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ABSTRACT

White catfish (*Ameiurus catus*) is native to the Hudson River and is now coexisting with the recently established channel catfish (*Ictalurus punctatus*). These species were sampled from four freshwater reaches and four habitat types of the Hudson River estuary to assess whether the two species overlapped in their habitat use, and whether any impact on the native species was evident. Catfishes were sampled in 1998 and 1999 using baited hoop nets (N = 708 net nights). Catch-per-unit-effort (CPUE, number of fish per net night; total catch = 368) of white catfish was significantly different among reaches and habitat types; CPUE was greatest in the upstream reach, and in offshore shoal habitat. Channel catfish (total catch = 344) were more abundant in offshore shoal habitats in upriver reaches, but were more abundant in nearshore and tributary mouth habitats in downstream reaches. Individuals of both species were largest upstream. Individual condition (as relative weight, *Wr*) varied with reach in white catfish, and was low in a downstream reach; in contrast, *Wr* did not vary among reaches in channel catfish. White catfish grew slowly compared to channel catfish. Relative to populations in other water bodies in North America, Hudson River fishes of both species grew slowly in their first year, but otherwise grew at expected rates. Channel catfish are becoming more abundant in the Hudson River, as white catfish appear to decline. Channel catfish establishment may be facilitated by greater flexibility in habitat use.

INTRODUCTION

This study was undertaken to determine the current status of two species of catfish in the Hudson River estuary, the white catfish (*Ameiurus catus*) and the channel catfish (*Ictalurus punctatus*); the former is native to the estuary, whereas the latter has been recently introduced. The Hudson River estuary extends from the Troy Lock and Dam at Albany to the mouth of the river in New York Bay, comprising a range of salinity and a wide range of habitats, including tidal flats, backwater coves, shoals, and deep channels (Cooper et al. 1988). Given recent sharp increases in channel catfish abundance in the estuary, there is interest in determining whether the two species overlap in their habitat use, and whether any impact on the native species is evident. The specific objectives of the research were to (1) compare relative abundance and size structure of catfishes among river reaches; (2) determine habitat associations; and (3) quantify growth rate and body condition of catfishes.

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Channel catfish is the most studied catfish species in North America (Irwin and Hubert 1999). It has been widely introduced outside its native range, including the Hudson River. The channel catfish was not reported in the Hudson River before 1979 (Beebe and Savidge 1988) but has been consistently recorded since (ASA Analysis and Communication 2003). In rivers, adult channel catfish use a variety of habitats including mainstreams (Dames et al. 1989), pools (Aadland 1993), and areas with natural and artificial cover (Layher and Maughan 1985). Channel catfish spawn in late spring, generally in or around protective cover (Gerhardt and Hubert 1990, Hubert 1999). Juvenile channel catfish used shallow habitats with slow velocities at night and main channel habitats during the day (Irwin et al. 1999).

White catfish is recreationally and economically important across its range and is native to Atlantic coastal drainages from New York to Florida, including the Hudson River (Schmidt 1986). White catfish population structure and life history were assessed in the Hudson River estuary in the early 1980's by Hughes and Carlson (1986), roughly coincident with the first appearance of the channel catfish. They found that white catfish spawned in shoal and rock pile habitats during the months of June and July, and the upper Hudson River estuary (above km 201) was the primary spawning area. These catfish were found predominantly in shoal and channel border areas throughout the year but were occasionally captured in vegetated backwater areas.

METHODS AND MATERIALS

Study sites and fish sampling

Four reaches of the Hudson River estuary were sampled, extending from Troy Lock and Dam (river km 246; hereafter, R1) downstream to Newburgh (river km 85; hereafter, R4). All reaches were freshwater and tidal and varied in their physical characteristics. R1 (km 226-246) was less than 0.5 km wide and shallower than 10 m in most sections, was channelized, had few tidal flats, had no backwaters, and contained a tailrace habitat below the lock and dam. The upstream limit of the 14.3 m navigation channel that is dredged throughout the Hudson River estuary is at the downstream end of R1. The Coxsackie reach (R2; km 185-205) was approximately 1 km wide, 20 m deep in many sections, and contained many islands, tidal flats, and vegetated backwater areas. The Kingston reach (R3; km 135-155) was approximately 1.5 km wide, over 30 m deep in some sections, and had large tidal flats and extensive vegetated backwater areas. R4 (km 85-105) was approximately 2 km wide, over 40 m deep in some sections, and contained expansive tidal flats but little vegetated backwater areas.

