10 Effect of Wetland Quality on Sampling Bias Associated with Two Fish Survey Methods for Coastal Wetlands of the Lower Great Lakes

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10.1 INTRODUCTION

Coastal wetlands provide important spawning and nursery habitat for many fishes of the Great Lakes (Jude and Pappas 1992) and have been the target of extensive restoration and conservation efforts in Canada over the past decade (Environment Canada and U.S. Environmental Protection Agency 1999). The ecology of these coastal wetlands are known to be strongly influenced by land-use characteristics of their watersheds (Crosbie and Chow-Fraser 1999; Lougheed et al. 2001; Thoma 1999); in heavily settled regions of the Great Lakes basin, many of the coastal wetlands have been severely degraded by increased sediment and nutrient loading from agricultural and urban runoff (Maynard and Wilcox 1997). Consequently, the current status of many of the wetlands in Lakes Erie and Ontario are highly variable, ranging from severely degraded coastal marshes of western Lake Ontario and Erie, to relatively undisturbed ones of eastern Lake Ontario (Chow-Fraser 2005). To properly assess their current status and to track changes in wetlands through time, ecologists must develop robust habitat assessment tools that can be used repeatedly and that can be applied widely across all environmental conditions and physiographic regions, similar to those that exist for other aquatic ecosystems (e.g. Munné et al. 2003).

A variety of sampling gear and protocols have been used in the literature to characterize the fish communities of Great Lakes coastal wetlands, and these include *passive-capture* gears such as gill nets, trap nets, and fyke nets, as well as *active-capture* gears such as beach seines, trawls, plankton nets and electroshockers (backpack or boat electrofishing) (e.g. Chubb and Liston 1986; Stephenson 1990; Jude and Pappas 1992; Leslie and Timmins 1992; Brazner 1997). Passive gear involves the capture of fish through an

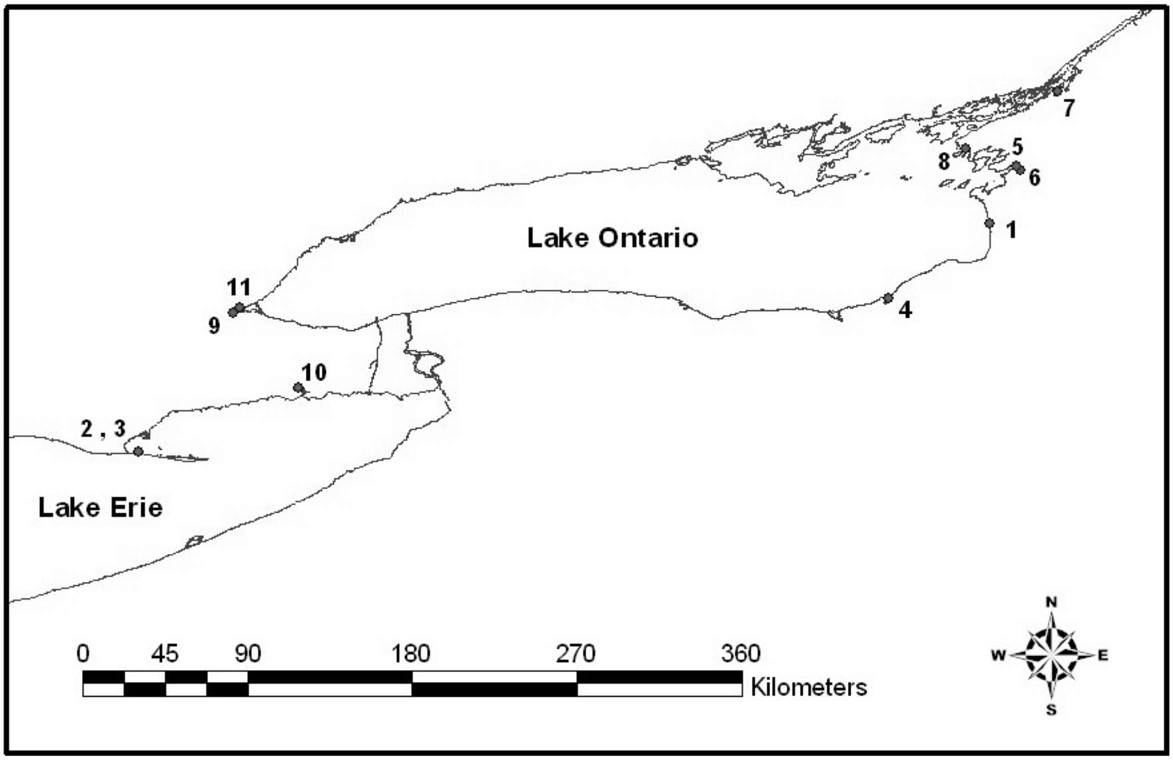

Figure 10.1 Map of wetland locations in this study. See Table 1 for wetland names associated with number codes.

1989). A good example of passive gear is the fyke net, which are most effective when they are set in pairs parallel to shore in coastal wetlands (Brazner 1997). These modified hoop nets have two wings, and a lead that connect their mouth opening. When fish swim away or into shore, they are guided into the funnel by wings and the lead. In contrast, electrofishing is an active method, since it is used to seek out fish where they occur at the time of sampling. The electrofishing unit creates an electrical field that momentarily stuns the fish and causes it to float to the surface so that it can be picked up by dip nets for processing (Reynolds 1989). The current density must be neither too low nor too high, else the fish would either escape or die, respectively.

The goal of this study is to investigate sampling biases associated with two differentsampling protocols (24-h fyke nets versus daytime boat electrofishing), both of which are currently used by researchers to develop indicators of habitat quality for coastal wetlands of the Great Lakes basin (Great Lakes Coastal Wetland Consortium; http://www.glc.org/wetlands). We wanted to compare differences with respect to the taxonomic affiliation, mode of feeding, size and number of fish caught by the two different methods. The feeding mode was of particular interest to us because fish communities tend to change from one dominated by piscivores to one dominated by benthivores and planktivores as wetlands become degraded (e.g. Chow-Fraser et al. 1998), and if sampling bias reflected differences in feeding mode of the fish, then wetland quality would be an important factor to consider. Hence, we examined the bias associated with these two gear types as a function of wetland quality. Our results will provide a scientific basis to set criteria for proper cross-study comparisons, and to guide development of meaningful long-term, basin-wide monitoring programs.

10.2 METHODS

10.2.1 Study Sites

During the summer of 2001 and 2002, we used two methods (see description below) to survey fish communities in eleven coastal wetlands of Lake Erie and Ontario (Table 10.1; Figure 10.1). Study sites were chosen to represent a range of wetland quality, based on Chow-Fraser's (2005) Wetland Water Quality Index (WQI), which classified 146 wetlands into six categories (excellent, very good, good, moderately degraded, very degraded and highly degraded), based on a suite of physico-chemical, nutrient, and water clarity variables. Five wetlands in this study had been classified as being in good or very good condition, while six had been classified as being moderately to highly degraded (Table 10.1).

TABLE 10.1.
Details of fish surveys conducted in each of the study sites. WQI scores and corresponding wetland quality category are from Chow-Fraser (2003). "EB" refers to the total shock time delivered by electrofishing boat. Names in bracket below wetland names indicate the agency responsible for electrofishing. * paired nets joined with leads.

Dates	ID #	Wetland	WQI	Wetland quality	No. of fyke nets		EB Time (sec)
					Large	Small	
7/18/01	1	Sandy Creek (USFWS Amherst)	1.226	Very good	2	1*	823
6/26/01	2	Long Point Prov Park (OMNR Port Dover)	0.954	Good	1	0	1000
6/26/01	3	Long Point Big Rice Bay (OMNR Port Dover)	0.760	Good	1	0	1000
7/19/01	4	Little Sodus Bay (USFWS Amherst)	0.417	Good	2	1*	1151
6/27/02	5	Perch River (USFWS Amherst)	0.162	Good	2*	1*	1116
6/26/02	6	Goose Bay (USFWS Amherst)	-0.050	Moderately degraded	2*	1*	942
6/27/02	7	Muskellunge River (USFWS Amherst)	-0.097	Moderately degraded	2*	1*	1204
6/25/02	8	Mud Bay (UWFWS Amherst)	-0.492	Moderately degraded	2*	1*	699
7/09/02	9	Cootes Paradise Marsh (RBG)	-1.019	Very degraded	2*	1*	1098
7/08/01	10	Grand River (OMNR Port Dover)	-1.791	Very degraded	2	0	1000
7/12/02	11	Grindstone Creek (RBG)	-1.813	Very degraded	2*	1*	517

10.2.2 Fish Sampling Methods

Data for this study were collected in collaboration among four different research groups/agencies. All fyke nets were set and processed by McMaster University, whereas fishing with electrofishing boat was performed by three different agencies, using slightly different protocols as indicated in Table 10.1. We purposely involved different agencies around the basin that are responsible for routine fish surveys so that our database would be a realistic reflection of the type of data that would be made available for basin-wide comparisons. We recognize that this type of collaborative sampling would introduce errors due to differences in protocols, effort and sampling gear, but we feel that the trends that emerge from such a heterogeneous database would be statistically robust and thus widely applicable. The main goal of this study was to identify possible biases associated with each method rather than to determine which of these gear types or protocols performed better overall.

