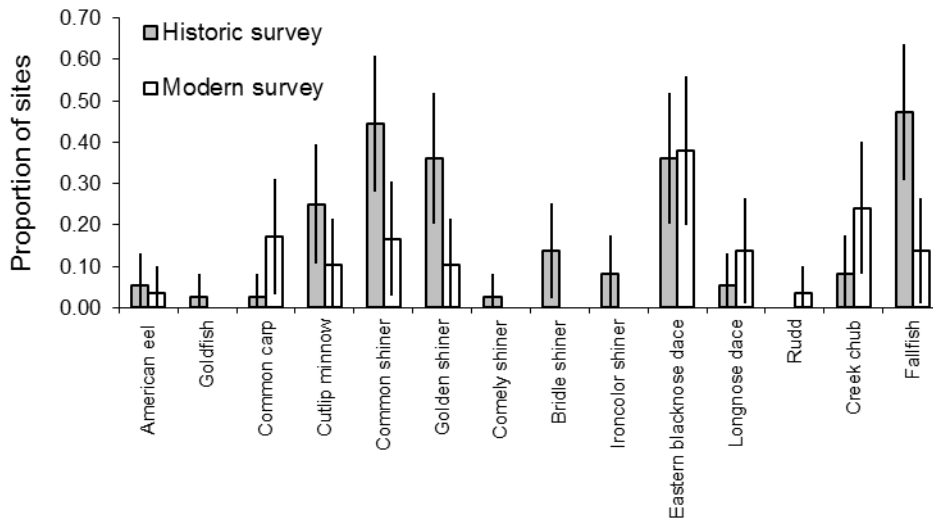


Figure A12-1. Catches (proportion of sites where detected) of fish species in the Newark Bay Watershed from historic and modern stream surveys. Families Anguillidae and Cyprinidae. Error bars represent 95% confidence intervals.

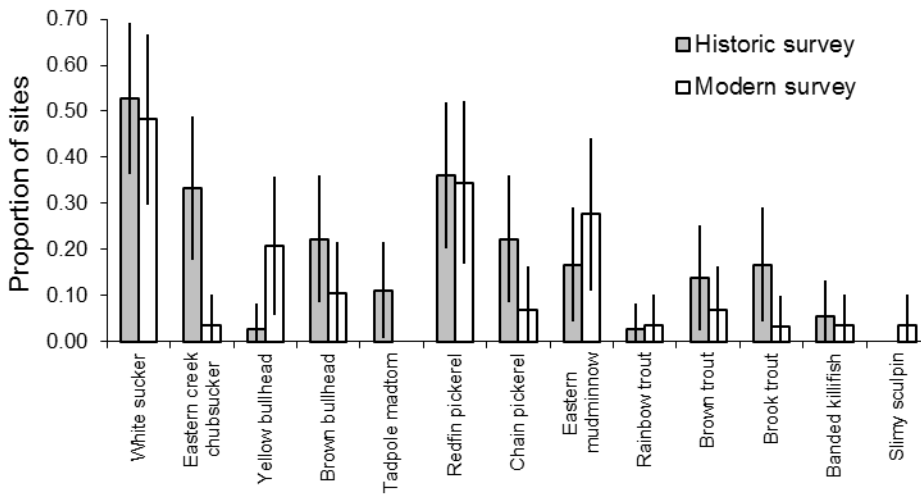


Figure A12-2. Catches (proportion of sites where detected) of fish species in the Newark Bay Watershed from historic and modern stream surveys. Families Catostomidae, Ictaluridae, Salmonidae, Esocidae, Fundulidae, and Cottidae. Error bars represent 95% confidence intervals.

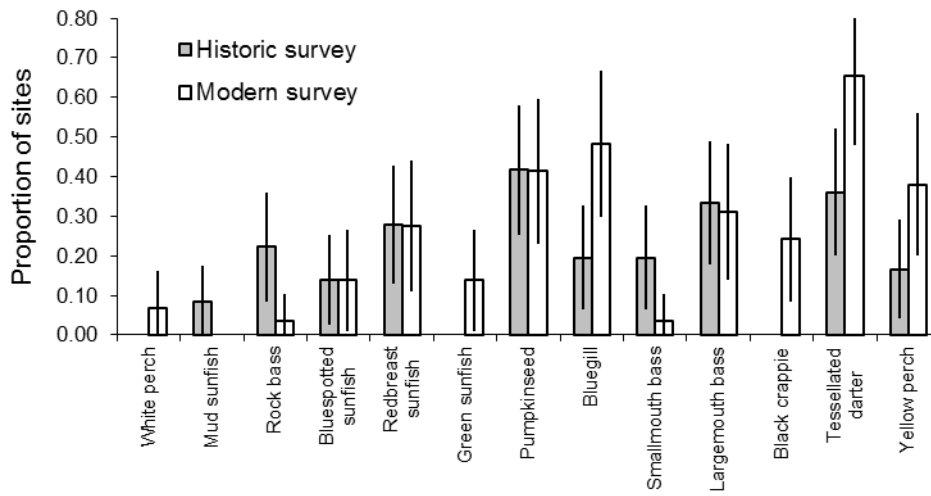


Figure A12-3. Catches (proportion of sites where detected) of fish species in the Newark Bay Watershed from historic and modern stream surveys. Families Moronidae, Centrarchidae, and Percidae. Error bars represent 95% confidence intervals.

OSWEGATCHIE RIVER WATERSHED



Table A13. Catches (proportion of sites where detected) of fish species in the Oswegatchie River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 73, Bonferroni inequality correction for significance: $0.05/73 = 0.0007$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=83)	Proportion of sites – Modern (n=152)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
Silver lamprey	0.000	0.007		1.000
Family Acipenseridae				
Lake sturgeon	0.012	0.046		0.266
Family Lepisosteidae				
Longnose gar	0.012	0.000		0.353
Family Amiidae				
Bowfin	0.012	0.020		1.000
Family Hiodontidae				
Mooneye	0.012	0.007		1.000
Family Anguillidae				
American eel	0.012	0.013		1.000
Family Cyprinidae				
Central stoneroller	0.012	0.000		0.353
Northern redbelly dace	0.121	0.145		0.693
Finescale dace	0.036	0.013		0.349
Redside dace	0.012	0.000		0.353
Lake chub	0.060	0.013		0.100
Satinfin shiner	0.000	0.007		1.000
Spotfin shiner	0.012	0.145	+	0.0005
Common carp	0.000	0.020		0.554
Cutlip minnow	0.012	0.079		0.036
Brassy minnow	0.036	0.040		1.000
Eastern silvery minnow	0.000	0.013		0.541
Common shiner	0.229	0.217		0.870
Pearl dace	0.060	0.020		0.135
Hornyhead chub	0.000	0.007		1.000
Golden shiner	0.133	0.336	+	0.0006
Emerald shiner	0.000	0.013		0.541
Bridle shiner	0.048	0.020		0.247
Blacknose shiner	0.024	0.013		0.616
Spottail shiner	0.024	0.007		0.285
Rosyface shiner	0.024	0.138		0.005
Mimic shiner	0.000	0.092		0.003
Bluntnose minnow	0.060	0.125		0.175
Fathead minnow	0.024	0.092		0.058
Eastern blacknose dace	0.253	0.132		0.030
Longnose dace	0.036	0.046		1.000
Creek chub	0.325	0.211		0.060
Fallfish	0.096	0.349	+	<0.0001
Family Catostomidae				
Longnose sucker	0.012	0.000		0.353
White sucker	0.386	0.415		0.679

Species	Proportion of sites – Historic (n=83)	Proportion of sites – Modern (n=152)	Direction of change	Fisher's exact test <i>p</i> -value
Summer sucker	0.012	0.013		1.000
Eastern creek chubsucker	0.000	0.046		0.054
Silver redhorse	0.000	0.007		1.000
Shorthead redhorse	0.036	0.000		0.043
Greater redhorse	0.000	0.026		0.300
Family Ictaluridae				
Yellow bullhead	0.000	0.007		1.000
Brown bullhead	0.265	0.408		0.033
Channel catfish	0.012	0.007		1.000
Tadpole madtom	0.012	0.013		1.000
Margined madtom	0.000	0.033		0.165
Family Salmonidae				
Rainbow trout	0.048	0.000		0.015
Brown trout	0.060	0.013		0.100
Brook trout	0.205	0.086		0.013
Family Esocidae				
Northern pike	0.241	0.217		0.745
Muskellunge	0.036	0.013		0.349
Chain pickerel	0.012	0.020		1.000
Central mudminnow	0.072	0.211		0.005
Family Gadidae				
Burbot	0.000	0.046		0.054
Family Atherinopsidae				
Brook silverside	0.000	0.046		0.054
Family Fundulidae				
Banded killifish	0.012	0.165	+	0.0001
Family Gasterosteidae				
Brook stickleback	0.072	0.046		0.390
Family Cottidae				
Slimy sculpin	0.024	0.007		0.285
Family Centrarchidae				
Rock bass	0.193	0.441	+	0.0002
Pumpkinseed	0.205	0.579	+	<0.0001
Bluegill	0.048	0.125		0.068
Smallmouth bass	0.265	0.329		0.375
Largemouth bass	0.024	0.290	+	<0.0001
Black crappie	0.000	0.105		0.0008
Family Percidae				
Eastern sand darter	0.000	0.033		0.165
Iowa darter	0.012	0.007		1.000
Fantail darter	0.036	0.040		1.000
Johnny darter	0.012	0.033		0.428
Tessellated darter	0.036	0.132		0.021
Yellow perch	0.157	0.329		0.005
Logperch	0.048	0.145		0.029
Channel darter	0.024	0.053		0.501
Walleye	0.048	0.072		0.583

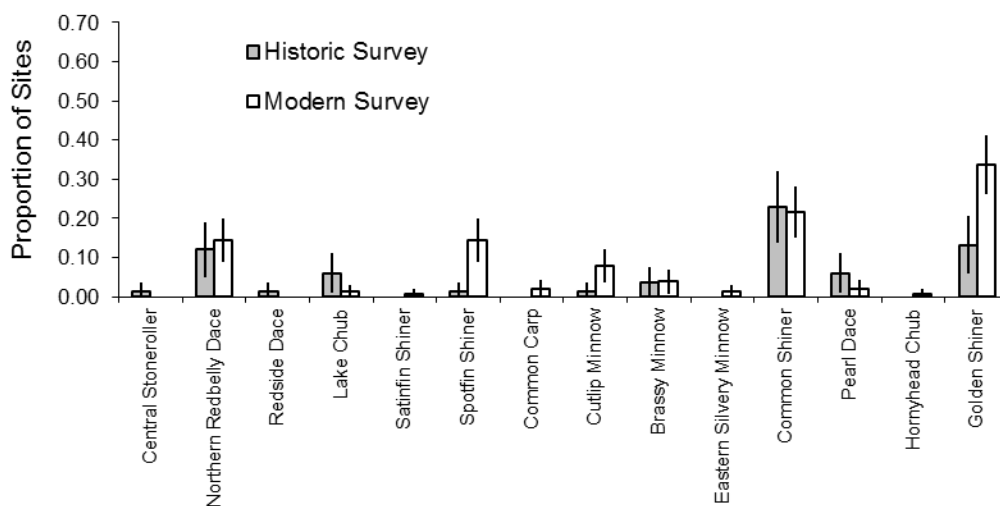


Figure A13-1. Catches (proportion of sites where detected) of fish species in the Oswegatchie River Watershed from historic and modern stream surveys. Families Petromyzontidae, Acipenseridae, Lepisosteidae, Amiidae, Hiodontidae and Anguillidae. Error bars represent 95% confidence intervals.