Catfishes were sampled from July to September 1998 and May to August 1999 using hoop nets. However, most sampling occurred during June to August of each year. Only the Troy and Coxsackie reaches were sampled in 1998, while all reaches were sampled in 1999. Hoop nets had a 0.9-m opening, 1.9-cm bar mesh, and were baited with cheese trimmings. Nets were set for 24 h and anchored to prevent their collapse with the changing tides. The total lengths and weights of all captured fishes were recorded. The right pectoral spines of five fish per 1-cm length group were removed using the methodology described by Sneed (1951).

Catfishes were sampled from tributary mouths, channel border/shoal areas (bottom shallower than the 9.8-m navigation channel but generally deeper than 4 m), and nearshore areas in all reaches. Mid-channel habitat was not sampled due to the potential conflicts with navigation and because depths were often prohibitive to effectively set hoop nets. The tailrace in R1 was also sampled. Usually, 12 nets per night were divided evenly among randomly selected habitats of each type within a reach. To select nearshore and shoal sampling locations, a global positioning system was used to locate a randomly selected latitudinal transect, and a hoop net was set in a shoal and nearshore habitat along that transect.

Population characteristics and data analyses

Relative abundance was indexed using catch-per-unit-effort (CPUE; number of fish per net night). Catch-per-unit-effort data deviated substantially from normality; thus, differences in mean CPUE among reaches and habitats were tested using the nonparametric two-way Friedman's test. Because only R1 and R2 were sampled in 1998 and all reaches were sampled in 1999, CPUE data for both years were combined to compare CPUE among reaches and among the three habitat types common to all reaches. An additional one-way Kruskal-Wallis test was used to test for differences among the four habitat types in R1. Multiple comparisons were performed using Fisher's Least Significant Difference Test. Statistical analyses were performed using the Statistical Analysis System (SAS Institute 1991)

Size structure was described using length-frequency histograms. Analysis of size structure was confined to only 1999 samples, because of evident inter year differences and larger sample sizes in that year. Insufficient sample sizes in some reaches necessitated pooling length-frequency data for the two upstream (R1 and R2) and two downstream reaches (R3 and R4), which were then compared using Kolmogorov-Smirnov tests. Body condition was quantified using the relative weight (*Wr*) index (Wege and Anderson 1978). Standard weight equations were $\log_{10}Ws = -5.851 + 3.395\log_{10}TL$ for white catfish (Bister et al. 1999) and $\log_{10}Ws = -5.800 + 3.294\log_{10}TL$ for channel catfish (Brown et al. 1995), where *Ws* is in g and TL is total length in mm. Relative weight values below 100 may indicate problems with food or feeding conditions (Anderson and Neumann 1996). Among fish larger than 200 mm, relative weight data were normally distributed and did not covary with length; hence, differences in mean *Wr* among reaches were tested using ANOVA, and multiple comparisons were performed using Fisher's Least Significant Difference Test.

Catfish spines were sectioned at the distal end of the basal groove (Sneed 1951, Marzolf 1955) at a thickness of approximately 0.60 mm using a low-speed saw. Sections were affixed to microscope slides and annular measurements were obtained using an image analysis system. Back-calculated length-at-age was determined using the direct proportion method assuming a zero intercept (DeVries and Frie 1996) and was consistent with back-calculation methods previously used to describe white catfish age and growth in the Hudson River (Hughes and Carlson 1986).

RESULTS AND DISCUSSION

Hoop nets were set for 708 net nights, and 368 white catfish and 344 channel catfish were captured (Table 1). During one sampling period (representing 22 net nights) in May 1999, 117 white catfish were captured in reach R1. This unusually large sample represented approximately one third of the entire white catfish catch and appeared to be due to high movement rates associated with a single high discharge event or with spawning activity. Thus, the sample obtained on that day was considered an outlier and was excluded from CPUE analyses; individuals from that sample were used in size structure, body condition, and age and growth analyses.