10.2.2.1 Fyke nets (FN)

One to three pairs of fyke nets were deployed in each wetland (see Table 10.1 for types and numbers of nets used at each site). The large nets (3 m long; 0.9 m x 1.2 m rectangular front openings; 1.27 cm for one net and 0.19 cm nylon mesh for the other) had five 76 cm stainless steel rings forming two throats that led to a cod end, and were deployed in approximately one meter of water. In contrast, the small nets (1.5 m long; 0.9 m x 0.3 m rectangular front openings; 0.19 cm nylon mesh for both nets) could only be deployed where water depths were shallow (< 0.5 m). Wings (0.9 m x 3 meters; 0.19 cm mesh) on each side of small and large nets were oriented at a 45° angle from the front opening. For many of these, fyke nets (large or small) were joined with 7.6 m leads (0.19 cm nylon mesh). Regardless of size and number of nets used, all nets were set in pairs parallel to shore, and staked into place with six pieces of 3 m steel conduit. Parallel set-up along the shoreline was chosen over perpendicular, based on recommendations of J. Brazner (U.S. Environmental Protection Agency, Duluth, Minnesota, personal communication). To prevent death due to suffocation of air-breathing species such as turtles, ducks and small mammals, 1000-mL nalgene bottles were placed at the cod end to provide an air pocket.

Fyke nets were left to capture fish for approximately 24 h in each wetland, after which all fish that were present in the nets were removed and identified to species (according to Scott and Crossman 1998) and then released. Unknown species (especially small fish) were anesthetized, labeled, and then kept frozen until they could be identified at a later date. Their lengths were measured and later used with length-weight regressions (Schneider et al. 2000) to generate biomass estimates. When certain species were too abundant to process individually, they were grouped into size classes (small and large) and a suitable subset was measured and the average lengths were applied to the sub-groups. To the extent possible, wetland fishing occurred in areas that best represented the distribution of habitat and variation in conditions. Criteria included appropriate depth, and proximity to emergent vegetation and the presence of submergent vegetation; however, this was not always possible, especially in degraded wetlands where there were little or no submergent vegetation present during the fishing surveys.

10.2.2.2 Electrofishing boat (EB)

Usually within a day or two of sampling a wetland with fyke nets, we surveyed the same location in the wetland with an electrofishing boat. Characteristics of depth, presence/type of aquatic vegetation, and general substrate type were similar to those for FN. The actual fishing was carried out by three different agencies: U.S. Fish and Wildlife Service (USFWS) at Amherst, New York, Ontario Ministry of Natural Resources (OMNR) at Port Dover, Ontario, and Royal Botanical Gardens (RBG) at Burlington, Ontario (Table 10.1). In all cases, the EB was conducted during daylight hours. The specific protocols used by each agency will be outlined in detail below. Total effort in shock-seconds for each wetland is given in Table 10.1. In all cases, fish were processed in the manner similar to that described above for fyke net fishing. Afterwards, all fish were returned to the site of capture and released.

USFWS (Amherst, NY): Electrofishing was conducted using a 15-foot (4.6 m) jonboat outfitted with a Smith-Root 2.5 GPP electrofishing system and a 15-hp outboard motor. The boat had a single boom-mounted anode, consisting of a 36-inch (91 cm) diameter collapsible umbrella-style array, with the boat hull acting as the cathode. The anode boom was positioned at an angle of approximately 20° left of boat centerline to accommodate close-shoreline sampling. Electrofishing settings were typically 120 pulses per second DC current, with output range of 6-8 amperes GPP, powered by a 5.5 horsepower gas-powered generator. In wetlands with lower conductivity (<130 μS), output range was often limited to 4-6 amperes GPP. Boat speed was approximately 1-m • sec^{-1}, depending upon wind direction, presence of vegetation, and flow rate (if any). Shocking was conducted in linear transects, typically parallel to shore, targeting depths of approximately 1 to 1.5 m in depth. Several transects (minimum of 300 shock sec per transect) were conducted in each wetland. Effective width of area shocked was approximately 2-3 m, centered around the submerged anode (umbrella array). During sampling, one person was stationed at the bow of the boat with a long-handled fiberglass dip net to retrieve fish, while the boat operator conducted additional fish netting, as needed. All fish shocked during transects were netted and placed into a live-well on board for identification to species level and measurement (total length to the nearest mm). Any stunned fish missed during the initial pass were netted while driving back over the length of the original transect (without deploying electrofishing equipment). During 2002 sampling, a DC-powered trolling motor was used for better control of the boat, and to minimize potential disturbance to fish. In general, transparency was relatively high, but in more turbid wetlands, it was potentially more difficult to spot and retrieve stunned fish. Presence of dense aquatic vegetation posed an additional problem, as fish would sometimes become entangled in plants below the surface and were difficult to retrieve. Smaller fish (larvae, juveniles, and some cyprinids), and ictalurids (all sizes), appeared more likely to be missed as a result of sampling in heavy vegetation.

OMNR (Port Dover, ON): Ontario Ministry of Natural Resources used a 6 m centre-console boat (Smith-Root SR-20) equipped with a Smith Root GPP 7.5 electrofisher. Dual cable-drop anodes were extended on 1.5 m booms from the bow of the boat at an approximate angle of 30° from the centreline. The boat hull acted as the cathode (anode/cathode ratio 1:10 maximum). The area to be sampled was shocked with pulsed (60 pulses/sec) DC current, correcting voltage and %-range settings to maintain a power output of 4000-5000 Watts (typically 400-500 Volts and 10 Amperes). Two people retrieved fish with 3-m long dip nets. Boat speed was maintained at a slow idle, backtracking over areas where the netters failed to obtain all stunned fish on the first pass. Effort was limited to 1,000 shock sec, covering an approximate area of 5-7,000 m^2. All fish captured were placed into an aerated live-well and allowed to recover before sampling.

Royal Botanical Gardens (Burlington, ON): Royal Botanical Gardens used an 5.5 m flat-bottom Grumman. During electrofishing, propulsion was provided by a Minn Kota 2 hp electric trolling motor, to avoid disturbing the fish. The electrofisher was the Smith-Root GPP 5.0 portable electrofishing unit with a 9 hp generator, a tote barge, and a 6 m anode line and anode. The anode used a 30-cm diameter anode ring. The area to be sampled was shocked with a series of point shocks (500 Volts, 6 Amperes; 60 pulses/sec). The crew consisted of 3-4 members, with one crew member operating the anode, while the others netted the stunned fish. All fish netted in a transect were placed in a live-well. Effort varied for the number of shock seconds per wetland, but always covered a minimum of one 100-m^2 transect (50 m x 2 m).

10.2.3 Determination of Functional Feeding Categories

We consulted Scott and Crossman (1998) to determine if the species and life stage of the fish in question was primarily piscivorous, carnivorous (mainly insects and other invertebrates in diet), omnivorous (consuming algae and zooplankton), benthivorous (primarily benthic invertebrates and other organisms that reside in the sediment), herbivorous (mainly algae and plant material) or planktivorous (eating primarily zooplankton). Hence, within one species, the juveniles may be carnivorous, whereas the adults would be piscivorous (e.g. largemouth bass).

10.2.4 Statistical Analysis

All data manipulation, cross-tabulation analyses, ANOVA, non-parametric (Wilcoxon sign test) and linear regression analysis were performed with SAS JMP 4.04 on a Macintosh™ computer. We first ensured that the variables were not spatially autocorrelated (using S-plus in Arcview) before we used the Chi-square goodness-of-fit test to determine if gear type had a significant effect on the distribution of functional feeding categories in the eleven wetlands.

10.3 RESULTS

We caught 9,592 fish, representing 47 species, totalling approximately 220 kg in the eleven wetlands (Table 10.2; Figure 10.2). The 47 species were further sorted according to functional feeding categories (piscivores, carnivores, omnivores, planktivores, benthivores, and herbivores) to yield a total of 55 species-functional groups (henceforth referred to as functional taxa) that accounted for both taxonomic affiliation and diet at the different life stages of the organism. Fyke net accounted for a disproportionate amount of the total catch and biomass (88% and 58%, respectively), and a larger proportion of the total species and functional taxa encountered (85 and 84%

versus 77 and 73% for FN and EB, respectively). Despite significant differences between catch data for the two methods (Wilcoxon Sign Test; P=0.0004), the average species richness per wetland was similar (12 versus 12.9 for EB and FN, respectively). However, there was a systematic bias towards larger fish (two-way ANOVA; P<0.0001) in the EB relative to FN surveys (85.8 vs 17.2 g and 122.3 vs 63.6 cm , respectively; Table 10.2).