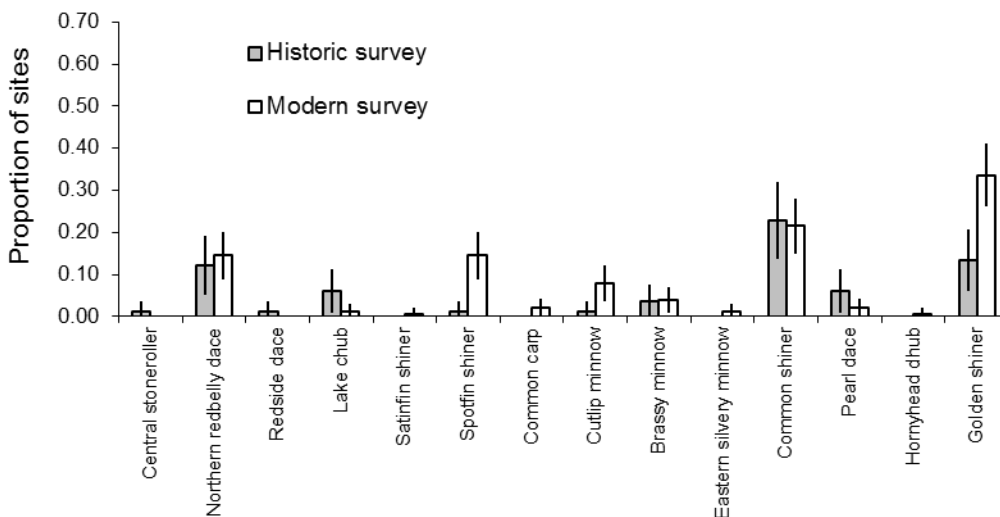


Figure A13-2. Catches (proportion of sites where detected) of fish species in the Oswegatchie River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

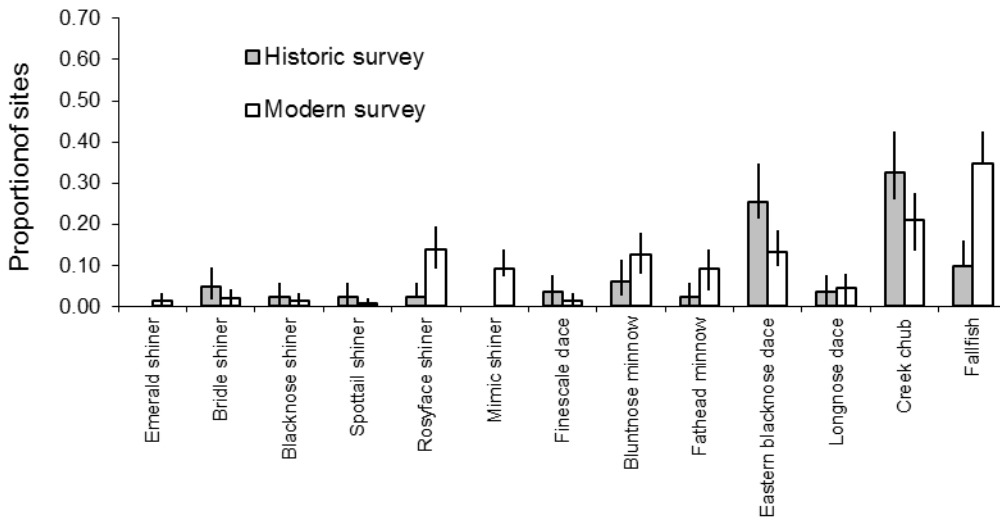


Figure A13-3. Catches (proportion of sites where detected) of fish species in the Oswegatchie River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

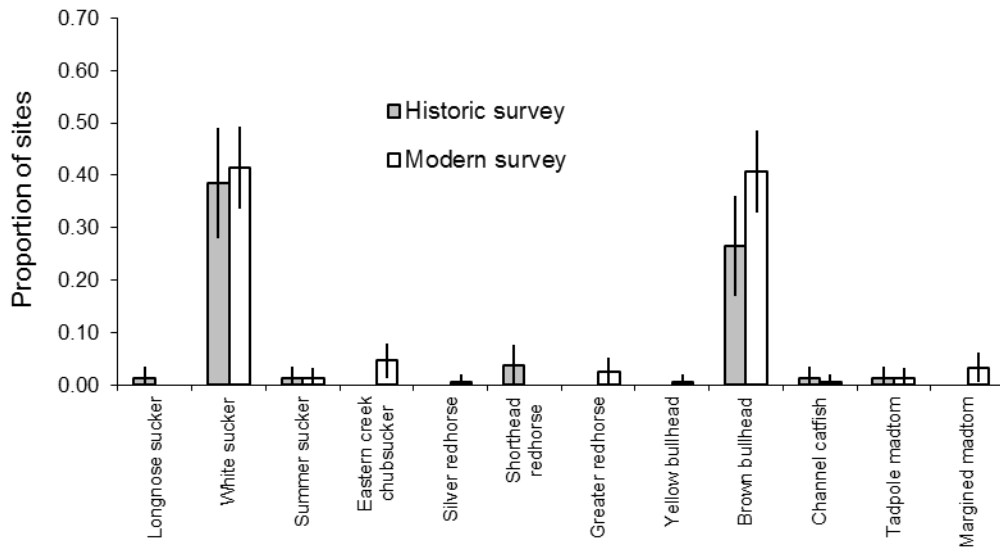


Figure A13-4. Catches (proportion of sites where detected) of fish species in the Oswegatchie River Watershed from historic and modern stream surveys. Families Catastomidae and Ictaluridae. Error bars represent 95% confidence intervals.

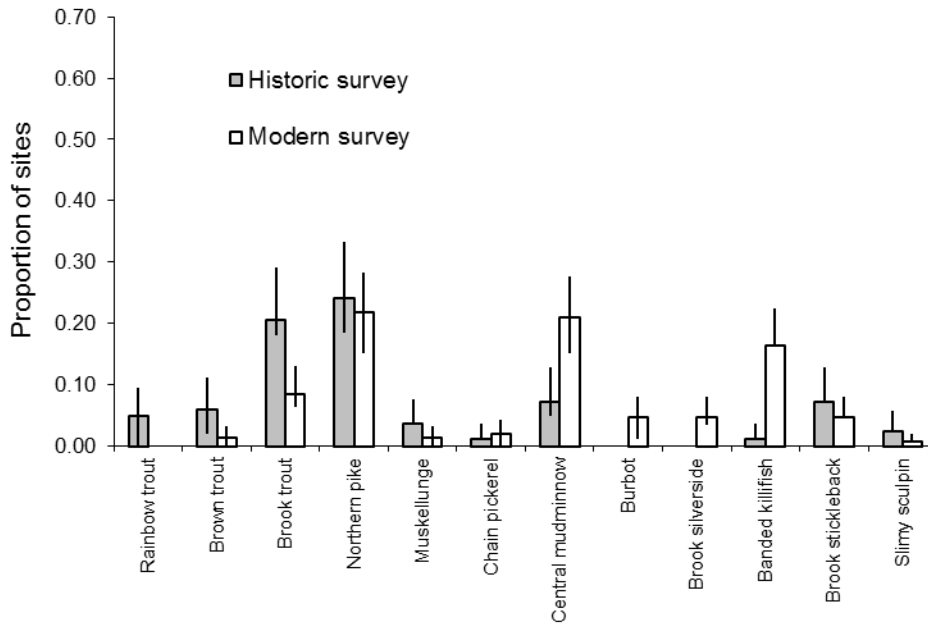


Figure A13-5. Catches (proportion of sites where detected) of fish species in the Oswegatchie River Watershed from historic and modern stream surveys. Families Salmonidae, Esocidae, Gadidae, Atherinopsidae, Fundulidae, Gasterosteidae, and Cottidae. Error bars represent 95% confidence intervals.

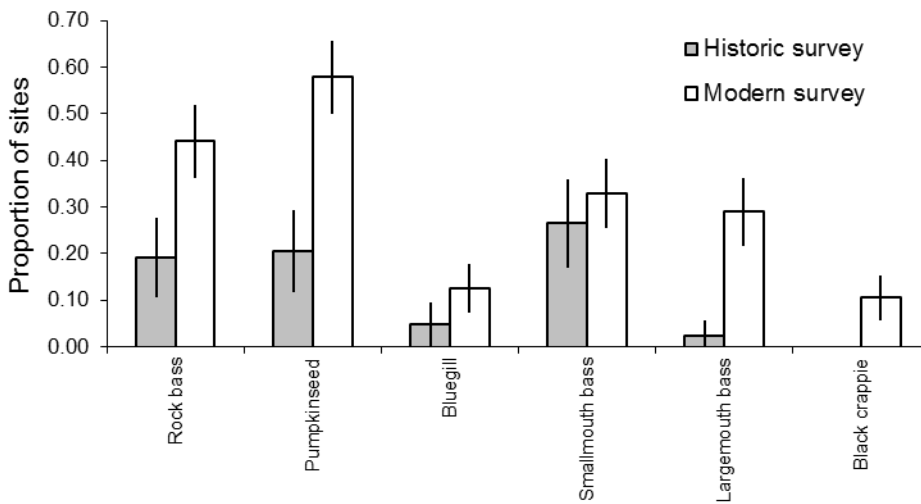


Figure A13-6. Catches (proportion of sites where detected) of fish species in the Oswegatchie River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

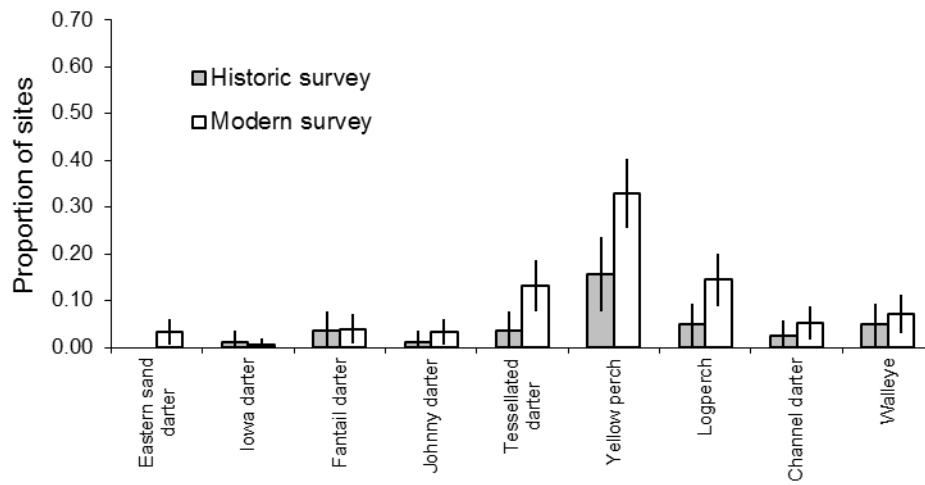


Figure A13-7. Catches (proportion of sites where detected) of fish species in the Oswegatchie River Watershed from historic and modern stream surveys. Family Percidae. Error bars represent 95% confidence intervals.

OSWEGO RIVER WATERSHED



Table A14. Catches (proportion of sites where detected) of fish species in the Oswego River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 87, Bonferroni inequality correction for significance: $0.05/87 = 0.0006$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=253)	Proportion of sites – Modern (n=203)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
American brook lamprey	0.004	0.000		1.000
Sea lamprey	0.004	0.005		1.000
Family Acipenseridae				
Lake sturgeon	0.000	0.015		0.088
Family Lepisosteidae				
Longnose gar	0.004	0.015		0.328
Family Amiidae				
Bowfin	0.000	0.010		0.198
Family Anguillidae				
American eel	0.004	0.000		1.000
Family Clupeidae				
Alewife	0.004	0.000		1.000
Gizzard shad	0.000	0.010		0.198
Family Cyprinidae				
Central stoneroller	0.020	0.108	+	<0.0001
Goldfish	0.004	0.005		1.000
Northern redbelly dace	0.004	0.020		0.177
Redside dace	0.020	0.030		0.550
Satinfin shiner	0.000	0.010		0.198
Spotfin shiner	0.008	0.118	+	<0.0001
Common carp	0.004	0.123	+	<0.0001
Cutlip minnow	0.182	0.251		0.084
Brassy minnow	0.000	0.005		0.445
Eastern silvery minnow	0.012	0.005		0.632
Striped shiner	0.012	0.035		0.118
Common shiner	0.059	0.158	+	0.0002
Pearl dace	0.016	0.005		0.387
Hornyhead chub	0.024	0.020		1.000
River chub	0.004	0.000		1.000
Golden shiner	0.123	0.153		0.410
Comely shiner	0.000	0.005		0.445
Emerald shiner	0.024	0.059		0.088
Bridle shiner	0.012	0.020		0.705
Bigmouth shiner	0.004	0.000		1.000
Blacknose shiner	0.008	0.025		0.250
Spottail shiner	0.016	0.059		0.019
Swallowtail shiner	0.004	0.000		1.000
Rosyface shiner	0.020	0.035		0.385
Mimic shiner	0.016	0.010		0.697
Bluntnose minnow	0.032	0.350	+	<0.0001
Fathead minnow	0.012	0.177	+	<0.0001
Eastern blacknose dace	0.099	0.237	+	<0.0001
Longnose dace	0.028	0.202	+	<0.0001

Species	Proportion of sites – Historic (n=253)	Proportion of sites – Modern (n=203)	Direction of change	Fisher's exact test <i>p</i> -value
Creek chub	0.150	0.261		0.005
Fallfish	0.071	0.172		0.001
Family Catostomidae				
Longnose sucker	0.000	0.010		0.198
White sucker	0.293	0.478	+	<0.0001
Eastern creek chubsucker	0.051	0.030		0.346
Northern hog sucker	0.051	0.207	+	<0.0001
Silver redhorse	0.004	0.010		0.588
Shorthead redhorse	0.012	0.015		1.000
Family Ictaluridae				
Black bullhead	0.004	0.000		1.000
Yellow bullhead	0.012	0.010		1.000
Brown bullhead	0.040	0.177	+	<0.0001
Channel catfish	0.004	0.000		1.000
Stonecat	0.000	0.030		0.008
Tadpole madtom	0.036	0.020		0.402
Margined madtom	0.000	0.054	+	<0.0001
Brindled madtom	0.000	0.010		0.198
Family Salmonidae				
Rainbow trout	0.016	0.074		0.004
Atlantic salmon	0.004	0.035		0.025
Brown trout	0.036	0.143	+	<0.0001
Brook trout	0.036	0.039		1.000
Family Esocidae				
Grass pickerel	0.016	0.020		1.000
Northern pike	0.040	0.069		0.206
Chain pickerel	0.083	0.113		0.339
Central mudminnow	0.079	0.059		0.464
Family Percopsidae				
Trout-perch	0.000	0.005		0.445
Family Gadidae				
Burbot	0.000	0.015		0.088
Family Atherinopsidae				
Brook silverside	0.016	0.084		0.001
Family Fundulidae				
Banded killifish	0.032	0.123	+	0.0002
Family Gasterosteidae				
Brook stickleback	0.127	0.069		0.060
Threespine stickleback	0.004	0.000		1.000
Family Cottidae				
Mottled sculpin	0.008	0.054		0.004
Slimy sculpin	0.008	0.030		0.147
Family Moronidae				
White perch	0.000	0.010		0.198
White bass	0.004	0.000		1.000
Family Centrarchidae				