Relative abundance among reaches and habitats

Mean CPUE of white catfish was significantly different among reaches ($P<0.0001$) and habitat types ($P=0.012$), and the reach*habitat type interaction was not significant ($P>0.05$). Mean CPUE was significantly greater in reach R1 compared to all other reaches (Fig. 1). The abundance of white catfish was significantly greater in the shoals habitat, compared to nearshore and tributary mouth habitats over all reaches, and compared to nearshore, tributary mouth, and tailrace habitats in reach R1 ($P=0.0021$). This pattern of habitat use and along-estuary distribution is consistent with previous

Table 1. Reaches and habitats sampled, number of hoop net nights, and number of white catfish and channel catfish captured in the Hudson River, New York.

Reach	Habitat type	Net-nights	White catfish	Channel catfish
Troy (R1)	Nearshore	53	21	22
	Shoal	43	72	44
	Tributary mouth	54	14	42
	Tailrace	27	14	18
Coxsackie (R2)	Nearshore	119	33	46
	Shoal	80	33	49
	Tributary mouth	55	7	14
Kingston (R3)	Nearshore	71	12	10
	Shoal	46	7	4
	Tributary mouth	20	3	3
Newburgh (R4)	Nearshore	47	12	45
	Shoal	42	17	13
	Tributary mouth	29	6	34
Total	Total	686	251	344

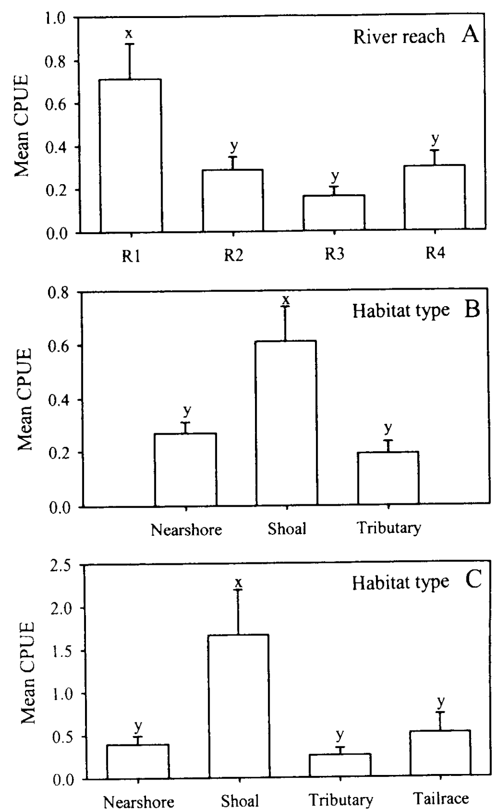

Figure 1. Mean catch-per-unit effort (CPUE; number of fish per net night) of white catfish in four reaches of the Hudson River (A), in three habitat types common to all reaches (B), and in four habitat types in the Troy reach (C). R1=Troy, R2=Coxsackie, R3=Kingston, R4=Newburgh. Means sharing the same letters are not significantly different (*P*>0.05).

findings in the Hudson River. Hughes and Carlson (1986) found that white catfish were mostly captured in offshore shoal and rock pile habitats, with lesser catches in vegetated backwater areas. They also found that most spawning of white catfish occurred in upstream reaches of the Hudson River estuary during June and July, which may explain why mean CPUE was highest in the Troy reach. Most sampling during this study occurred from June to August when white catfish were likely to be in upper reaches of the estuary.