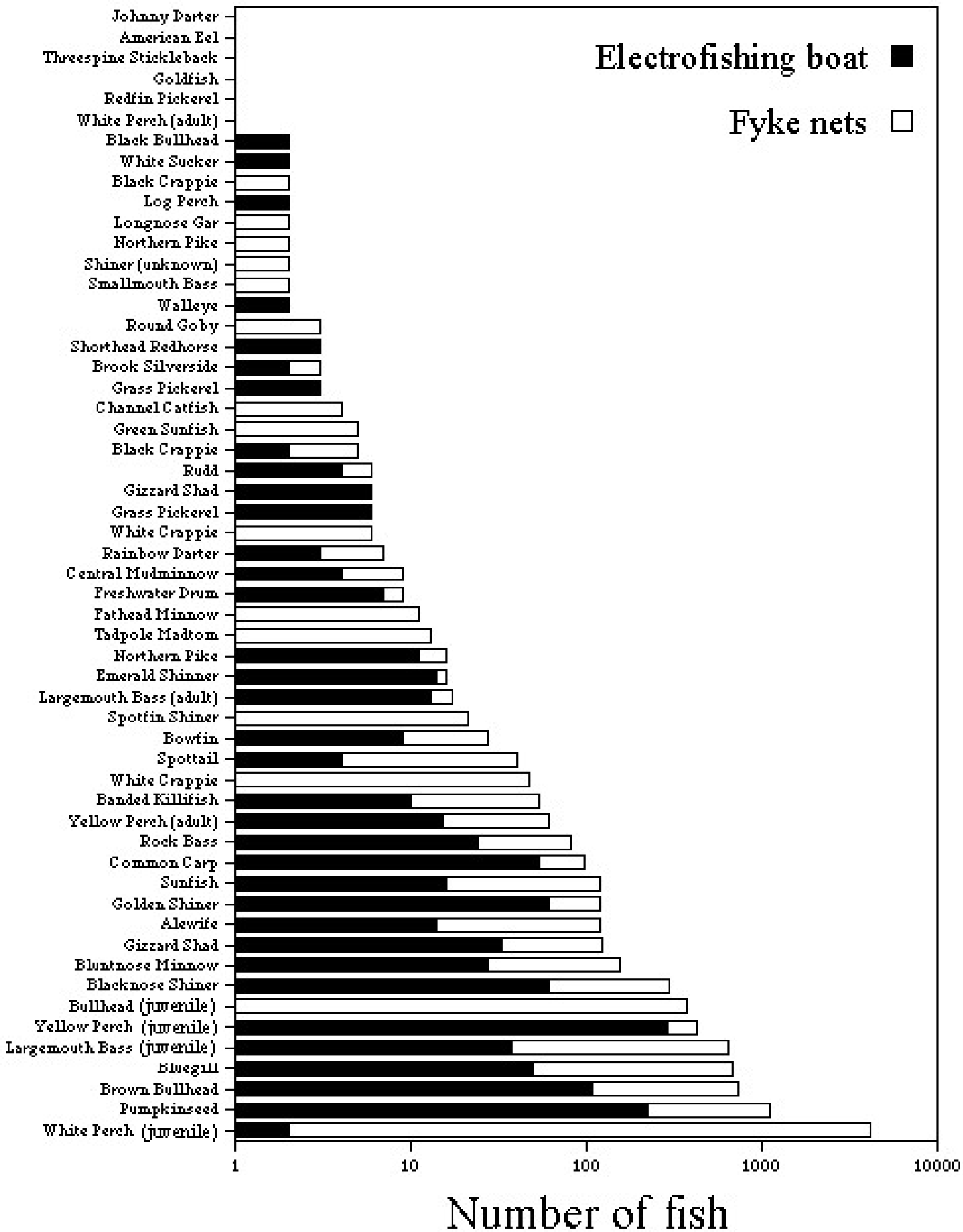

Figure 10.2 Histogram of number of fish caught in 55 taxa-functional categories according to survey method used.

Species that were encountered frequently (more than 100 occurrences in the wetlands combined) in these surveys included white perch, pumpkinseed, bluegills, juvenile largemouth bass, adult brown bullhead, yellow perch, blacknose shiner, alewife, sunfish and adult gizzard shad (Figure 10.2). Of the 55 functional taxa, six were ubiquitous, found in eight or more of the eleven wetlands when catch data from either gear type were considered (Table 10.3). These included rockbass, pumpkinseed, bluegill, juvenile and adult yellow perch, and brown bullhead. Except for juvenile yellow perch, FN recovered twice as many fish as did EB. There were similar disparities in the number of fish recovered for juvenile largemouth bass, white perch, and bullheads.

We compared how the two methods represented overall species richness in each wetland (Table 10.2). The average number of species and functional taxa recovered for both methods combined were 17.1 and 19, respectively. There were no significant differences between the mean number of species for EB and FN (11.3 versus 12.9; Wilcoxon sign test; P=0.19), nor between the number of functional taxa for either method (mean of 12.1 versus 14.2 for EB and FN, respectively; Wilcoxon sign test; P=0.14; Table 10.2). However, when we accounted for differences in wetland quality, we found a predictable bias associated with the two gear types. The number of functional taxa captured in wetlands by FN decreased significantly with WQI score (see Table 10.1) whereas that captured by EB increased significantly with WQI scores (Figure 10.3a). Therefore, there was a systematic bias towards more species being recovered by fyke net surveys in the poor-quality wetlands, and towards more species being caught by electrofishing boat in good-quality wetlands. These relationships were confirmed when we regressed the corresponding percentages against WQI scores (Figure 10.3b).

We also wanted to determine if there were sampling bias in the size of fish caught by the two methods once we accounted for differences in functional feeding groups. Functional category and gear type each had a significant effect on the mean length and mean size of fish caught, and there was also a significant interaction between these two factors (two-way ANOVA with interaction; P<0.0001 for all effect tests). Mean weight

TABLE 10.2.
Comparison of summary statistics for fish collected in wetlands in this study using the two fish survey methods (EB = Boat electrofishing; FN = Fyke nets). Where applicable, numbers in bracket indicate the SE. * This number refers to the mean number recovered for wetlands regardless of survey method.

Parameter	All fish	Survey method	
		EB	FN
No. of fish caught	9,592	1,120	8,472
% all fish caught	---	11.7	88.3
Biomass of fish (kg)	218.5	92.7	125.8
% all fish biomass	---	42.4	57.6
No. of species recovered	47	36	40
% total species recovered	---	76.6	85.1
No. functional taxa recovered	55	40	46
% total functional taxa recovered	---	72.7	83.6
Mean fish weight (g)	25.19 (±1.46)	85.82 (± 9.48)	17.17 (± 1.05)
Mean fish length (cm)	70.5 (± 0.62)	122.3 (± 2.83)	63.6 (± 0.56)
Mean species richness per wetland	17.1* (±0.93)	11.2 (±0.58)	12.9 (± 0.99)
Mean number of functional taxa per wetland	19.0* (±0.84)	12.1 (±0.76)	14.2 (±1.10)
Mean no. fish per wetland	872.0 (± 384.92)	101.8 (± 17.85)	770.2 (± 382.80)

and length of benthivores, planktivores, carnivores and herbivores were significantly larger for fish caught by EB (Figure 10.4a and 10.4b), whereas corresponding size of omnivores were significantly larger in FN surveys. However, there was no significant difference in the size of piscivore caught by the two sampling gear, either in regards to the mean length or mean weight.

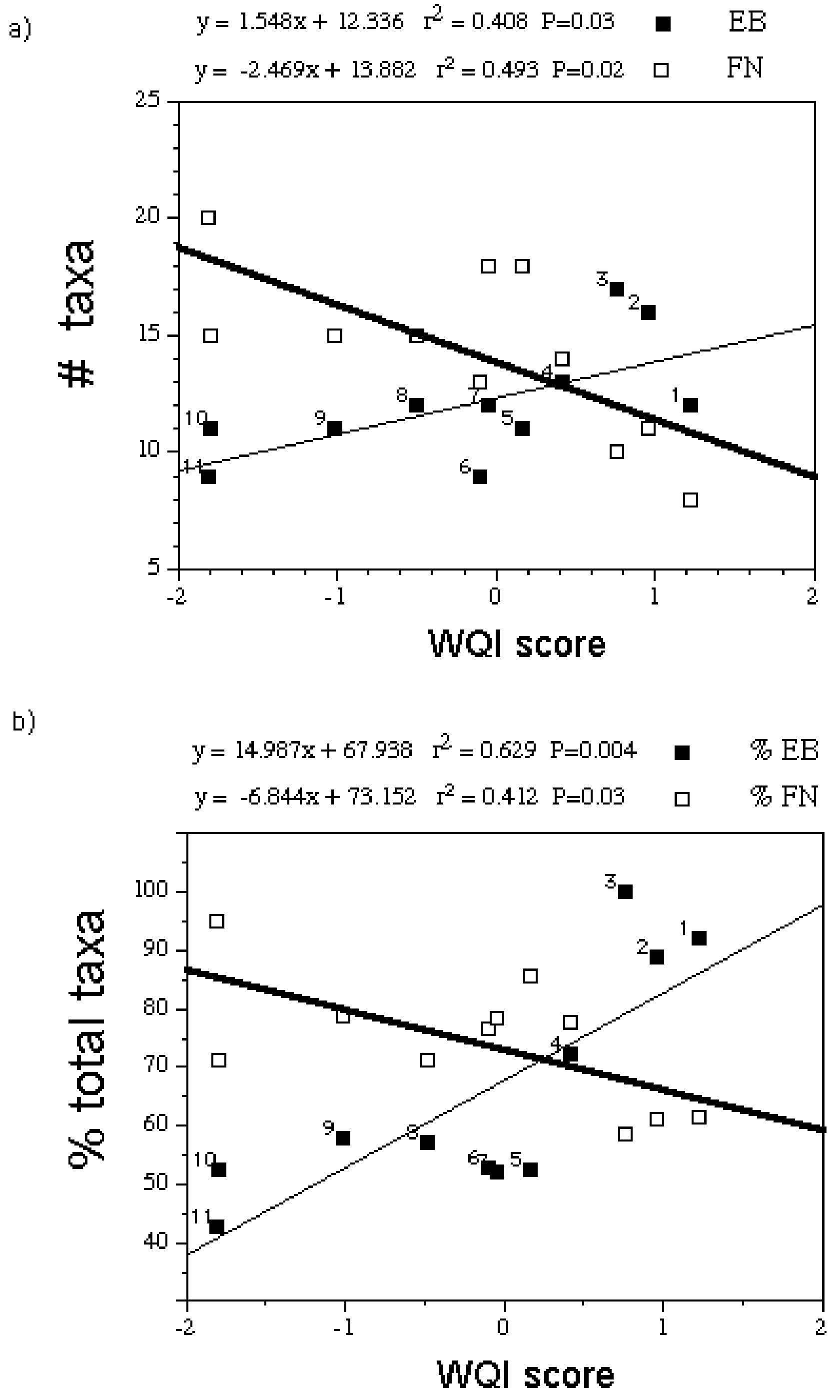

Figure 10.3 a) Number of functional taxa versus WQI score for data recovered by fyke net (open square) or by electrofishing boat (solid square). Numbers above symbols are the wetland codes (see Table 1). b) % of total number of functional taxa versus WQI score for data recovered by fyke net (open square) and electrofishing boat (solid square).

TABLE 10.3.
Total number of taxa encountered during Electrofishing Boat (EB) and Fyke net (FN) surveys in this study.