Species	Proportion of sites – Historic (n=253)	Proportion of sites – Modern (n=203)	Direction of change	Fisher's exact test <i>p</i> -value
Rock bass	0.095	0.310	+	<0.0001
Green sunfish	0.000	0.064	+	<0.0001
Pumpkinseed	0.130	0.522	+	<0.0001
Bluegill	0.004	0.276	+	<0.0001
Smallmouth bass	0.008	0.246	+	<0.0001
Largemouth bass	0.079	0.246	+	<0.0001
Black crappie	0.008	0.054		0.004
Family Percidae				
Greenside darter	0.020	0.049		0.112
Fantail darter	0.020	0.192	+	<0.0001
Johnny darter	0.000	0.010		0.198
Tessellated darter	0.051	0.478	+	<0.0001
Yellow perch	0.083	0.315	+	<0.0001
Logperch	0.024	0.158	+	<0.0001
Blackside darter	0.004	0.069	+	<0.0001
Walleye	0.012	0.015		1.000
Family Scianidae				
Freshwater drum	0.004	0.010		0.588

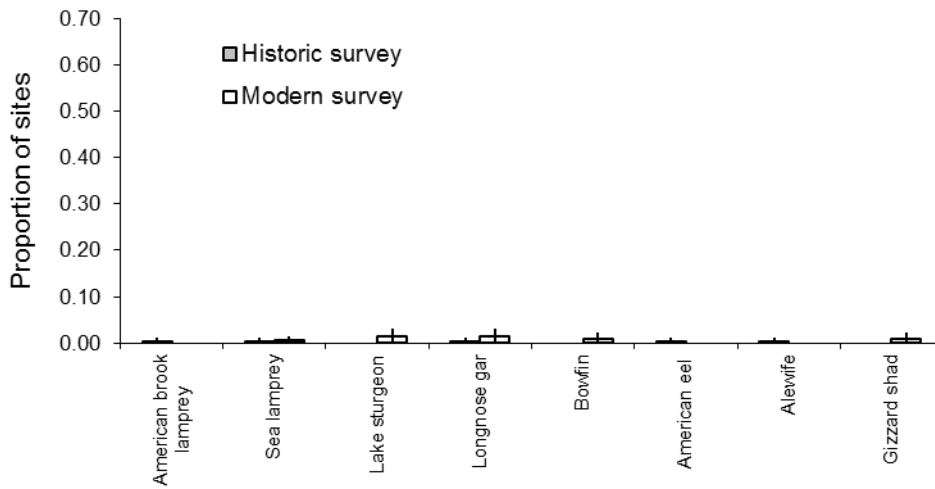


Figure A14-1. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Families Petromyzontidae, Acipenseridae, Lepisosteidae, Amiidae, Anguillidae, and Clupeidae. Error bars represent 95% confidence intervals.

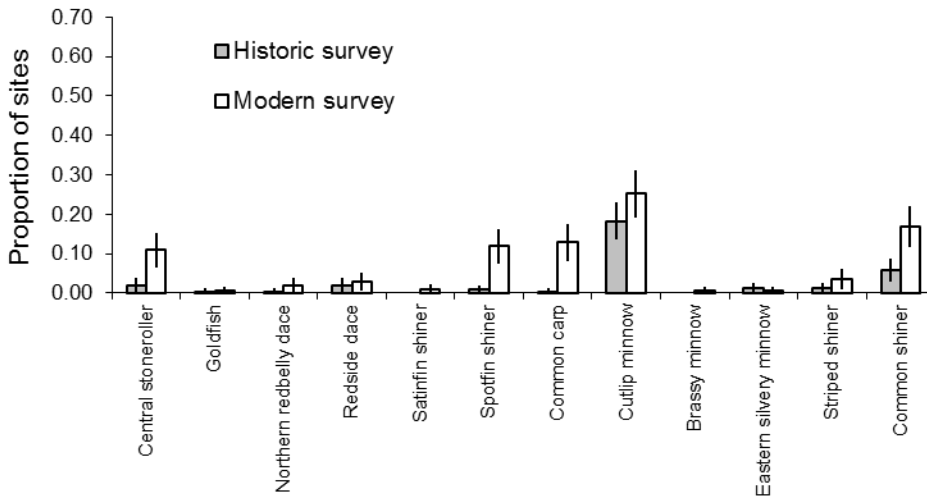


Figure A14-2. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

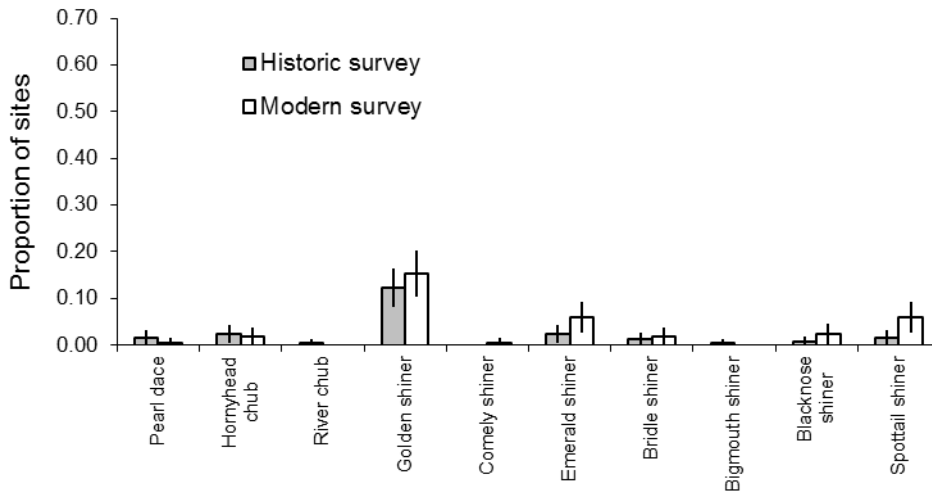


Figure A14-3. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

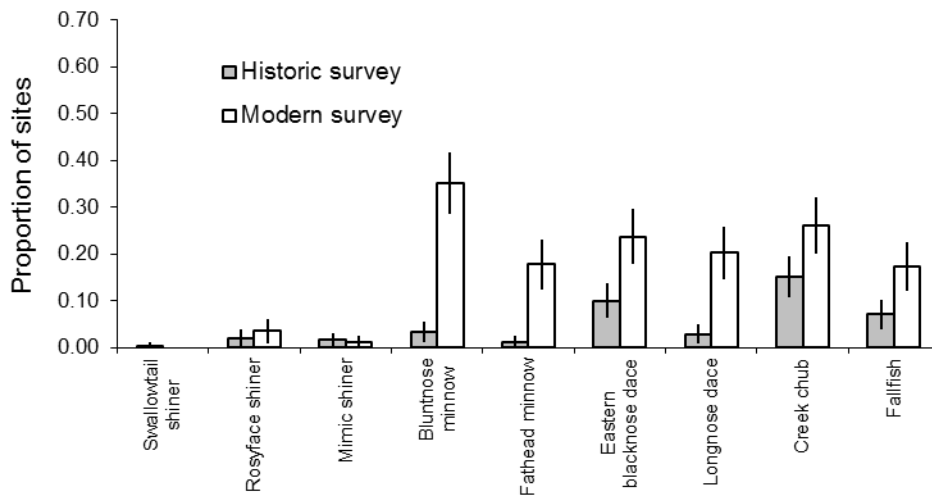


Figure A14-4. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

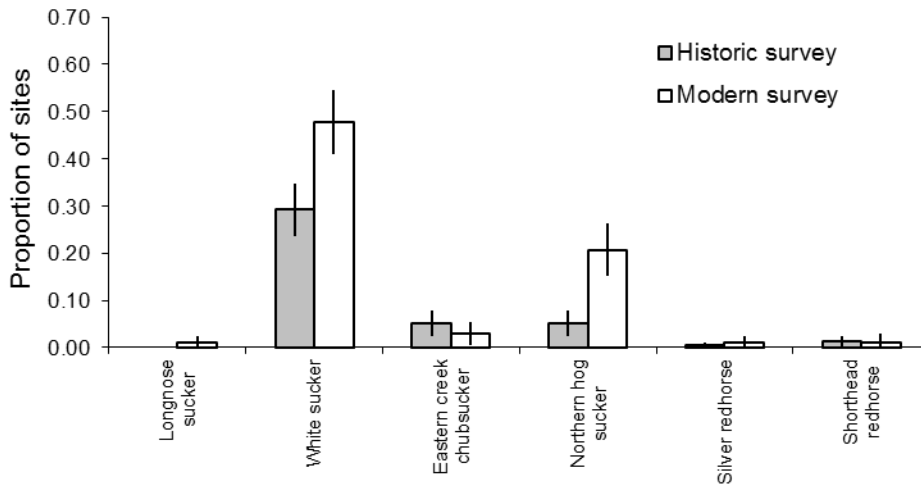


Figure A14-5. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Family Catastomidae. Error bars represent 95% confidence intervals.

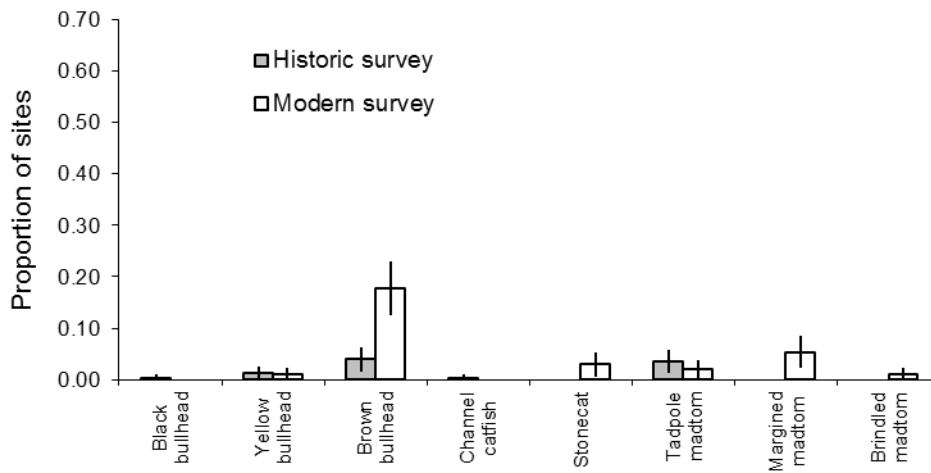


Figure A14-6. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Family Ictaluridae. Error bars represent 95% confidence intervals.

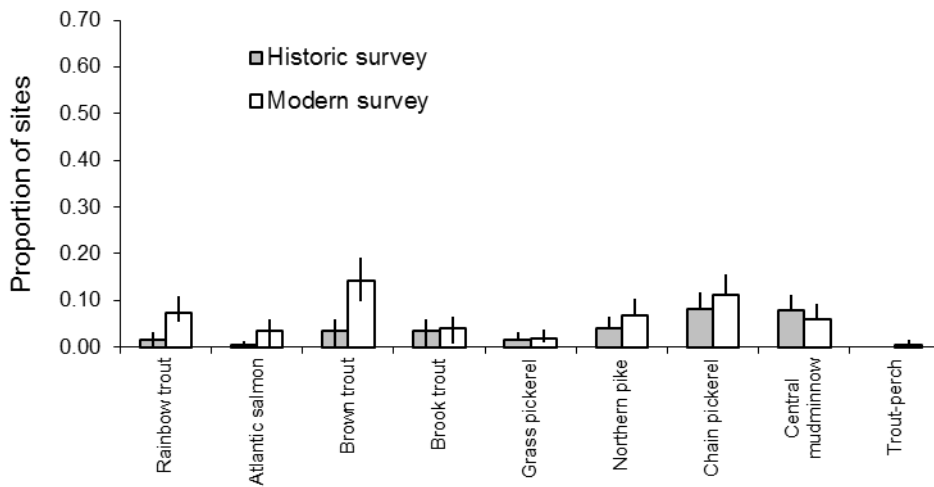


Figure A14-7. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Families Salmonidae, Esocidae, and Percopsidae. Error bars represent 95% confidence intervals.