Channel catfish were most abundant in a different habitat in the downstream reaches, providing evidence for limited spatial segregation of the two catfish species. The highest CPUE of channel catfish shifted from shoals in upstream reaches to nearshore and tributary mouth habitats in downstream reaches (Fig. 2). There was a significant interaction (P=0.0082) of CPUE among reaches and habitat types. One-way Kruskal-Wallis tests were used to test for differences in CPUE in the same habitats among reaches and among habitats within each reach. In the nearshore habitat, abundance was greater in R4 than in other reaches (P=0.012), whereas in the shoal habitat, abundance was greatest in R1 (P=0.0002). Channel catfish relative abundance tended to be highest in reaches R1 and R4 for all habitats. No differences in CPUE among habitats were found for reaches R1 to R3. However, in reach R4, relative abundance of channel catfish was higher in nearshore and tributary mouth habitats, compared to shoals (P=0.037).

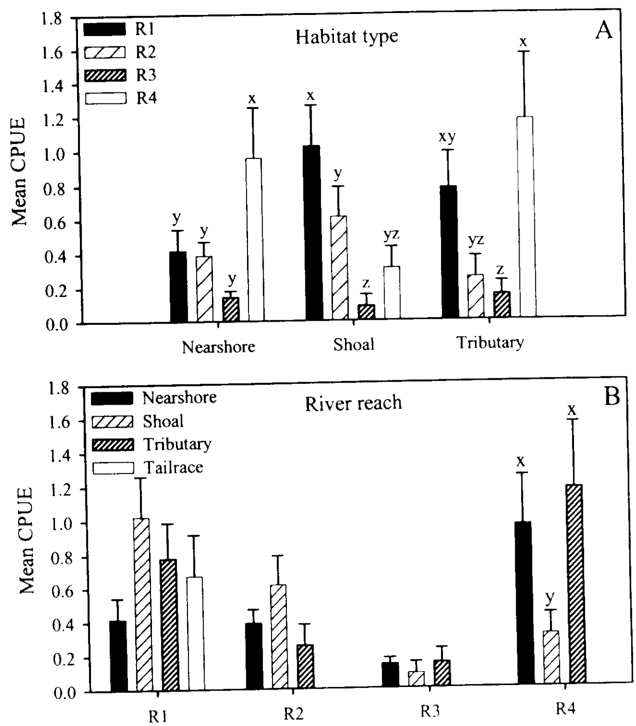

Figure 2. Mean catch-per-unit effort (CPUE; number of fish per net night) of channel catfish in three habitat types among reaches of the Hudson River (A), and among habitat types within each reach (B). R1=Troy, R2=Coxsackie, R3=Kingston, R4=Newburgh. Means sharing the same letters are not significantly different (P>0.05).

Population characteristics

Both species showed a pronounced along-estuary change in size distribution. The size ranges in upstream and downstream reaches were comparable; however, smaller size classes of both species were most abundant in downstream reaches, while intermediate and large white and channel catfish were most abundant upstream (differences in size distribution $P<0.0001$; Fig. 3).

Differences in size structure of both species between the upstream and downstream reaches may reflect size-related patterns in food availability and behavior. The largest fish of both species shared moderately deep shoal habitat in R1. This reach has moderately deep shoal and old channel habitat but lacks tidal flats and backwaters. Carlson (1989) found a high abundance of clupeids during spring at Troy Lock and Dam, and large catfishes may be taking advantage of feeding on a high concentration of prey fish. This reach may also function as a spawning ground for both species. The lower reaches have a wider range of habitats, with expansive tidal flats and low velocity zones in addition to the navigation channel and deeper shoals. Juvenile fishes favored low velocity shore zones in the Hudson River (Gladden et al. 1988, Beebe and Savidge 1988), possibly because of shelter from predation as well as high rates of invertebrate production in tidal flat areas.

There was an along-river effect on condition in white catfish. For both species, mean *Wr* was above 90 in most reaches, indicating fish were in fair condition. However, mean *Wr* of white catfish in R3 was below 90 and was lower than in R1 ($P=0.001$). Relative weight is related to growth rate and prey availability in several fish species