Family	Common name	Scientific name	Number of Specimens			Number of Wetlands		
			Both	EB	FN	Both	EB	FN
Carnivore								
Anguillidae	American eel	Anguilla rostrata	1	0	1	0	0	1
Atherinidae	Brook silverside	*Labidesthes sicculus*	3	2	1	0	2	1
Centrarchidae	Rock bass	*Ambloplites rupestris*	80	24	56	4	4	8
Centrarchidae	Green sunfish	*Lepomis cyanellus*	5	0	5	0	0	1
Centrarchidae	Pumpkinseed	*Lepomis gibbosus*	1110	220	890	10	11	10
Centrarchidae	Bluegill	*Lepomis macrochirus*	682	49	633	7	7	10
Centrarchidae	Sunfish (juvenile)	*Lepomis sp.*	118	16	102	2	2	5
Centrarchidae	Largemouth bass (30-70mm)	*Micropterus salmoides*	637	37	600	4	6	5
Centrarchidae	White crappie (young-of-year)	*Pomoxis annularis*	47	0	47	0	0	3
Centrarchidae	Black crappie (0-160mm)	*Pomoxis nigromaculatus*	2	0	2	0	0	1
Cyprinidae	Blacknose shiner	*Notropis heterolepis*	299	61	238	2	2	4
Cyprinidae	Spotfin shiner	*Cyprinella spilopterus*	21	1	17	0	1	2
Gasterosteidae	Threespine stickleback	*Gasterosteus aculeatus*	1	0	1	0	0	1
Esocidae	Grass pickerel (0-100mm)	*Esox a. vermiculatus*	3	3	0	0	3	0
Esocidae	Northern pike (larval/+50mm)	*Esox lucius*	2	0	2	0	0	1
Fundulida	Banded killifish	*Fundulus diaphanus*	53	10	43	4	5	6
Lepisosteidae	Longnose gar	*Lepisosteus osseus*	2	1	1	0	1	1
Moronidae	White perch (young-of-year)	*Morone americana*	4102	2	4100	1	2	2
Percidae	Logperch	*Percina caprodes*	2	2	0	0	1	0
Percidae	Yellow perch (1-150mm)	*Perca flavescens*	423	287	136	8	10	9

Family	Common name	Scientific name	Number of Specimens			Number of Wetlands		
			Both	EB	FN	Both	EB	FN
Piscivore								
Amiidae	Bowfin	*Amia calva*	27	9	18	4	5	7
Centrarchidae	Smallmouth bass (20+mm/Adults)	Micropterus dolomieu	2	0	2	0	0	2
Centrarchidae	Largemouth bass (Adult)	Micropterus salmoides	17	13	4	1	5	4
Centrarchidae	White crappie (+152mm)	*Pomoxis annularis*	6	0	6	0	0	2
Centrarchidae	Black crappie (+160mm)	*Pomoxis nigromaculatus*	5	2	3	0	2	1
Esocidae	Redfin pickerel	*Esox a. americanus*	1	0	1	0	0	1
Esocidae	Grass pickerel (+100mm)	*Esox a. vermiculatus*	6	6	0	0	4	0
Esocidae	Northern pike (Adult)	*Esox lucius*	15	11	5	2	4	4
Moronidae	White perch (Adult +178mm)	*Morone americana*	1	0	1	0	0	1
Percidae	Yellow perch (+150mm)	*Perca flavescens*	60	15	46	4	4	8
Percidae	Walleye	*Sander vitreus*	2	2	0	0	2	0
Benthivore								
Catostomidae	White sucker	*Catostomus commersonii*	2	2	0	0	1	0
Catostomidae	Shorthead redhorse	*Moxostoma macrolepidotum*	3	3	0	0	1	0
Cyprinidae	Common carp	*Cyprinus carpio*	94	53	45	2	4	3
Cyprinidae	Bluntnose minnow	*Pimephales notatus*	155	27	129	3	4	7
Cyprinidae	Rudd	*Scardinius erythrophthalmus*	6	4	2	0	2	1
Gobiidae	Round goby	*Neogobius melanostomus*	3	0	3	0	0	1
Ictaluridae	Brown bullhead	*Ameiurus nebulosus*	735	107	628	9	9	11
Ictaluridae	Black bullhead	*Ameiurus melas*	2	2	0	0	2	0
Ictaluridae	Bullhead (juvenile)	*Ameiurus sp.*	368	0	368	0	0	2
Ictaluridae	Channel catfish	*Ictalurus punctatus*	4	1	3	0	1	2

Ictaluridae	Tadpole madtom	*Noturus gyrinus*	13	0	13	0	0	4
Percidae	Rainbow darter	*Etheostoma caeruleum*	7	3	4	0	1	1
Percidae	Johnny darter	*Etheostoma nigrum*	1	0	1	0	0	1
Sciaenidae	Freshwater drum	Aplodinotus grunniens	9	7	2	1	2	1
Umbridae	Central mudminnow	*Umbra limi*	9	4	5	1	3	2
Omnivore								
Cyprinidae	Goldfish	Carassius auratus	1	1	0	0	1	0
Cyprinidae	Golden shiner	*Notemigonus crysoleucas*	120	61	59	3	7	5
Cyprinidae	Spottail shiner	*Notropis hudsonius*	40	4	36	3	3	4
Cyprinidae	Shiner (juvenile)	*Cyprinidae*	2	0	2	0	0	1
Cyprinidae	Fathead minnow	*Pimephales promelas*	11	1	10	1	1	3
Planktivore								
Clupeidae	Alewife	*Alosa pseudoharengus*	120	14	106	1	2	3
Clupeidae	Gizzard shad (0-20mm)	*Dorosoma cepedianum*	6	6	0	0	1	0
Cyprinidae	Emerald shiner	*Notropis atherinoides*	16	14	2	0	1	1
Herbivore								
Clupeidae	Gizzard shad (+20mm)	Dorosoma cepedianum	123	33	90	1	3	1

We sorted the data by functional feeding category to further examine sampling bias associated with the two gear types within wetlands. Catch data for the eleven wetlands are presented in Figure 10.5. The general tendency for FN to catch a larger number of fish was confirmed. Another obvious feature in this comparison is the distinct absence of planktivores and herbivores in the good-quality and moderately degraded wetlands (WQI scores < 0.1); only the very degraded wetlands (WQI scores > 0.1) had fish in this functional feeding group. General trends for the corresponding biomass data were very similar (Figure 10.6).

To properly test the hypothesis that there were no significant differences in fish distribution among the feeding categories that could be attributed to sampling methods used, we carried out a categorical analysis (log-likelihood ratio in Chi-square goodness-of-fit test) after first verifying that the data were not spatially autocorrelated. The results were highly significant ($P<0.0001$), confirming an effect of gear type on the distribution of fish in the six functional categories. We then performed Chi-square tests for individual wetlands to determine if all wetlands were similarly affected. To make these tests valid, we had to reduce the number of categories to three (piscivores, benthivores and others) to avoid empty cells. In all cases except for the most degraded sites (Grand River and Grindstone Creek), we found a significant effect of sampling gear on the fish distributions (Table 10.5).

We summarized all taxa that were recovered exclusively by one gear type in this survey. There were eight taxa recovered exclusively by EB, compared with ten by FN (Table 10.6). Consistent with previous trends, FN tended to catch comparatively more of the smaller individuals. All taxa recovered by EB occurred in relatively low numbers (< 6), whereas several of those caught by FN occurred in greater numbers (up to 279 individuals). Because grass pickerel had been recovered exclusively in five of the eleven wetlands by EB, we suggest that FN is not effective at sampling this taxa. Using the same reasoning, EB appears to be ineffective for sampling tadpole madtom, since this taxa was caught exclusively by FN in four of the eleven wetlands, presumably because it is a very small fish that would be difficult to catch with EB. Nevertheless, most of the other species listed in Table 10.6 occurred in low numbers (1 or 2 individuals) except for juvenile bullheads and white crappie.

We also compared the performance of the two sampling gear on a species-by-species basis; to ease comparison, data were presented according to the six functional feeding categories. Except for rock bass, both EB and FN were similar in their ability to capture carnivorous species across the full spectrum of wetland conditions (Figure 10.7). In most cases, the higher catch-per-unit effort associated with the FN method relative to EB was evident for carnivores, but this could not be said generally for the other feeding categories (Figure 10.8 and 10.9). For piscivores, however, EB was better at capturing largemouth bass and northern pike but did not appear to be as effective as FN in capturing yellow perch in degraded wetlands (Figure 10.8). Both techniques appeared to be equally effective in sampling benthivores (Figure 10.8). The main observation regarding omnivores was that FN was better at capturing these species in the degraded sites, whereas EB appeared to be better at the good-quality sites, especially for golden shiner (Figure 10.9). Both planktivores and herbivores were present only in the more disturbed wetlands, and whereas the former were caught with both gear types without any obvious bias, EB appeared to be better at capturing gizzard shad (Figure 10.9).

10.4 DISCUSSION

A variety of methods have been used to assess fish communities of Great Lakes coastal wetlands. In this study, we compared the performance of two very common methods, paired fyke nets (FN) set for 24-h, and electrofishing boat (EB) performed during the daytime. In the eleven wetlands sampled in this survey, FN recovered significantly more fish than EB per effort, and this was generally true when the data were sorted according to species or to functional feeding categories (Tables 10.3 and 10.5). However, the EB method generally caught larger fish (Table 10.2); mean weight and length of benthivores, planktivores, carnivores and herbivores caught in EB surveys were significantly larger than those caught in FN surveys (Figure 10.4a and 10.4b). A more important finding is that the quality of wetland affected the number of functional taxa captured in the wetland. As wetlands became more degraded (i.e., WQI score decreased), the number of functional taxa recovered by FN increased ($P=0.02$), whereas that recovered by EB decreased ($P=0.03$) (Figure 10.3a). These trends were upheld when we standardized the data as a percent of total functional taxa and performed the regression again ($P=0.03$ and 0.004 for FN and EB, respectively) (Figure 10.3b). Therefore, sampling bias associated with gear type was dependent on wetland quality, and when this difference was ignored, there were no significant differences in the number of species (mean of 11.3 versus 12.9 for EB and FN, respectively) or functional taxa (mean of 12.1 versus 14.2 for EB and FN, respectively) associated with the two methods (Table 10.2).