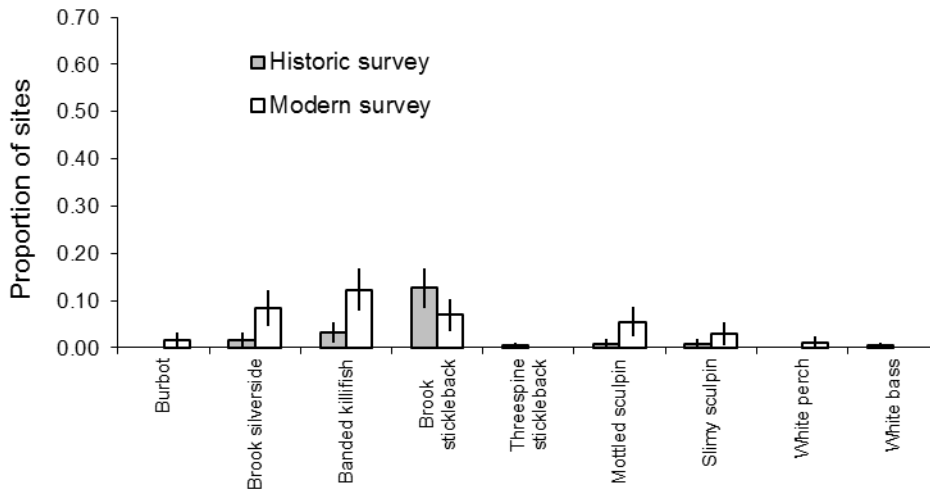


Figure A14-8. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Families Gadidae, Atherinopsidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

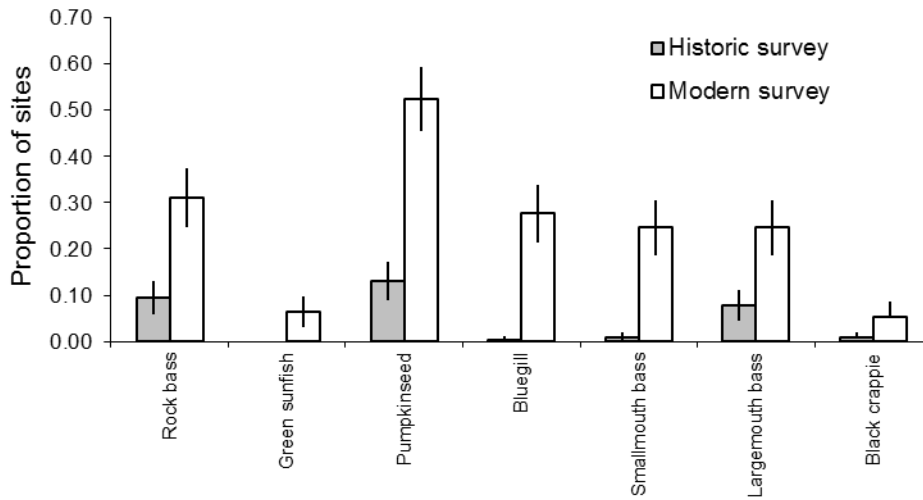


Figure A14-9. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

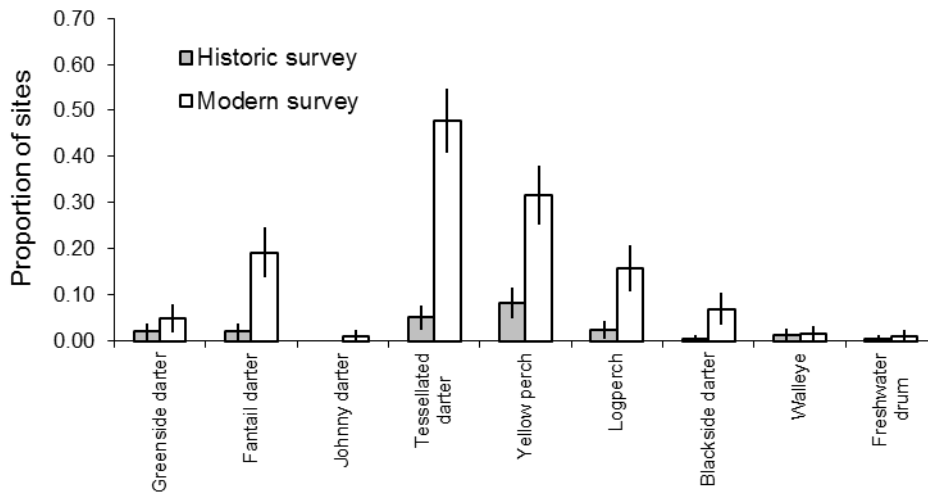


Figure A14-10. Catches (proportion of sites where detected) of fish species in the Oswego River Watershed from historic and modern stream surveys. Families Percidae and Scianidae. Error bars represent 95% confidence intervals.

RAQUETTE RIVER WATERSHED



Table A15. Catches (proportion of sites where detected) of fish species in the Raquette River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 65, Bonferroni inequality correction for significance: $0.05/65 = 0.0008$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=183)	Proportion of sites – Modern (n=60)	Direction of change	Fisher's exact test p-value
Family Petromyzontidae				
Sea lamprey	0.000	0.033		0.060
Family Lepisosteidae				
Longnose gar	0.000	0.083	+	0.0008
Family Amiidae				
Bowfin	0.006	0.000		1.000
Family Cyprinidae				
Central stoneroller	0.000	0.017		0.247
Northern redbelly dace	0.060	0.150		0.054
Finescale dace	0.006	0.000		1.000
Lake chub	0.027	0.000		0.337
Spotfin shiner	0.006	0.200	+	<0.0001
Common carp	0.006	0.017		0.434
Cutlip minnow	0.169	0.200		0.565
Brassy minnow	0.022	0.200	+	<0.0001
Common shiner	0.290	0.317		0.745
Pearl dace	0.016	0.017		1.000
Golden shiner	0.087	0.317	+	<0.0001
Emerald shiner	0.000	0.033		0.060
Bridle shiner	0.022	0.150	+	0.0006
Blacknose shiner	0.011	0.033		0.256
Rosyface shiner	0.011	0.167	+	<0.0001
Sand shiner	0.000	0.033		0.060
Mimic shiner	0.022	0.233	+	<0.0001
Bluntnose minnow	0.098	0.400	+	<0.0001
Fathead minnow	0.016	0.167	+	<0.0001
Eastern blacknose dace	0.180	0.050		0.012
Longnose dace	0.077	0.017		0.125
Creek chub	0.383	0.333		0.540
Fallfish	0.142	0.267		0.032
Family Catostomidae				
Longnose sucker	0.006	0.000		1.000
White sucker	0.372	0.417		0.544
Silver redbhorse	0.011	0.100		0.003
Shorthead redbhorse	0.011	0.067		0.034
Greater redbhorse	0.027	0.017		1.000
Family Ictaluridae				
Yellow bullhead	0.000	0.017		0.247
Brown bullhead	0.159	0.350		0.003
Channel catfish	0.006	0.000		1.000
Stonecat	0.011	0.033		0.256
Margined madtom	0.000	0.067		0.003
Family Salmonidae				
Lake whitefish	0.006	0.000		1.000

Species	Proportion of sites – Historic (n=183)	Proportion of sites – Modern (n=60)	Direction of change	Fisher's exact test <i>p</i> -value
Rainbow trout	0.011	0.000		1.000
Chinook salmon	0.000	0.033		0.060
Atlantic salmon	0.011	0.017		0.575
Brown trout	0.066	0.017		0.196
Brook trout	0.284	0.117		0.009
Family Osmeridae				
Rainbow smelt	0.006	0.000		1.000
Family Esocidae				
Northern pike	0.164	0.117		0.534
Muskellunge	0.006	0.033		0.152
Central mudminnow	0.022	0.150	+	0.0006
Family Gadidae				
Burbot	0.006	0.000		1.000
Family Atherinopsidae				
Brook silverside	0.000	0.050		0.015
Family Fundulidae				
Banded killifish	0.000	0.233	+	<0.0001
Family Gasterosteidae				
Brook stickleback	0.022	0.050		0.368
Family Cottidae				
Slimy sculpin	0.049	0.017		0.458
Family Centrarchidae				
Rock bass	0.109	0.550	+	<0.0001
Redbreast sunfish	0.027	0.133		0.004
Pumpkinseed	0.240	0.550	+	<0.0001
Smallmouth bass	0.257	0.367		0.137
Largemouth bass	0.000	0.200	+	<0.0001
Black crappie	0.000	0.033		0.060
Family Percidae				
Iowa darter	0.000	0.050		0.015
Fantail darter	0.066	0.133		0.108
Johnny darter	0.006	0.167	+	<0.0001
Tessellated darter	0.060	0.267	+	<0.0001
Yellow perch	0.186	0.233		0.456
Logperch	0.049	0.317	+	<0.0001
Channel darter	0.011	0.083		0.011
Walleye	0.049	0.000		0.118

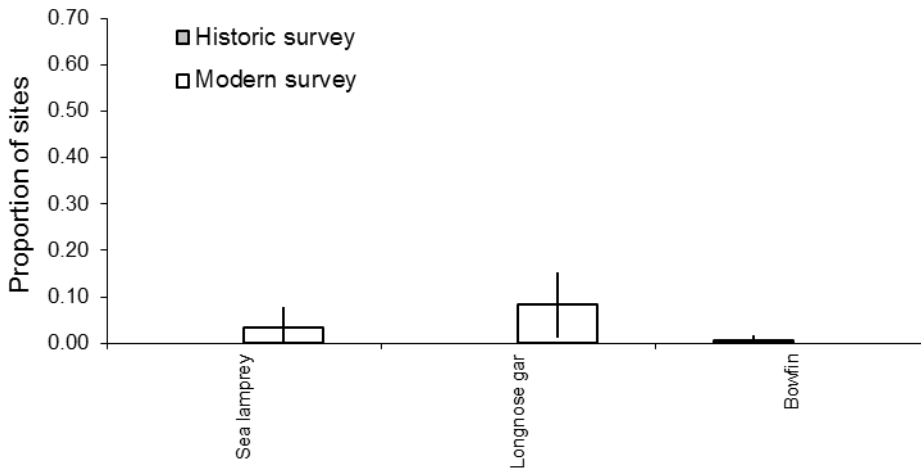


Figure A15-1. Catches (proportion of sites where detected) of fish species in the Raquette River Watershed from historic and modern stream surveys. Families Petromyzontidae, Lepisosteidae, and Amiidae. Error bars represent 95% confidence intervals.

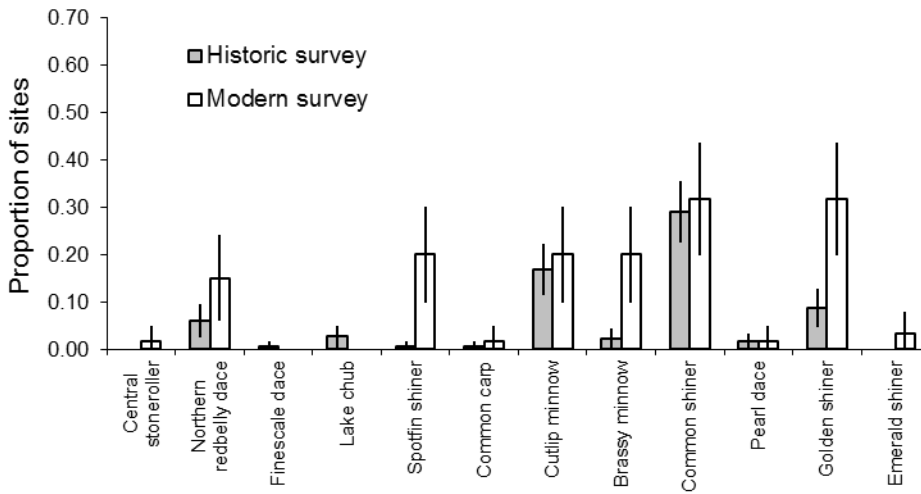


Figure A15-2. Catches (proportion of sites where detected) of fish species in the Raquette River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

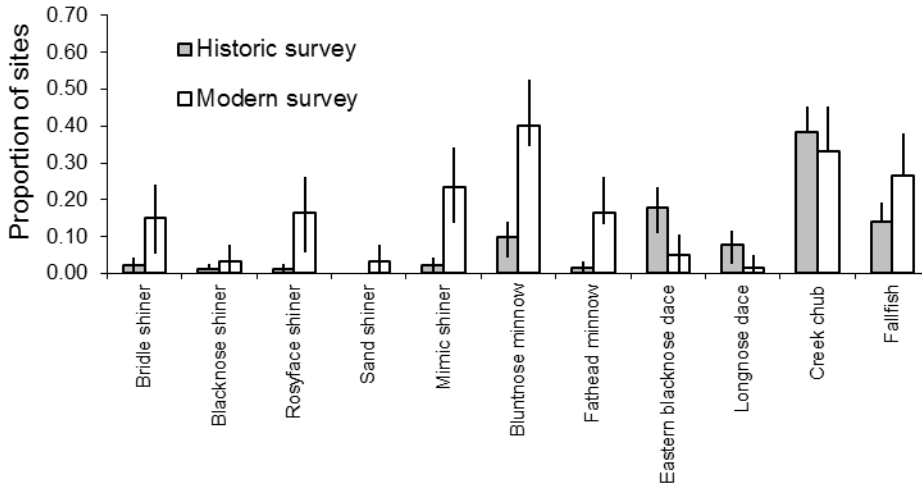


Figure A15-3. Catches (proportion of sites where detected) of fish species in the Raquette River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

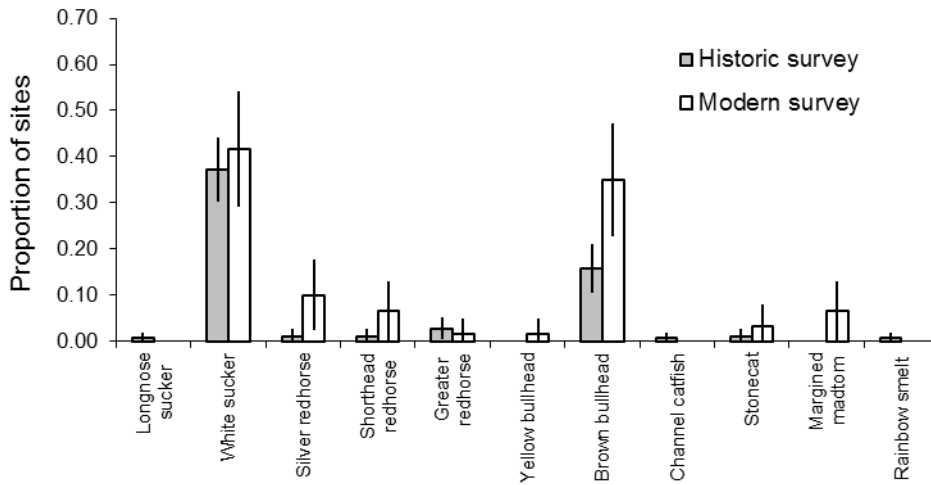


Figure A15-4. Catches (proportion of sites where detected) of fish species in the Raquette River Watershed from historic and modern stream surveys. Families Catastomidae, Ictaluridae, and Osmeridae. Error bars represent 95% confidence intervals.