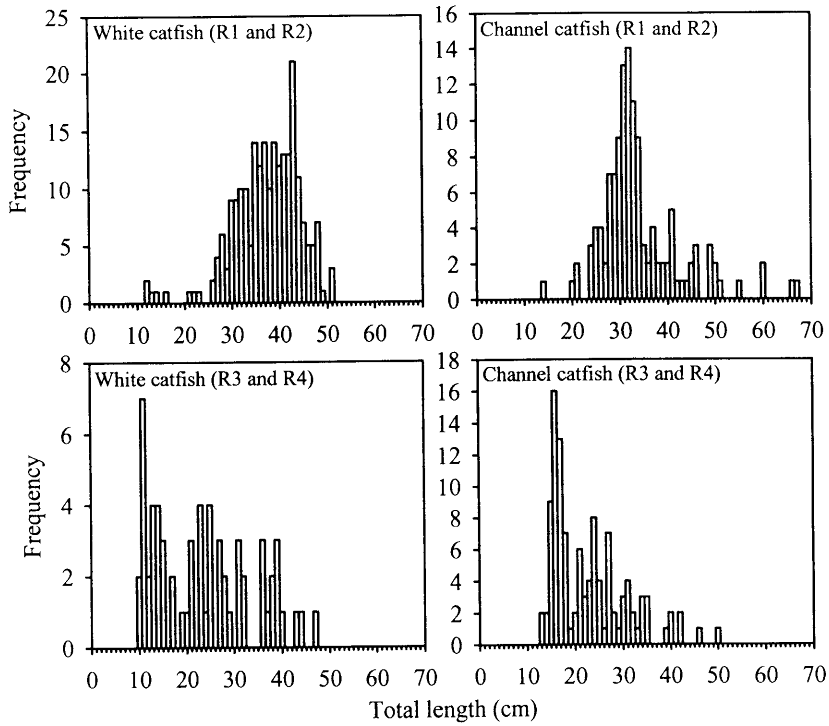

Figure 3. Length-frequency histograms for white catfish and channel catfish captured in the upper reaches (R1 and R2) and the lower reaches (R3 and R4) of the Hudson River estuary, 1999.

(Blackwell et al. 2000), and lower *Wr* values in R3 may be indicative of lower food availability compared to other reaches. There were no significant differences in *Wr* among reaches for channel catfish. Taking these results in conjunction with the observation that channel catfish in downriver reaches shifted to nearshore habitats while white catfish remained in offshore shoals, suggests that channel catfish are more flexible in habitat use according to feeding opportunity. The readiness with which this species becomes established in new rivers may be attributable to this adaptability.

White catfish are slow growing and long lived compared to channel catfish in the Hudson River (Table 2). White catfish reached stock length (20 cm) by age 3 and quality length (33 cm) by age 6. The maximum age observed for white catfish during this study was 14 years, while Hughes and Carlson (1986) aged white catfish to eight years. In the Hudson River, channel catfish reached stock length (28 cm) by age 3 and quality length (41 cm) by age 5. The oldest channel catfish captured was eight years, which is near the maximum age in many water bodies in North America (Hubert 1999). For both species, growth to age 1 appeared slow in the Hudson River, while lengths at ages greater than age 1 were similar to those reported for other waterbodies in North America.

The introduction and proliferation of channel catfish in the Hudson River could have impacts on other benthic species. Channel catfish can thrive in a wide range of environmental conditions (Hubert 1999) and is becoming well established in rivers in the northeastern U.S. In the Hudson River, the channel catfish was rare in trawl catches through the early 1990's, but its abundance has been increasing consistently since (ASA Analysis and Communication 2003). In the Connecticut River, Connecticut, the channel catfish was relatively uncommon in the early 1970's but now outnumbers white catfish in northern and central areas of the river by 59% (Jacobs and O'Donnell 1996). In the upper Delaware River, there has been a similar shift in relative abundance of the two species (S. Jinks, ASA Analysis and Communication, pers. comm.). While white catfish abundance has fluctuated periodically, the overall abundance of this species has declined coincident with channel catfish establishment.

Table 2. Mean back-calculated length-at-age (mm) of white catfish and channel catfish up to age 8 in the Hudson River, 1998 and 1999.

		Age							
Site	*N*	1	2	3	4	5	6	7	8
White catfish	169	72	154	233	285	321	349	372	391
Channel catfish	140	79	208	300	388	456	511	521	556

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