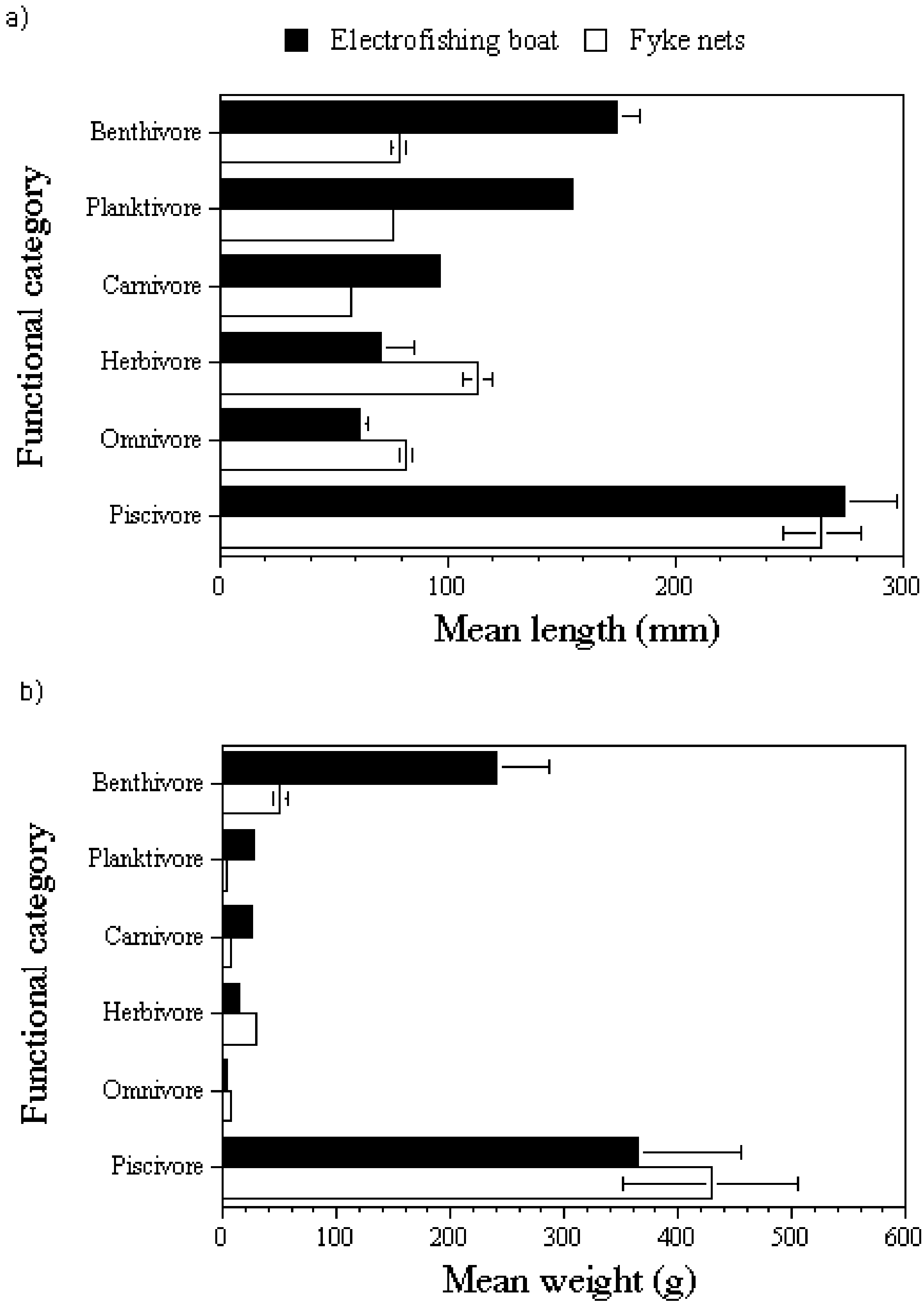

Figure 10.4 Comparison of a) mean length and b) mean weight of fish in 6 functional categories for the two survey methods.

Differences in capture efficiency observed in this study can be attributed to differences in specific features of the gear and how they operate in the wetlands. All else being equal, both the size of the frame and size of mesh used in the fyke nets will affect fish size (Hubert 1989; Shoup et al. 2003). Therefore, surveys that include both large and small (sometimes referred to as mini-fyke nets) nets would catch fish with overall smaller mean size. On the other hand, the EB will tend to select for larger fish since the total body voltage increases with length, and small fish are not as easily stunned as large fish for a given voltage. As well, larger fish are more visible to the operator and may be preferentially removed from the water column during the transect (Reynolds 1989; Wiley and Tsai 1983). That we used both small and large fyke nets in 8 of 11 wetlands (Table 10.1) may explain why the overall size of fish caught by FN was significantly smaller than that caught by EB. This tendency for EB to capture bigger fish has been well documented in other studies (e.g. Bohlin et al. 1989; Copp 1989).

TABLE 10.4.
Comparison of numbers of functional taxa captured during Electrofishing Boat (EB)and/or Fykenet (FN) surveys. "Total" refers to the total number of taxa encountered regardless of method; "EB and FN" refers to the number of taxa that were caught by both EB and FN; "EB" and "FN" refer to the number of taxa recovered by each of the methods. "Only EB" and "Only FN" refer to the number of exclusive taxa that were captured by EB or FN.
Numbers in italics are the total number of fish caught with each method. Wetlands are presented in order of WQI scores.

			Number of functional taxa captured by				
Wetland	**Lake**	**Total**	**EB and FN**	**EB**	**FN**	**Only EB**	**Only FN**
Sandy Creek	Ontario	**13**	**6**	**11**	**8**	**7**	**2**
#1		*465*		*76*	*389*		
Long Pt Prov Pk	Erie	**18**	**9**	**16**	**11**	**7**	**2**
#2		*357*		*157*	*200*		
Long Pt Big Rice	Erie	**17**	**10**	**17**	**10**	**7**	**0**
#3		*910*		*197*	*54*		
Little Sodus	Ontario	**18**	**9**	**13**	**14**	**4**	**5**
#4		*415*		*127*	*288*		
Perch River	Ontario	**21**	**8**	**11**	**18**	**3**	**10**
#5		*580*		*70*	*510*		
Goose Bay	Ontario	**17**	**5**	**12**	**13**	**8**	**8**
#6		*335*		*108*	*227*		
Muskellunge River	Ontario	**23**	**7**	**12**	**18**	**5**	**11**
#7		*261*		*76*	*185*		
Mud Bay	Ontario	**21**	**6**	**12**	**15**	**6**	**9**
#8		*441*		*56*	*385*		
Cootes Paradise	Ontario	**19**	**7**	**11**	**15**	**4**	**8**
#9		*4631*		*121*	*4510*		
Grand River	Erie	**21**	**3**	**11**	**15**	**8**	**10**
#10		*127*		*59*	*68*		
Grindstone Creek	Ontario	**21**	**8**	**9**	**20**	**1**	**12**
#11		*1070*		*29*	*1041*		

TABLE 10.5.
Summary of Chi-square statistics for functional groups. *P*<0.05 indicates that there is a significant bias in gear type used.

Wetland	Others		Piscivore		Benthivore		Total		Prob
	EB	FN	EB	FN	EB	FN	EB	FN	
Sandy Creek	66	379	4	4	6	6	76	389	0.0016
Long Point Prov Pk	138	188	12	3	7	9	157	200	0.0140
Long Point Rice Bay	210	658	12	8	19	3	241	669	<0.0001
Little Sodus Bay	115	248	9	11	3	29	127	288	0.0055
Perch River	39	161	2	3	29	346	70	510	<0.0001
Goose Bay	98	196	5	5	5	26	108	227	0.0586
Muskellunge River	45	52	7	10	24	123	76	185	<0.0001
Mud Bay	35	297	1	26	20	62	56	385	0.0020
Cootes Paradise Marsh	57	4443	0	6	64	61	121	4510	<0.0001
Grand River	31	47	6	7	22	14	59	68	0.1035
Grindstone Creek	28	924	0	3	1	115	29	1041	0.3020

The apparent shift in the fish community along the degradation gradient from one in which carnivores and piscivores dominated in the better quality wetlands (low WQI scores) to one in which planktivores and herbivores dominated in the poor-quality sites (Figures 10.5 and 10.6) is consistent with documented changes in aquatic food-webs associated with wetland degradation in Cootes Paradise Marsh, a Lake Ontario coastal wetland that became degraded by cultural eutrophication over the course of 6 decades (Chow-Fraser et al. 1998). During the 1940s, when the marsh had been extensively vegetated, piscivores such as northern pike and largemouth bass and other sunfishes dominated, and there had been many shiner species as well as rock bass that fed on the abundant insects and other invertebrates associated with macrophytes. However, as the marsh became degraded from sewage effluent over the course of the next three decades, the macrophyte community declined while the algal community proliferated and became dominated by several nitrogen-fixing blue-green species as well as filamentous and colonial green algae that formed blooms throughout the summer. The fish community that dominated this degraded state during the 1970 and 1980s consisted mainly of benthivores such as common carp and brown bullheads, planktivores such as alewife that migrated seasonally into the marsh, and gizzard shad, a herbivore that fed on the plentiful algae in the marsh (Chow-Fraser et al. 1998).