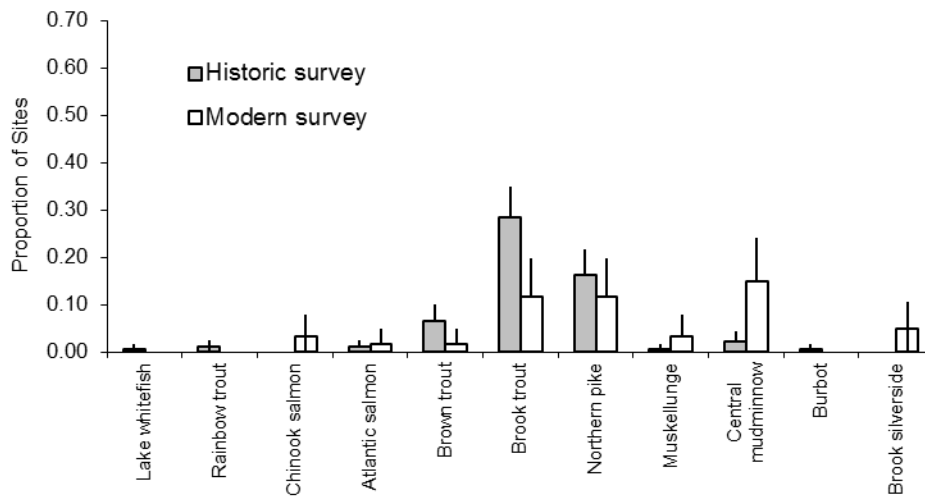


Figure A15-5. Catches (proportion of sites where detected) of fish species in the Raquette River Watershed from historic and modern stream surveys. Families Salmonidae, Esocidae, Gadidae, and Atherinopsidae. Error bars represent 95% confidence intervals.

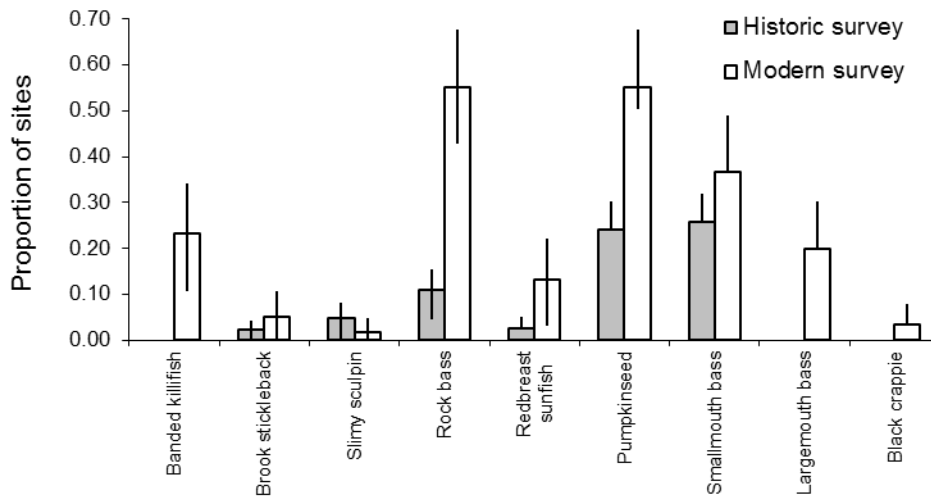


Figure A15-6. Catches (proportion of sites where detected) of fish species in the Raquette River Watershed from historic and modern stream surveys. Families Fundulidae, Gasterosteidae, Cottidae, and Centrarchidae. Error bars represent 95% confidence intervals.

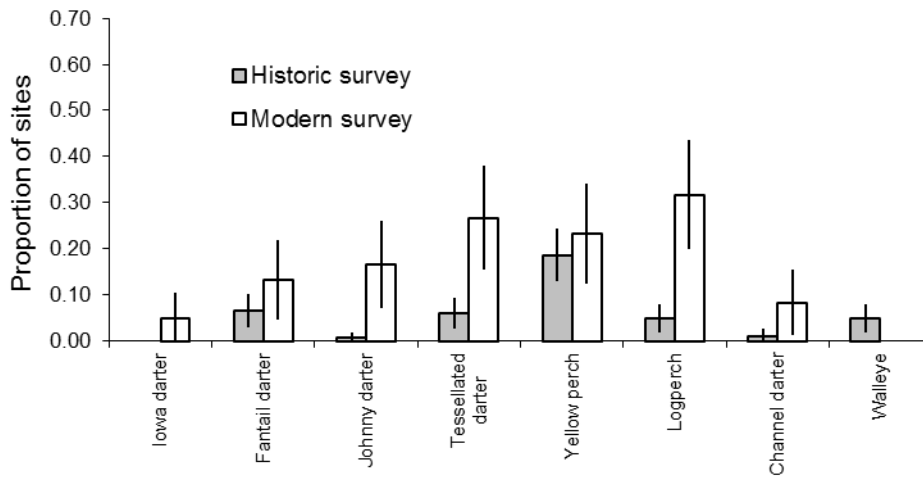


Figure A15-7. Catches (proportion of sites where detected) of fish species in the Raquette River Watershed from historic and modern stream surveys. Family Percidae. Error bars represent 95% confidence intervals.

ST. LAWRENCE RIVER WATERSHED



Table A16. Catches (proportion of sites where detected) of fish species in the St. Lawrence River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 90, Bonferroni inequality correction for significance: $0.05/90 = 0.0006$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=266)	Proportion of sites – Modern (n=344)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
Northern brook lamprey	0.000	0.038		0.0009
Silver lamprey	0.004	0.003		1.000
American brook lamprey	0.000	0.076	+	<0.0001
Sea lamprey	0.004	0.009		0.636
Family Acipenseridae				
Lake sturgeon	0.004	0.038		0.005
Family Lepisosteidae				
Longnose gar	0.008	0.017		0.476
Family Amiidae				
Bowfin	0.030	0.029		1.000
Family Hiodontidae				
Mooneye	0.011	0.000		0.082
Family Anguillidae				
American eel	0.000	0.047	+	0.0001
Family Clupeidae				
Blueback herring	0.000	0.003		1.000
Alewife	0.004	0.012		0.393
American shad	0.008	0.000		0.190
Family Cyprinidae				
Northern redbelly dace	0.008	0.128	+	<0.0001
Finescale dace	0.004	0.003		1.000
Lake chub	0.011	0.000		0.082
Satinfin shiner	0.000	0.003		1.000
Spotfin shiner	0.034	0.180	+	<0.0001
Common carp	0.041	0.047		0.844
Cutlip minnow	0.177	0.189		0.752
Brassy minnow	0.023	0.029		0.800
Eastern silvery minnow	0.000	0.023		0.011
Common shiner	0.346	0.256		0.020
Pearl dace	0.030	0.015		0.259
Golden shiner	0.132	0.250	+	0.0003
Pugnose shiner	0.034	0.012		0.087
Emerald shiner	0.026	0.015		0.381
Bridle shiner	0.139	0.079		0.017
Blackchin shiner	0.075	0.026		0.007
Blacknose shiner	0.068	0.044		0.210
Spottail shiner	0.117	0.038	-	0.0002
Rosyface shiner	0.034	0.212	+	<0.0001
Sand shiner	0.023	0.017		0.771
Mimic shiner	0.181	0.241		0.074
Bluntnose minnow	0.290	0.340		0.190
Fathead minnow	0.023	0.137	+	<0.0001

Species	Proportion of sites – Historic (n=266)	Proportion of sites – Modern (n=344)	Direction of change	Fisher's exact test <i>p</i> -value
Eastern blacknose dace	0.248	0.125	-	0.0001
Longnose dace	0.079	0.105		0.327
Rudd	0.000	0.003		1.000
Creek chub	0.305	0.204		0.005
Fallfish	0.203	0.308		0.004
Family Catostomidae				
Longnose sucker	0.008	0.000		0.190
White sucker	0.500	0.401		0.017
Silver redhorse	0.011	0.212	+	<0.0001
Shorthead redhorse	0.041	0.023		0.243
Greater redhorse	0.011	0.017		0.738
Family Ictaluridae				
Yellow bullhead	0.000	0.003		1.000
Brown bullhead	0.226	0.230		0.923
Channel catfish	0.004	0.003		1.000
Stonecat	0.023	0.012		0.345
Tadpole madtom	0.038	0.020		0.222
Family Salmonidae				
Cisco	0.011	0.000		0.082
Lake whitefish	0.008	0.000		0.190
Rainbow trout	0.026	0.009		0.112
Chinook salmon	0.000	0.003		1.000
Brown trout	0.056	0.023		0.052
Brook trout	0.165	0.041	-	<0.0001
Lake trout	0.004	0.000		0.436
Family Esocidae				
Grass pickerel	0.030	0.017		0.415
Northern pike	0.105	0.119		0.609
Muskellunge	0.015	0.058		0.006
Chain pickerel	0.008	0.006		1.000
Tiger muskellunge	0.000	0.003		1.000
Central mudminnow	0.060	0.160	+	0.0001
Family Percopsidae				
Trout-perch	0.004	0.003		1.000
Family Gadidae				
Burbot	0.008	0.003		0.583
Family Atherinopsidae				
Brook silverside	0.038	0.044		0.838
Family Fundulidae				
Banded killifish	0.109	0.140		0.271
Family Gasterosteidae				
Brook stickleback	0.064	0.067		1.000
Threespine stickleback	0.023	0.000		0.007
Family Cottidae				
Mottled sculpin	0.004	0.017		0.144
Slimy sculpin	0.049	0.017		0.034

Species	Proportion of sites – Historic (n=266)	Proportion of sites – Modern (n=344)	Direction of change	Fisher's exact test <i>p</i> -value
Family Moronidae				
White perch	0.008	0.003		0.583
Family Centrarchidae				
Rock bass	0.271	0.564	+	<0.0001
Green sunfish	0.000	0.003		1.000
Pumpkinseed	0.226	0.456	+	<0.0001
Bluegill	0.000	0.055	+	<0.0001
Smallmouth bass	0.132	0.430	+	<0.0001
Largemouth bass	0.083	0.148		0.016
Black crappie	0.041	0.052		0.570
Family Percidae				
Eastern sand darter	0.004	0.079	+	<0.0001
Iowa darter	0.045	0.009		0.006
Fantail darter	0.011	0.140	+	<0.0001
Johnny darter	0.056	0.134		0.002
Tessellated darter	0.192	0.305		0.002
Yellow perch	0.278	0.288		0.856
Logperch	0.124	0.253	+	<0.0001
Channel darter	0.015	0.108	+	<0.0001
Walleye	0.049	0.125		0.001
Family Gobiidae				
Round goby	0.000	0.017		0.038

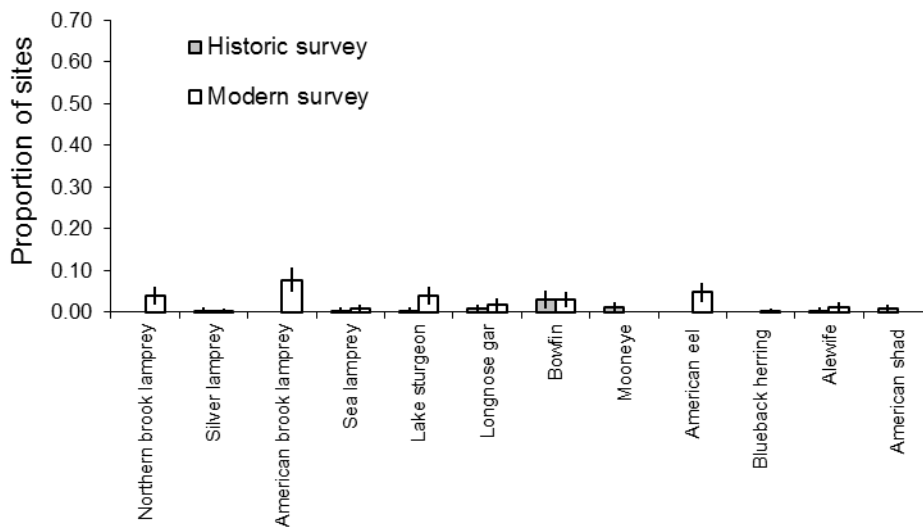


Figure A16-1. Catches (proportion of sites where detected) of fish species in the St. Lawrence River Watershed from historic and modern stream surveys. Families Petromyzontidae, Acipenseridae, Lepisosteidae, Amiidae, Hiodontidae, Anguillidae, and Clupeidae. Error bars represent 95% confidence intervals.