A possible explanation for the differential effect of wetland quality on the capture efficiency of the two fishing methods (Figures 10.3a and 10.3b), is that EB is better at capturing the sedentary, territorial, or less active species (Hubert 1989; Holland and Peters 1992) such as nest guarders (e.g., black crappie and largemouth bass) and ambush predators (e.g., northern pike) that tend to be associated with the well vegetated shallow environments in good-quality wetlands (Scott and Crossman 1998). This is because the electrofishing boat can cover a large sampling area and thereby increase encounter probability for these individuals within macrophyte beds. We speculate that in poor-quality wetlands, where both submergent and emergent vegetation are scarce and the shallow waters warm up during the day, the fish must migrate to the cooler, deeper water where they are not easily sampled by EB (e.g., northern pike and yellow perch in Figure 10.8). Under these degraded conditions, then, FN would be more effective because the nets could trap the fish when they migrate back inshore during the evening. Pierce et al. (2001) found that bluegills and yellow perch were caught in significantly higher numbers at night than during the day in their EB surveys. Hence, for fish that exhibit horizontal migration patterns, EB must be carried out at night to eliminate this bias. In general, fyke nets appear to be better at capturing species that school and that undergo migration between the offshore and inshore (e.g., golden shiner, Figure 10.9).

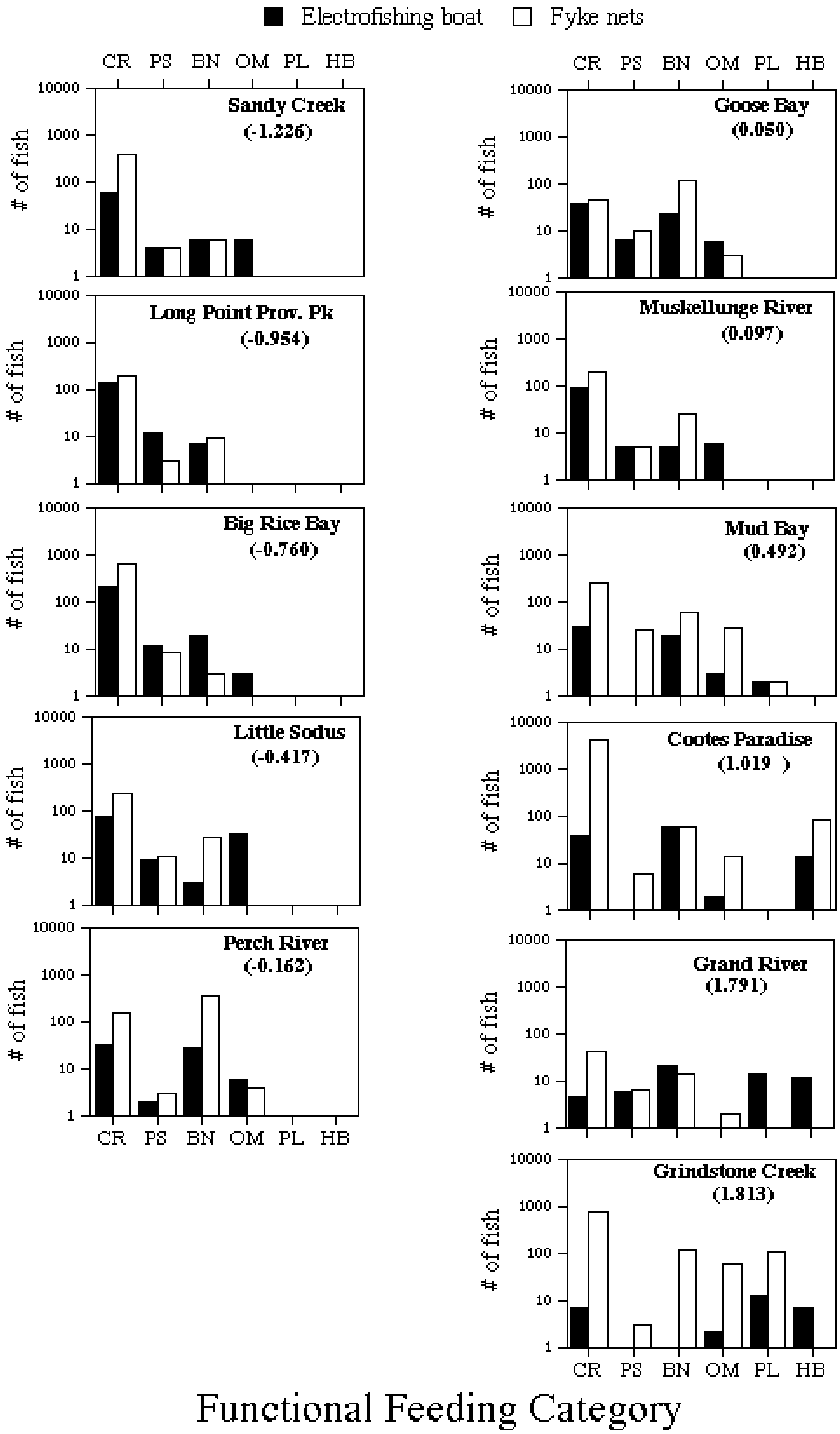

Figure 10.5 Comparison of number of fish caught in six functional feeding categories presented in descending order of wetland degradation. CR=carnivore; PS=piscivore; BN=benthivore; OM=omnivore; PL=planktivore; HB=herbivore. See Table 3 for taxa that are included in each functional feeding category.

TABLE 10.6.
Summary of taxa recovered exclusively by one gear type in this survey. Numbers are the individuals captured in each wetland. EB =electrofishing boat; FN = fyke nets.

		Wetland ID											
Species	**Method**	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**Total**
Black bullhead	EF	-	1	1	-	-	-	-	-	-	-	-	2
Freshwater drum	EF	-	-	1	-	-	-	-	-	-	6	-	7
Goldfish	EF	-	-	-	-	-	-	-	-	1	-	-	1
Grass pickerel	EF	3	2	2	1	-	1	-	-	-	-	-	9
Logperch	EF	-	-	-	-	-	-	-	-	-	2	-	2
Shorthead redhorse	EF	-	-	-	-	-	-	-	3	-	-	-	3
Walleye	EF	-	-	-	-	-	-	-	1	-	1	-	2
White sucker	EF	-	-	-	-	-	-	-	2	-	-	-	2
American eel	FN	-	-	-	-	-	-	-	1	-	-	-	1
Bullhead (juvenile)	FN	-	-	-	-	279	-	89	-	-	-	-	368
Green sunfish	FN	-	-	-	-	-	-	-	-	-	-	5	5
Johnny darter	FN	-	-	-	-	1	-	-	-	-	-	-	1
Redfin pickerel	FN	1	-	-	-	-	-	-	-	-	-	-	1
Round goby	FN	-	-	-	-	-	-	-	-	-	-	3	3
Smallmouth bass	FN	-	-	-	-	-	1	-	-	1	-	-	2
Tadpole madtom	FN	-	2	-	-	2	1	8	-	-	-	-	13
Threespine stickleback	FN	-	-	-	-	1	-	-	-	-	-	-	1
White crappie	FN	-	-	-	-	-	-	-	-	2	26	25	53

Another reason that may explain the differential performance of FN versus EB along the degradation gradient (Figure 10.3a and 10.3b) is that species that tolerate conditions in degraded wetlands are smaller (e.g., brown bullhead, shiners and gizzard shad) and are therefore not readily captured by EB as explained earlier. High turbidity normally associated with degraded wetlands can also obscure fish retrieval and this has been cited as a drawback of EB when compared with other gear such as a drop net or a pop net when sampling in vegetation (Dewey 1992). Reynolds (1989) has also noted that the fright response of fish is greater in areas with little submerged vegetation (e.g. in more degraded sites), although this response is dampened at night.

We found that capture efficiency of the two methods was affected by the life stage of some fish. For instance, we obtained greater catches with FN for juvenile largemouth bass (Figure 10.7) while greater catches were obtained with EB for mature individuals (Figure 10.8). Reynolds and Simpson (1978) also found that the capture efficiency of electrofishing techniques increased as size of largemouth bass increased, and warned that electrofishing may seriously underestimate the number of young bass.

Besides differences in capture efficiencies, each method has its own advantages and disadvantages. Fyke nets are easy to handle, require relatively little training to operate properly (Hubert 1989), and do not depend on the use of a boat, even though access to a boat can be an asset. Nets can be set in very shallow habitats (as low as 0.3 to 0.5 m), and water characteristics do not limit their effectiveness (e.g., turbidity, temperature, conductivity etc.). They can be set at anytime during the day and used throughout the ice-free season. When used properly, fyke nets will not generally harm the fish they capture (Holland and Peters 1992). On the other hand, there are a number of disadvantages. An often-cited drawback is the 24-h required to capture the fish, as well as the amount of time required to set the nets. Secondly, the gear cannot be deployed in water much deeper than 2 m. When non-target animals, such as muskrats or turtles, are inadvertently caught, they may eat some of the catch or else chew holes in the net that would allow the fish to escape.