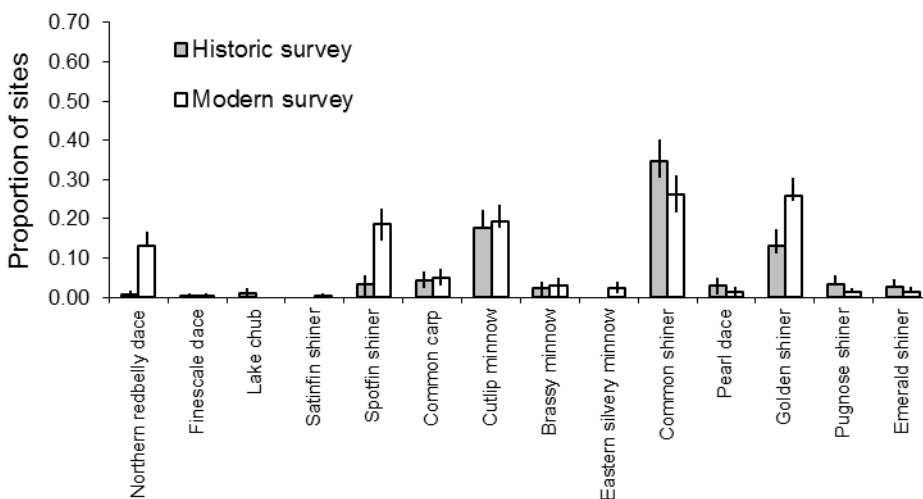


Figure A16-2. Catches (proportion of sites where detected) of fish species in the St. Lawrence River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

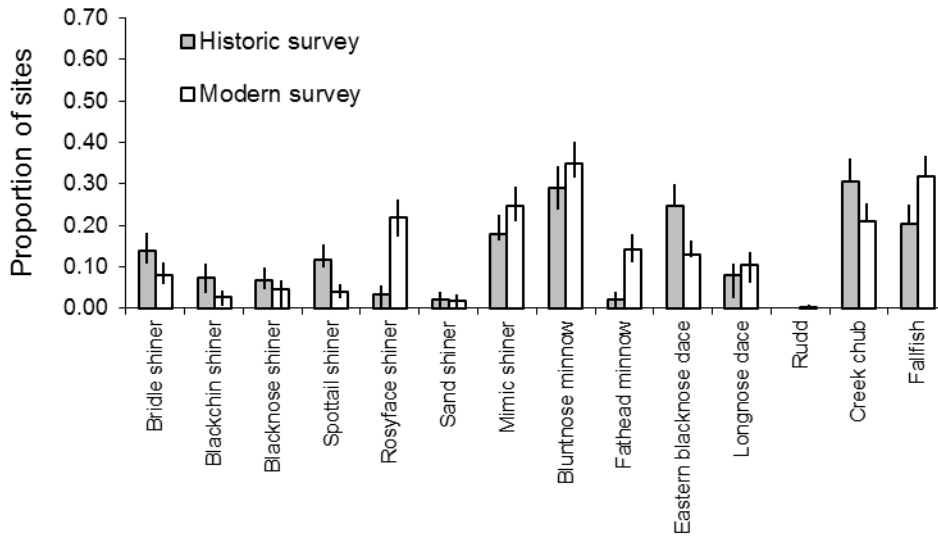


Figure A16-3. Catches (proportion of sites where detected) of fish species in the St. Lawrence River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

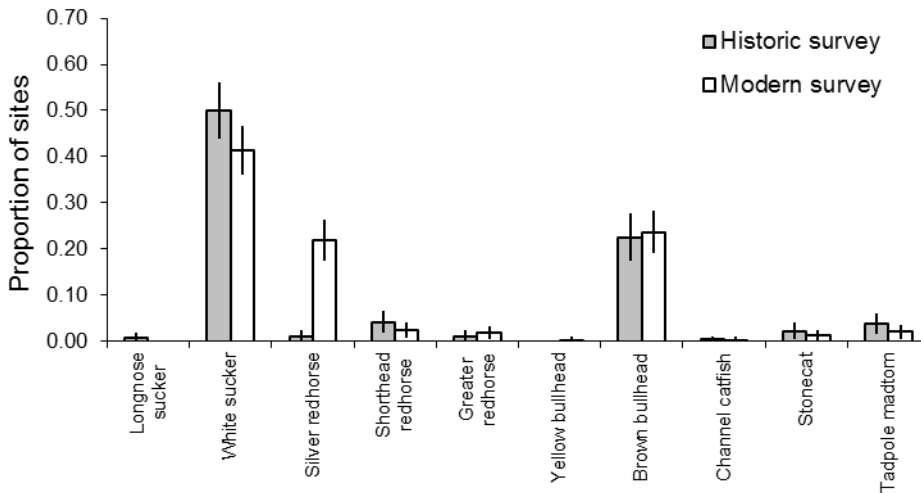


Figure A16-4. Catches (proportion of sites where detected) of fish species in the St. Lawrence River Watershed from historic and modern stream surveys. Families Catastomidae and Ictaluridae. Error bars represent 95% confidence intervals.

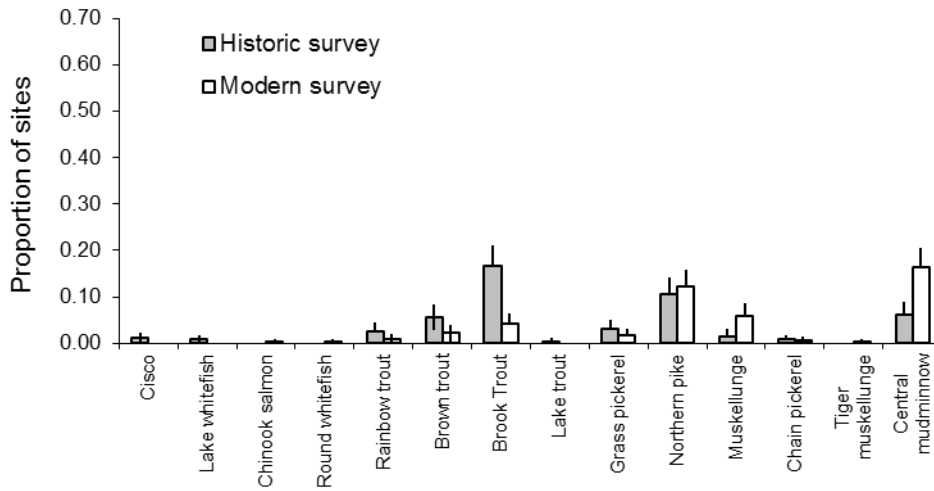


Figure A16-5. Catches (proportion of sites where detected) of fish species in the St. Lawrence River Watershed from historic and modern stream surveys. Families Salmonidae and Esocidae. Error bars represent 95% confidence intervals.

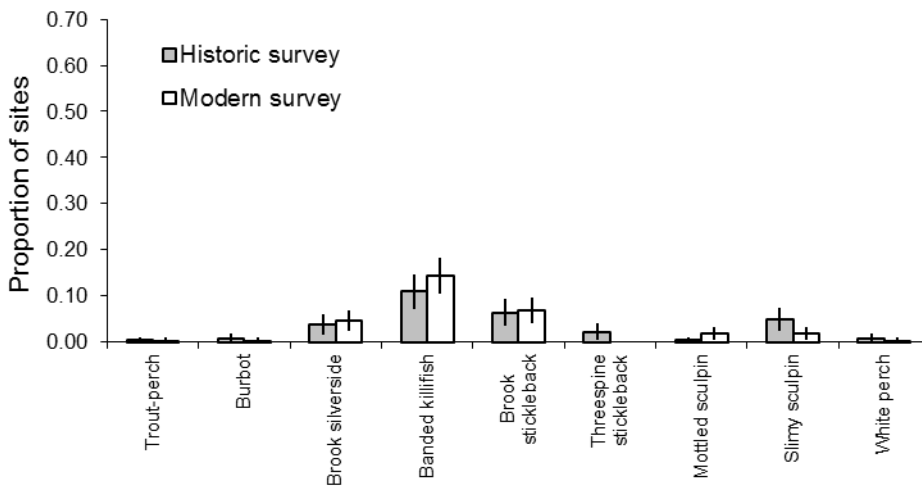


Figure A16-6. Catches (proportion of sites where detected) of fish species in the St. Lawrence River Watershed from historic and modern stream surveys. Families Percopsidae, Gadidae, Atherinopsidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

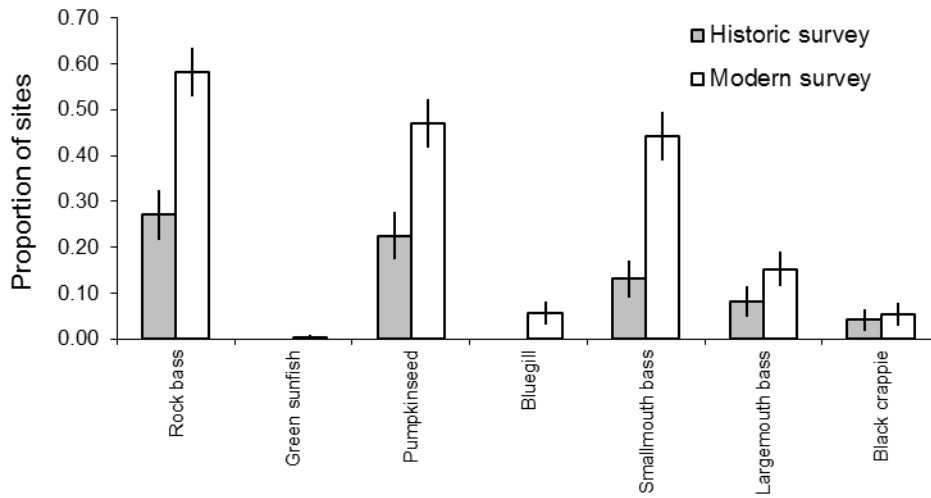


Figure A16-7. Catches (proportion of sites where detected) of fish species in the St. Lawrence River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

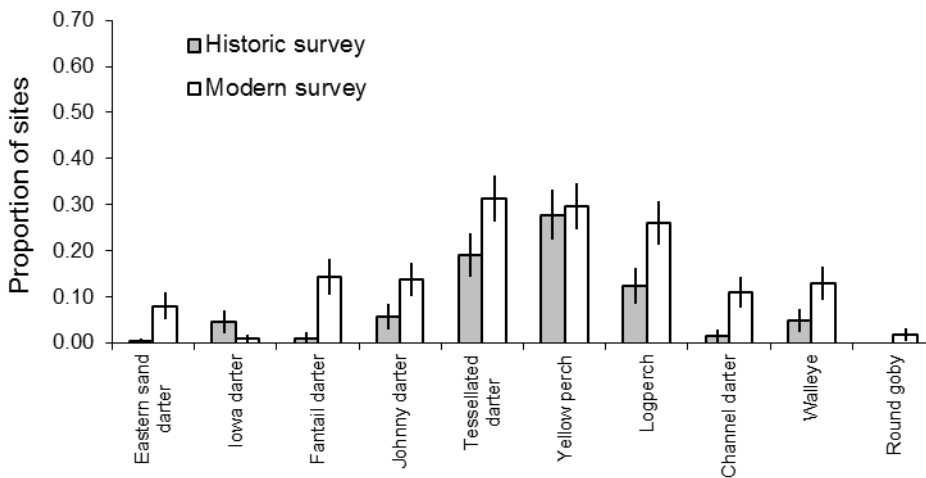


Figure A16-8. Catches (proportion of sites where detected) of fish species in the St. Lawrence River Watershed from historic and modern stream surveys. Families Percidae and Gobiidae. Error bars represent 95% confidence intervals.