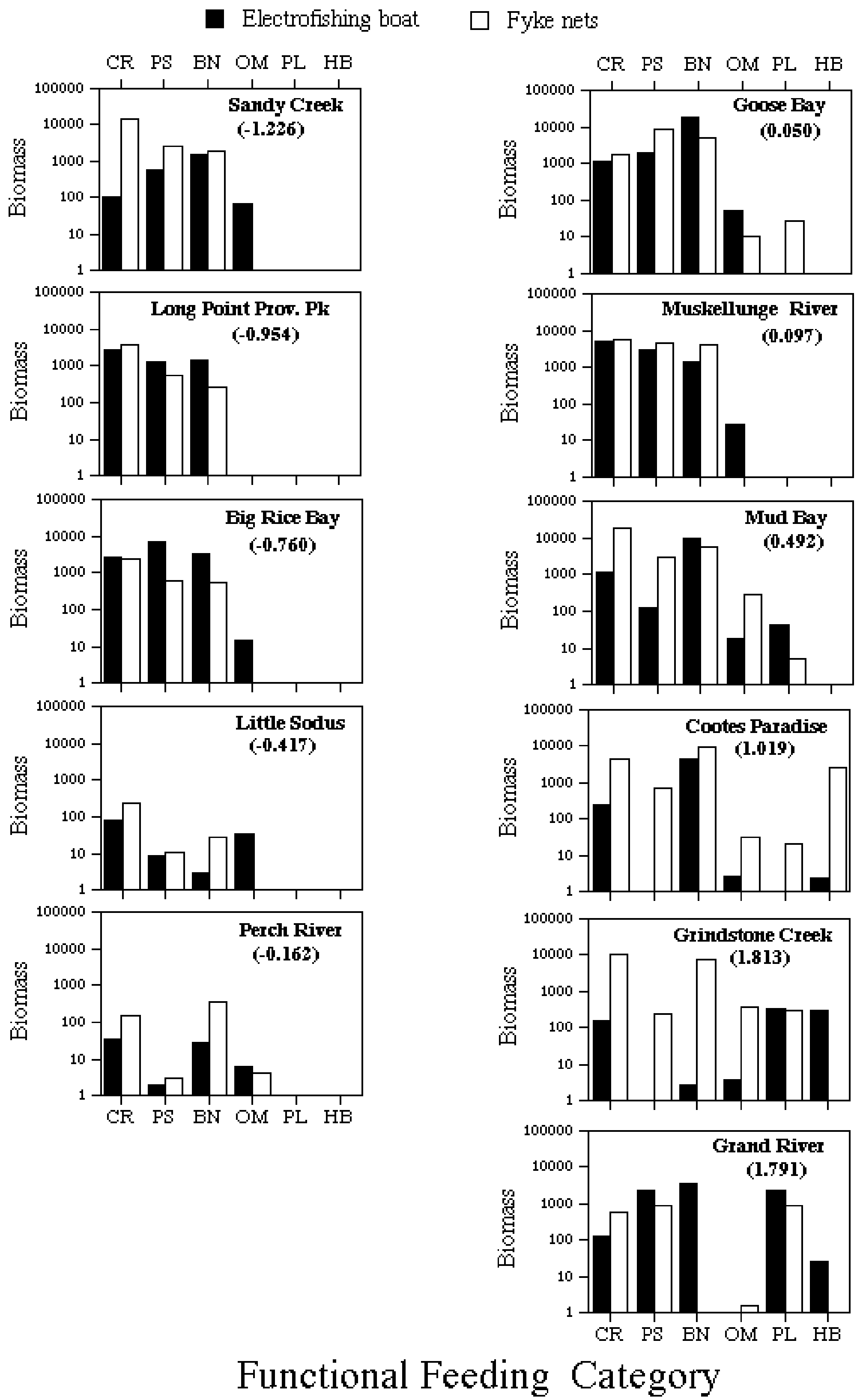

Figure 10.6 Comparison of fish biomass in six functional feeding categories presented in descending order of wetland degradation. See Figure 5 legend for explanation of functional feeding categories.

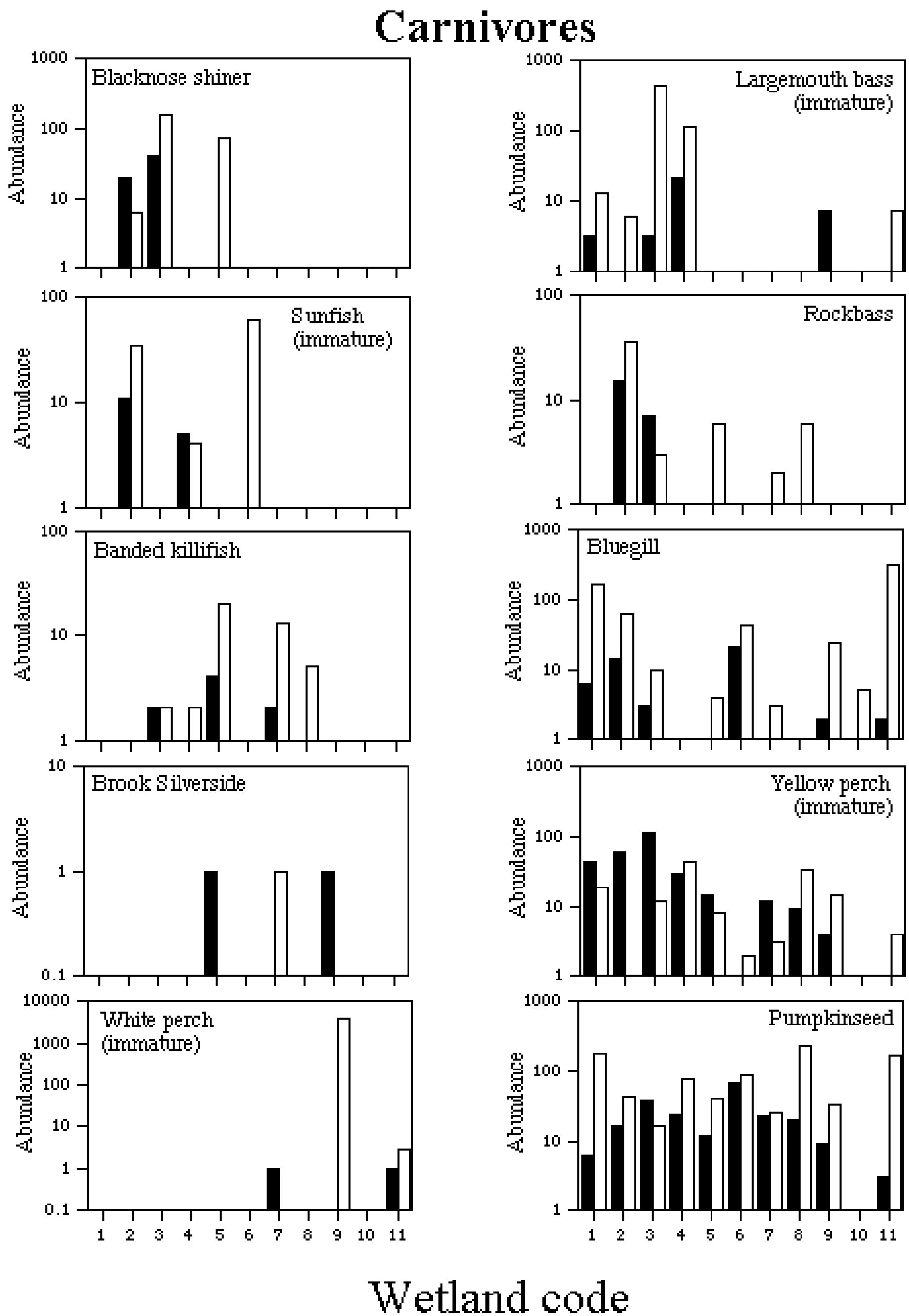

Figure 10.7 Comparison of common carnivorous species recovered by EB (solid bars) and FN (open bars) in study sites. Wetland codes are explained in Table 1.

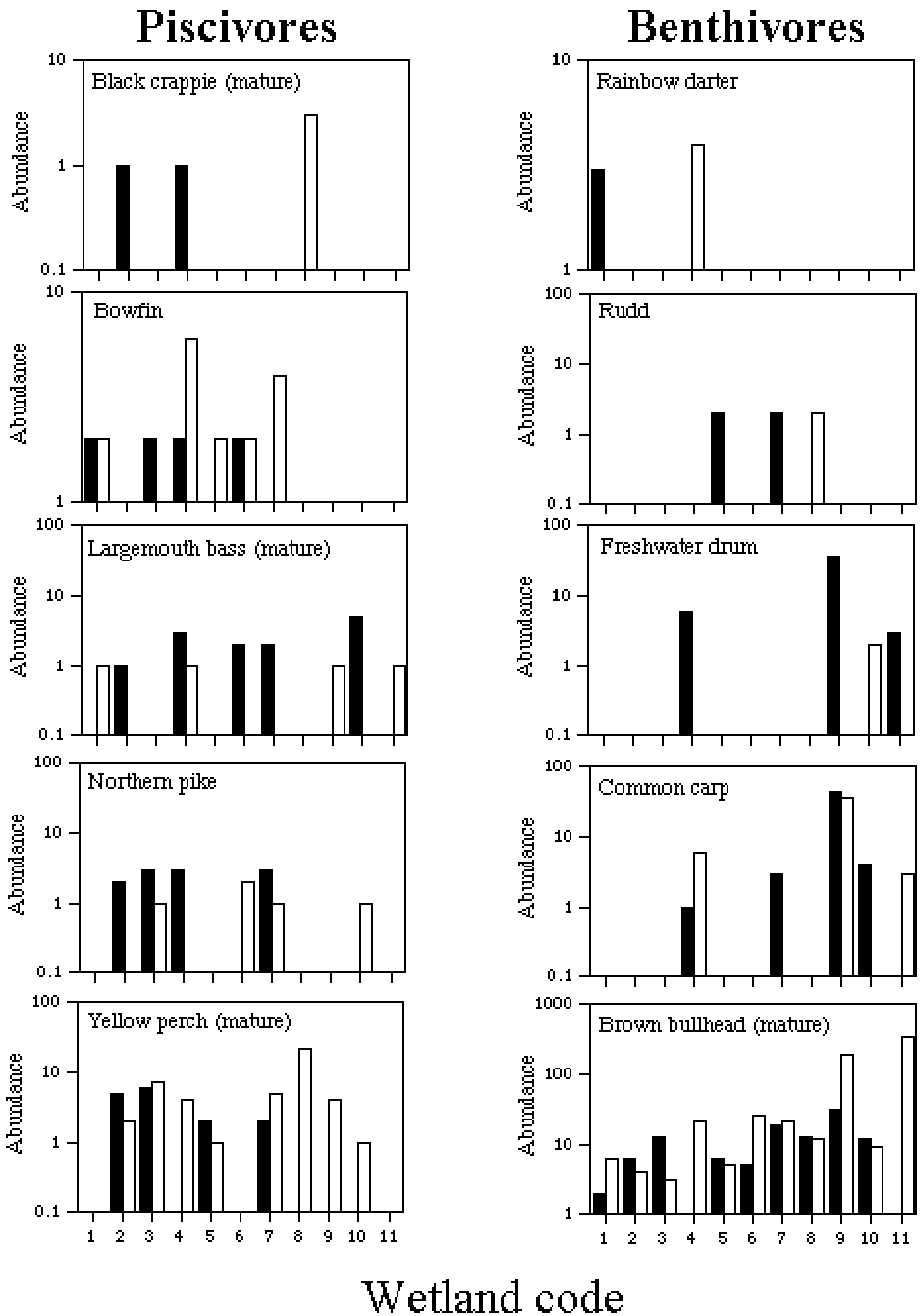

Figure 10.8 Comparison of common piscivorous and benthivorous species recovered by EB (solid bars) and FN (open bars) in study sites. Wetland codes are explained in Table 1.

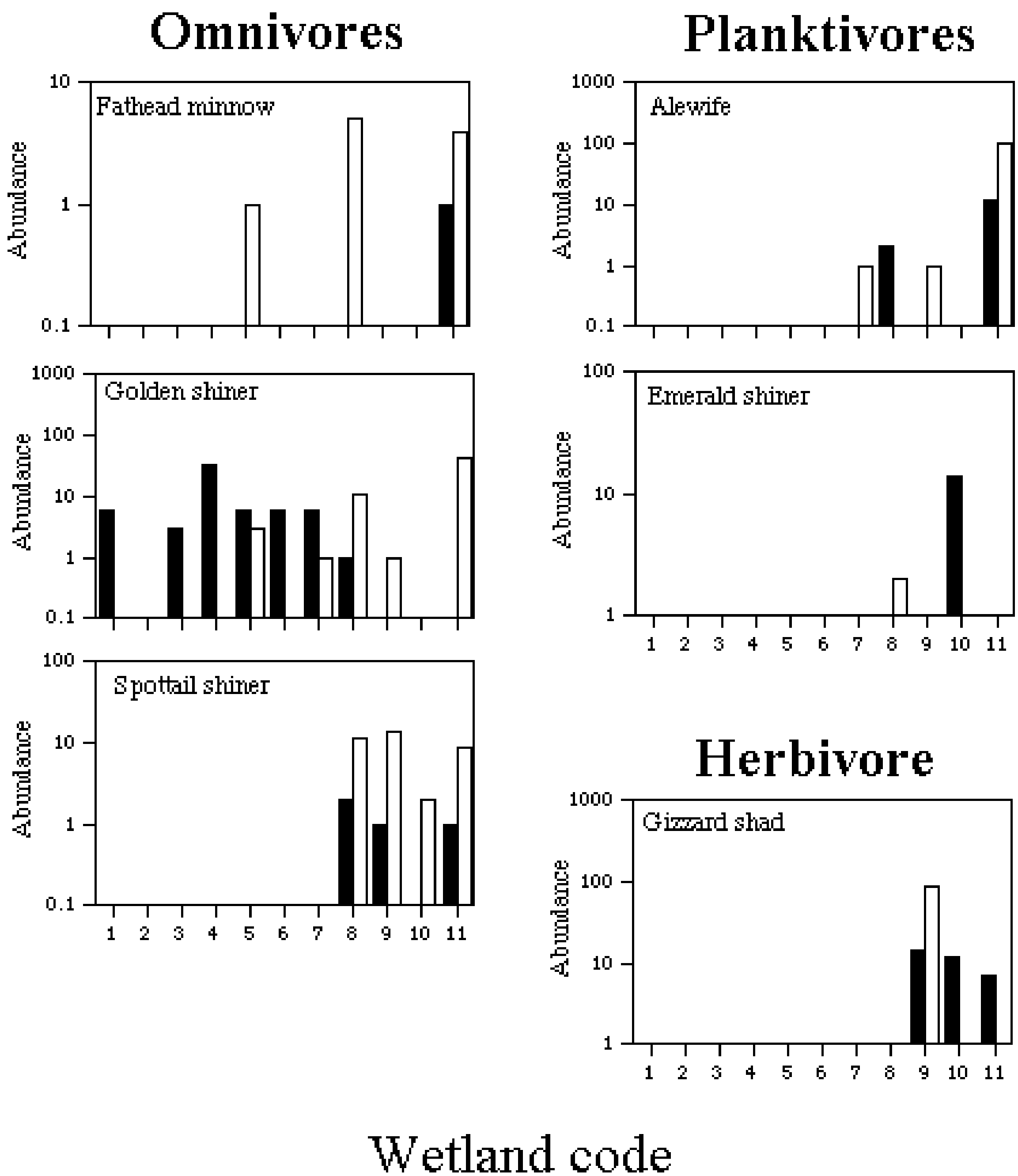

Figure 10.9 Comparison of common omnivorous, planktivorous and herbivorous species recovered by EB (solid bars) and FN (open bars) in study sites. Wetland codes are explained in Table 1.

A major advantage of using boat electrofishing in routine survey is the amount of time and labour saved per unit area (Pugh and Schramm 1998). It has been used in a wide variety of habitats, including rivers, lakes and wetlands, and can be effective for sampling large systems. However, EB requires intensive training and is expensive to purchase and to maintain. Results of the sampling may also be dependent on operator experience and the field protocol (due to the variation among agencies in this study) used as well as the degree of disturbance of the wetland (Hardin and Conner 1992). Capture efficiency can be influenced by the type of fish (e.g., bony fish conduct current more readily that cartilaginous fishes). Habitat characteristics, such as water temperature, water transparency, and dissolved oxygen concentration can also influence the efficiency of the catch (Reynolds 1989). Lastly, as was evident in this study, the type of vegetation present (Hardin and Connor 1992), time of day (e.g., Paragamian 1989) and time of season (Dumont and Dennis 1997) may all affect capture rates of certain species.

One obvious limitation of this study was involvement of different EB protocols by three different agencies, which affected the level of confidence in our conclusions. We emphasize the need for further studies involving a comparison of gear in which both the EB and FN protocols are standardized. Since FN sampling always preceded EB sampling in this study, it is possible that this systematic bias may have led to artificially lower fish abundances, and this possibility should be formally addressed in a future study.

On its own, neither EB nor FN was able to capture all of the species that both techniques could recover in any of the eleven wetlands (Table 10.4). Nevertheless, on average FN was able to catch a higher proportion of the total captured within each wetland (mean of 74 % vs. 66% for FN and EB, respectively). It is clear that when time and labour pool are available, both FN and EB should be used to survey the fish community of wetlands, a recommendation that was echoed by Fago (1998) when he compared the performance of mini fyke nets with a combination of electrofishing and small-mesh seine in Wisconsin lakes. However, when only one method can be employed, the choice should reflect the overall quality of the wetland as well as the local distribution of aquatic plants. As we have demonstrated in this study, the particular dynamics in good quality wetlands tend to make EB the preferred method, whereas degraded wetlands seem to be more effectively sampled by FN.

10.5 CONCLUSIONS

We compared sampling biases associated with two different methods (24-h fyke nets [FN] versus daytime boat electrofishing [EB]) that are commonly used to survey fish communities in coastal wetlands of the Great Lakes. During June and July of 2001 and 2002, we employed both methods to survey the fish community in eleven coastal marshes of Lakes Erie and Ontario that ranged from very degraded to excellent quality based on the Water Quality Index (WQI; scores range from -3 to +3 where a value of –3 indicates the most degraded wetland and +3 indicates the highest quality. Of the 9592 fish (totaling 218.5 kg), FN surveys accounted for 88% and 58% of the total number and biomass, respectively. Regardless of wetland quality, there was a consistently higher catch associated with FN, with an average of 770.2 (± 382.8 SE) for FN versus 101.81 (± 17.85 SE) for EB. However, the average size of the fish caught by EB was almost twice as long (122.3 ± 2.83 cm) as that caught by FN (63.6 ± 0.56 cm), and had a weight that was four times greater (85.8 ± 9.48 g versus 17.2 ± 1.05 g for EB and FN, respectively). There were no significant differences with respect to the total number of species encountered per wetland (11.2 ± 0.58 versus 12.9 ± 0.99 for EB and FN, respectively); on average, FN caught 75% of the species encountered whereas EB captured 68%.

When data were sorted according to six functional feeding categories (piscivores, benthivores, omnivores, carnivores, herbivores, planktivores), we found a significant effect of fishing method on distributions among the six categories (P=0.0001; Chi-square); further analysis of the data by wetland revealed significant effect of the method for all wetlands except the two most degraded. Eight species were recovered exclusively by EB and all occurred in relatively low numbers (<6 individuals/ species in all wetlands). By comparison, there were ten species that were captured exclusively by FN, and four were present in relatively high numbers (up to 279 individuals in one wetland). Overall, EB appeared to systematically catch larger (with respect to both size and weight) benthivores, planktivores, carnivores, and herbivores. The number of species-functional groups recovered by FN in wetlands decreased significantly (P=0.02) with WQI score, whereas that recovered by EB increased significantly (P=0.03) with WQI score. In a similar manner, the percent of total species-functional groups recovered by FN decreased significantly whereas that recovered by EB increased significantly with WQI score (P=0.03 and 0.004, respectively). Therefore, sampling bias associated with fishing method was dependent on wetland quality, a factor that should be taken into consideration in the design of large-scale sampling programs when both gear types are used, and when data from basin-wide surveys involving both gear types and sampling protocols are compared.

ACKNOWLEDGEMENTS

This project was funded by a grant from Great Lakes Fishery Commission to PC-F. We thank the following people for assisting in the field: B. Reich, S. McNair, B. Radix, J. Labuda, D. Quinn, and M. Strack. We are grateful for suggested improvements to an earlier draft from three anonymous reviewers.

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