SUSQUEHANNA RIVER WATERSHED



Table A17. Catches (proportion of sites where detected) of fish species in the Susquehanna River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 70, Bonferroni inequality correction for significance: $0.05/70 = 0.0007$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=369)	Proportion of sites – Modern (n=200)	Direction of change	Fisher's exact test <i>p</i> -value
Family Petromyzontidae				
Sea lamprey	0.005	0.000		0.543
Family Anguillidae				
American eel	0.022	0.000		0.056
Family Clupeidae				
American shad	0.000	0.005		0.352
Family Cyprinidae				
Central stoneroller	0.241	0.305		0.111
Goldfish	0.003	0.000		1.000
Redside dace	0.217	0.040	-	<0.0001
Satinfin shiner	0.141	0.010	-	<0.0001
Spotfin shiner	0.041	0.195	+	<0.0001
Common carp	0.008	0.020		0.248
Cutlip minnow	0.493	0.505		0.793
Common shiner	0.762	0.405	-	<0.0001
Pearl dace	0.073	0.050		0.373
Hornyhead chub	0.000	0.025		0.005
River chub	0.198	0.120		0.020
Golden shiner	0.046	0.085		0.066
Comely shiner	0.149	0.015	-	<0.0001
Emerald shiner	0.003	0.015		0.127
Bridle shiner	0.052	0.015		0.039
Blackchin shiner	0.008	0.000		0.555
Blacknose shiner	0.005	0.000		0.543
Spottail shiner	0.252	0.090	-	<0.0001
Swallowtail shiner	0.098	0.020	-	0.0003
Rosyface shiner	0.087	0.300	+	<0.0001
Sand shiner	0.000	0.025		0.005
Mimic shiner	0.000	0.150	+	<0.0001
Bluntnose minnow	0.092	0.385	+	<0.0001
Fathead minnow	0.016	0.150	+	<0.0001
Eastern blacknose dace	0.583	0.395	-	<0.0001
Longnose dace	0.396	0.400		0.929
Creek chub	0.591	0.415	-	<0.0001
Fallfish	0.477	0.315	-	0.0002
Family Catostomidae				
Quillback	0.000	0.005		0.352
Longnose sucker	0.003	0.000		1.000
White sucker	0.672	0.610		0.142
Eastern creek chubsucker	0.071	0.030		0.056
Northern hog sucker	0.287	0.210		0.046
Shorthead redhorse	0.008	0.005		1.000
Family Ictaluridae				
Yellow bullhead	0.000	0.030		0.002
Brown bullhead	0.111	0.065		0.098

Species	Proportion of sites – Historic (n=369)	Proportion of sites – Modern (n=200)	Direction of change	Fisher's exact test <i>p</i> -value
Tadpole madtom	0.003	0.000		1.000
Margined madtom	0.171	0.305	+	0.0003
Family Salmonidae				
Rainbow trout	0.016	0.010		0.719
Brown trout	0.054	0.130		0.002
Brook trout	0.057	0.100		0.063
Family Esocidae				
Redfin pickerel	0.003	0.000		1.000
Northern pike	0.000	0.025		0.005
Chain pickerel	0.244	0.110	-	<0.0001
Tiger muskellunge	0.000	0.005		0.352
Central mudminnow	0.000	0.003		0.005
Family Gadidae				
Burbot	0.005	0.035		0.011
Family Fundulidae				
Banded killifish	0.027	0.025		1.000
Family Gasterosteidae				
Brook stickleback	0.005	0.095	+	<0.0001
Family Cottidae				
Mottled sculpin	0.230	0.450	+	<0.0001
Slimy sculpin	0.024	0.025		1.000
Family Centrarchidae				
Rock bass	0.293	0.250		0.327
Redbreast sunfish	0.089	0.035		0.016
Green sunfish	0.000	0.015		0.043
Pumpkinseed	0.182	0.215		0.374
Bluegill	0.003	0.090	+	<0.0001
Smallmouth bass	0.344	0.295		0.262
Largemouth bass	0.160	0.155		0.905
Black crappie	0.008	0.009		1.000
Family Percidae				
Greenside darter	0.000	0.080	+	<0.0001
Fantail darter	0.000	0.010		0.123
Tessellated darter	0.577	0.650		0.106
Banded darter	0.000	0.135	+	<0.0001
Yellow perch	0.138	0.170		0.326
Shield darter	0.152	0.255		0.003
Walleye	0.014	0.065		0.002

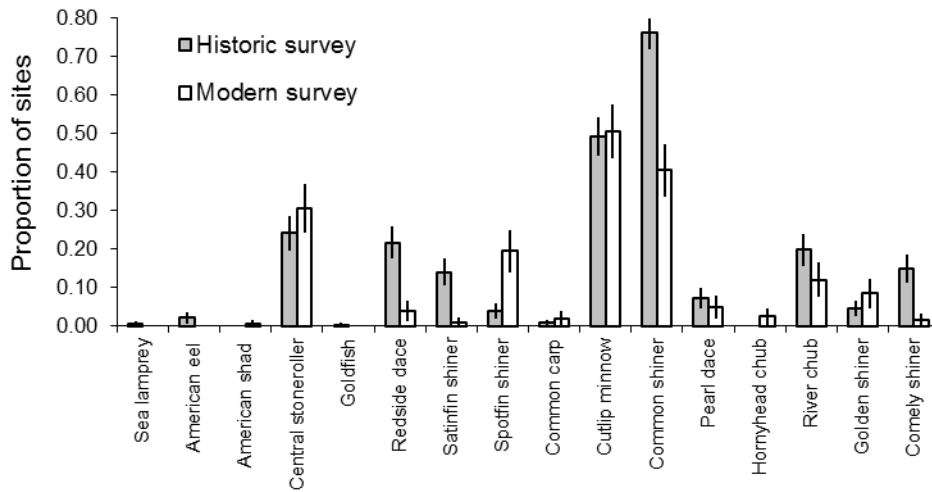


Figure A17-1. Catches (proportion of sites where detected) of fish species in the Susquehanna River Watershed from historic and modern stream surveys. Families Petromyzontidae, Anguillidae, Clupeidae, and Cyprinidae. Error bars represent 95% confidence intervals.

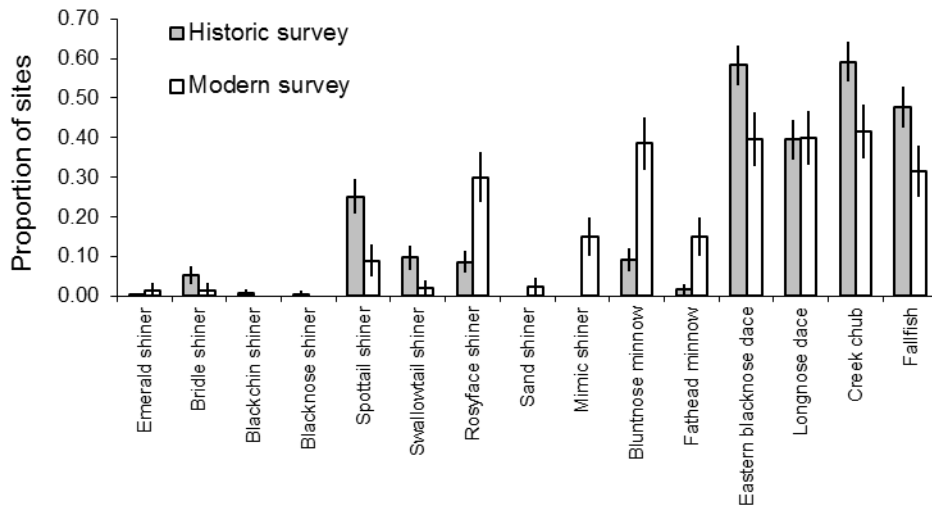


Figure A17-2. Catches (proportion of sites where detected) of fish species in the Susquehanna River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

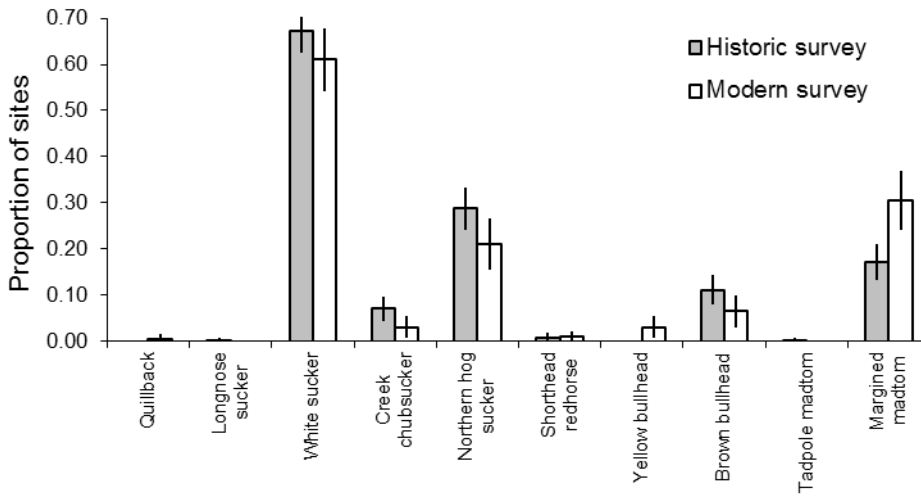


Figure A17-3. Catches (proportion of sites where detected) of fish species in the Susquehanna River Watershed from historic and modern stream surveys. Families Catostomidae and Ictaluridae. Error bars represent 95% confidence intervals.

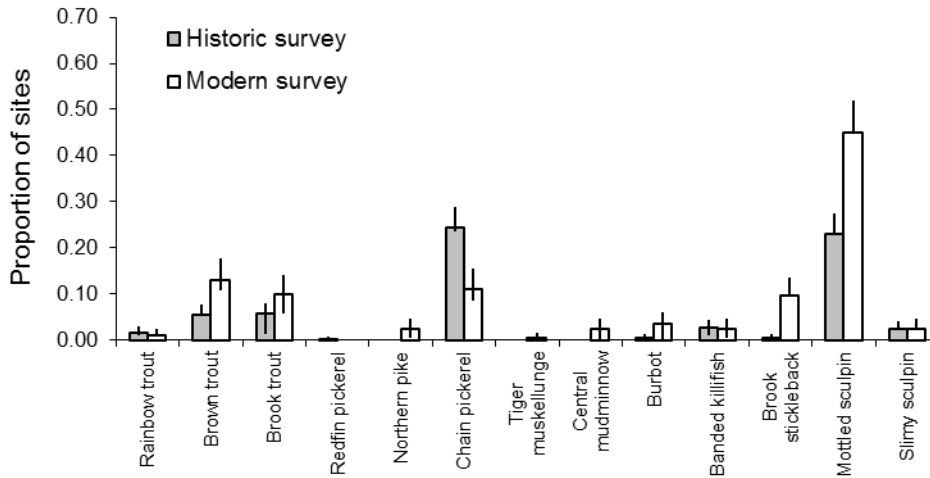


Figure A17-4. Catches (proportion of sites where detected) of fish species in the Susquehanna River Watershed from historic and modern stream surveys. Families Salmonidae, Esocidae, Gadidae, Fundulidae, Gasterosteidae, and Cottidae. Error bars represent 95% confidence intervals.

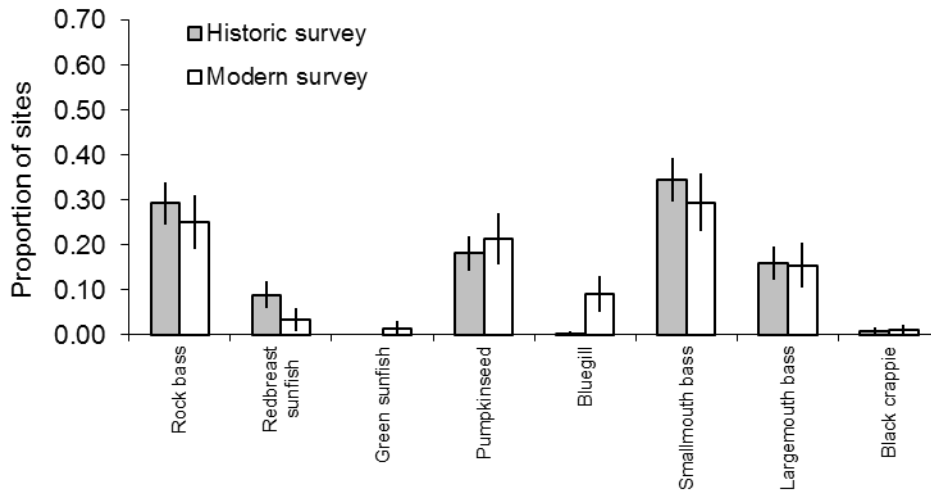


Figure A17-5. Catches (proportion of sites where detected) of fish species in the Susquehanna River Watershed from historic and modern stream surveys. Family Centrarchidae. Error bars represent 95% confidence intervals.

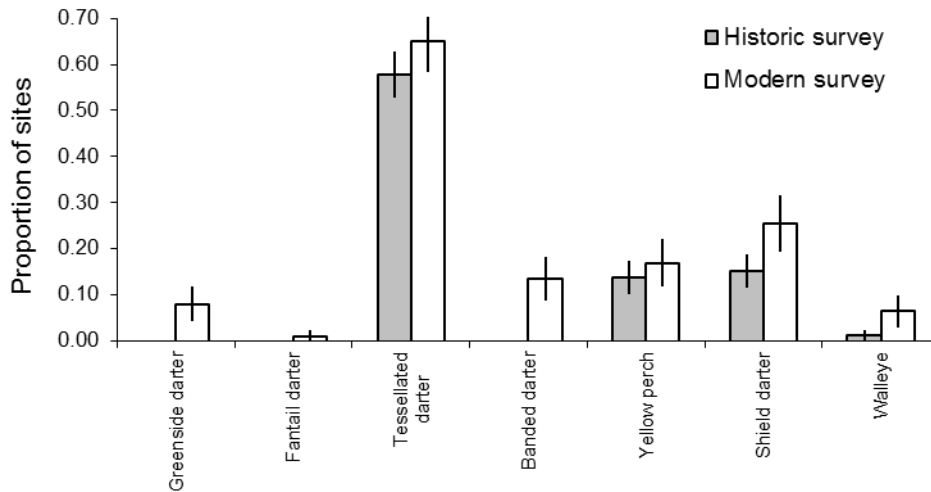


Figure A17-6. Catches (proportion of sites where detected) of fish species in the Susquehanna River Watershed from historic and modern stream surveys. Family Percidae. Error bars represent 95% confidence intervals.

UPPER HUDSON RIVER WATERSHED



Table A18. Catches (proportion of sites where detected) of fish species in the Upper Hudson River watershed from historic and modern stream surveys, and results of Fisher's exact test for differences (total number of species represented: 66, Bonferroni inequality correction for significance: $0.05/66 = 0.0008$; significant changes in distribution indicated in **bold**).

Species	Proportion of sites – Historic (n=188)	Proportion of sites – Modern (n=108)	Direction of change	Fisher's exact test p-value
Family Anguillidae				
American eel	0.016	0.000		0.556
Family Clupeidae				
Alewife	0.000	0.009		0.365
Family Cyprinidae				
Goldfish	0.021	0.000		0.300
Northern redbelly dace	0.011	0.111	+	0.0002
Lake chub	0.005	0.000		1.000
Satinfish	0.021	0.019		1.000
Spotfin shiner	0.032	0.111		0.010
Common carp	0.043	0.019		0.336
Cutlip minnow	0.197	0.389	+	0.0006
Brassy minnow	0.021	0.000		0.300
Eastern silvery minnow	0.043	0.046		1.000
Common shiner	0.442	0.556		0.070
Pearl dace	0.027	0.028		1.000
Golden shiner	0.207	0.278		0.199
Emerald shiner	0.005	0.000		1.000
Bridle shiner	0.075	0.056		0.635
Blackchin shiner	0.011	0.000		0.535
Blacknose shiner	0.000	0.009		0.365
Spottail shiner	0.069	0.120		0.141
Rosyface shiner	0.027	0.065		0.130
Sand shiner	0.000	0.009		0.365
Mimic shiner	0.000	0.056		0.002
Bluntnose minnow	0.176	0.259		0.101
Fathead minnow	0.005	0.130	+	<0.0001
Eastern blacknose dace	0.431	0.444		0.903
Longnose dace	0.255	0.232		0.677
Creek chub	0.356	0.444		0.139
Fallfish	0.229	0.046	-	<0.0001
Family Catostomidae				
Longnose sucker	0.059	0.037		0.584
White sucker	0.527	0.602		0.226
Summer sucker	0.000	0.019		0.132
Creek chubsucker	0.000	0.009		0.365
Northern hog sucker	0.011	0.056		0.055
Family Ictaluridae				
Black bullhead	0.005	0.000		1.000
Yellow bullhead	0.005	0.037		0.061
Brown bullhead	0.245	0.167		0.143
Stonecat	0.005	0.000		1.000
Tadpole madtom	0.005	0.000		1.000
Margined madtom	0.000	0.102	+	<0.0001

Species	Proportion of sites – Historic (n=188)	Proportion of sites – Modern (n=108)	Direction of change	Fisher's exact test <i>p</i> -value
Family Salmonidae				
Rainbow trout	0.016	0.056		0.078
Brown trout	0.117	0.185		0.121
Brook trout	0.165	0.139		0.619
Family Esocidae				
Redfin pickerel	0.011	0.083		0.002
Northern pike	0.085	0.028		0.082
Chain pickerel	0.085	0.157		0.083
Central mudminnow	0.000	0.102	+	<0.0001
Family Percopsidae				
Trout-perch	0.064	0.019		0.092
Family Atherinopsidae				
Brook silverside	0.000	0.028		0.048
Family Fundulidae				
Banded killifish	0.053	0.083		0.331
Family Gasterosteidae				
Fourspine stickleback	0.005	0.000		1.000
Brook stickleback	0.005	0.000		1.000
Family Cottidae				
Slimy sculpin	0.075	0.120		0.211
Family Moronidae				
White perch	0.011	0.009		1.000
Striped bass	0.000	0.009		0.365
Family Centrarchidae				
Rock bass	0.239	0.306		0.220
Redbreast sunfish	0.059	0.083		0.473
Pumpkinseed	0.271	0.528	+	<0.0001
Bluegill	0.032	0.194	+	<0.0001
Smallmouth bass	0.159	0.278		0.010
Largemouth bass	0.138	0.259		0.012
Black crappie	0.021	0.028		0.709
Family Percidae				
Fantail darter	0.000	0.019		0.132
Tessellated darter	0.202	0.500	+	<0.0001
Yellow perch	0.287	0.289		0.789
Logperch	0.037	0.157	+	0.0006
Walleye	0.027	0.000		0.163

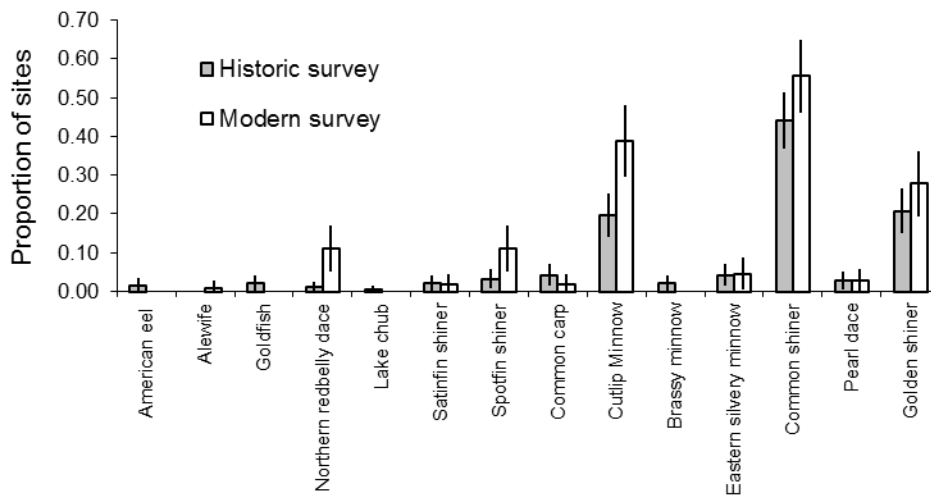


Figure A18-1. Catches (proportion of sites where detected) of fish species in the Upper Hudson River Watershed from historic and modern stream surveys. Families Anguillidae and Cyprinidae. Error bars represent 95% confidence intervals.

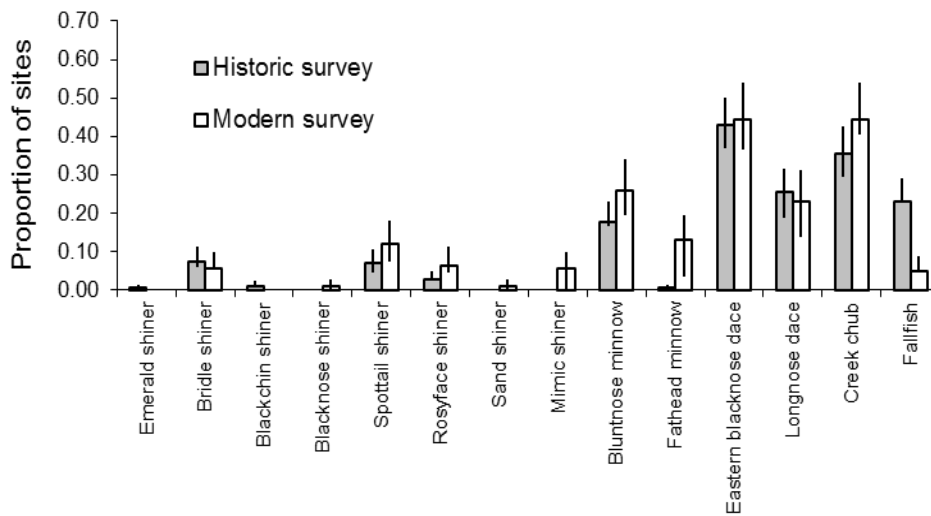


Figure A18-2. Catches (proportion of sites where detected) of fish species in the Upper Hudson River Watershed from historic and modern stream surveys. Family Cyprinidae. Error bars represent 95% confidence intervals.

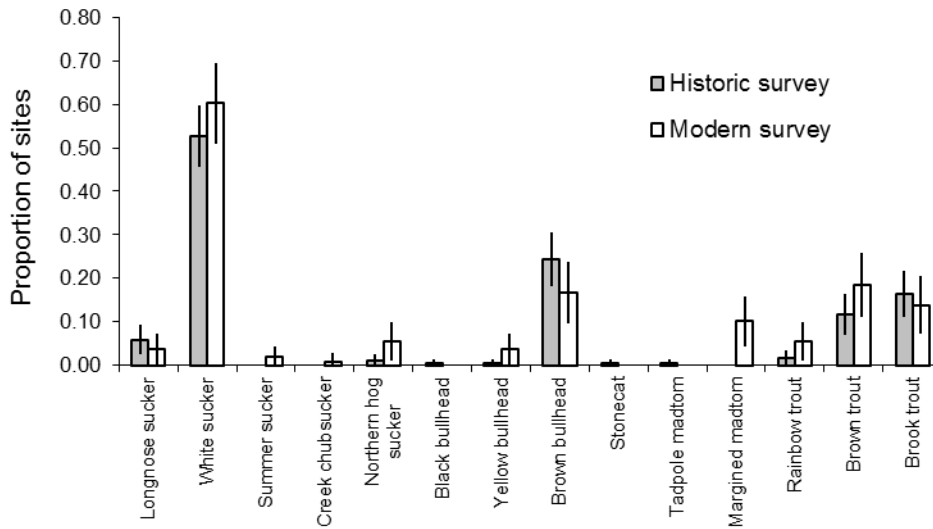


Figure A18-3. Catches (proportion of sites where detected) of fish species in the Upper Hudson River Watershed from historic and modern stream surveys. Families Catastomidae, Ictaluridae, and Salmonidae. Error bars represent 95% confidence intervals.

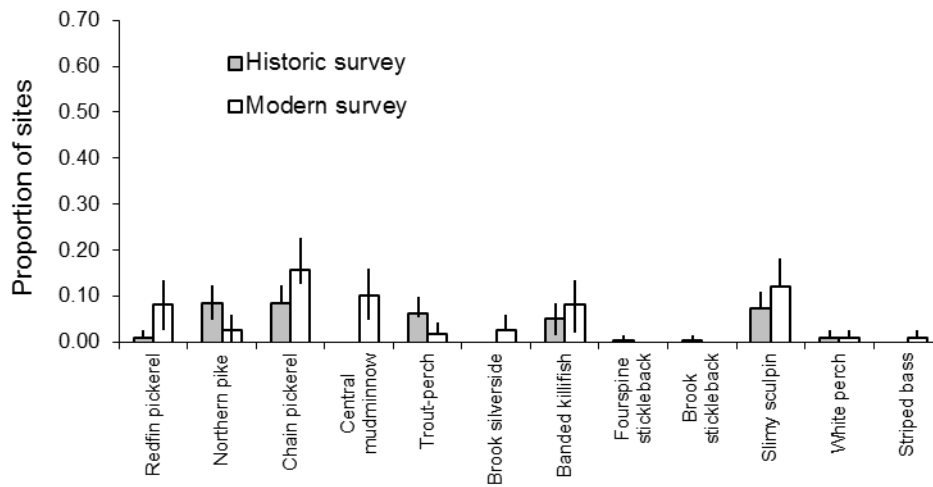


Figure A18-4. Catches (proportion of sites where detected) of fish species in the Upper Hudson River Watershed from historic and modern stream surveys. Families Essocidae, Percopsidae, Atherinopsidae, Fundulidae, Gasterosteidae, Cottidae, and Moronidae. Error bars represent 95% confidence intervals.

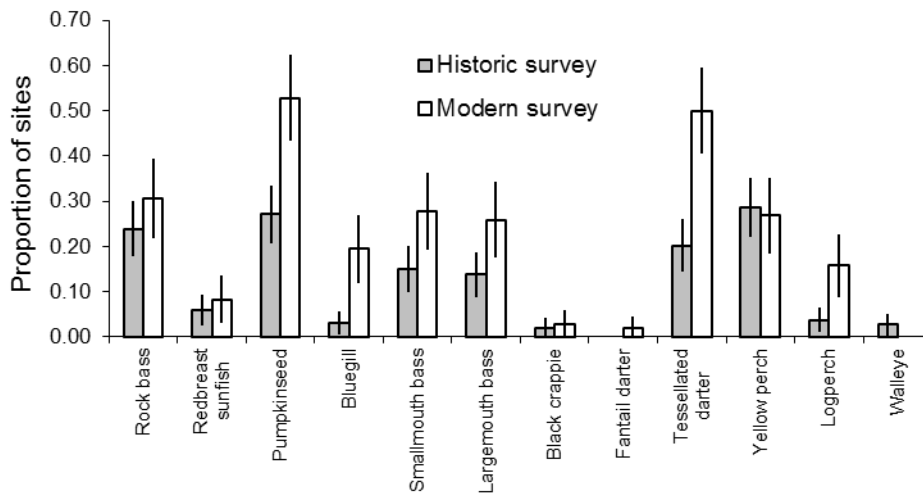


Figure A18-5. Catches (proportion of sites where detected) of fish species in the Upper Hudson River Watershed from historic and modern stream surveys. Families Centrarchidae and Percidae. Error bars represent 95% confidence intervals.