Observations on Oriental Weatherfish (*Misgurnus anguillicaudatus*), an Exotic Species in the Hudson River Valley, New York

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Abstract - We collected data on the distribution, sex, size, fecundity, and food habits of a newly discovered population of *Misgurnus anguillicaudatus* (Oriental Weatherfish) in the Hudson Valley, NY. Oriental Weatherfish were distributed throughout the Dwaar Kill in Orange and Ulster counties and at least 7 km of the Wallkill River, principally in the soft substrates of stream margins. Males were smaller than females and apparently had shorter life spans. Sexual maturity and spawning attributes were evident. Mature males had pronounced dorsolateral ridges on at least the posterior third of the body, and females exhibited post-spawning abrasions dorsal and anterior to the vent. Female Oriental Weatherfish are batch-spawners producing up to 18,000 eggs at one time. Oriental Weatherfish in the Dwaar Kill consumed a variety of aquatic macroinvertebrates and exhibited generalist feeding habits. This species does not seem to be affecting other vertebrates where currently found, but potential negative interactions with the native *Umbra pygmaea* (Eastern Mudminnow) merit attention. Monitoring of the Hudson Valley populations is needed to determine if Oriental Weatherfish abundance or range changes dramatically, and to determine if their presence is causing any lasting effects on the ecosystem.

Introduction

Misgurnus anguillicaudatus (Cantor) (Oriental Weatherfish) is a temperate fish of the family Cobitidae from eastern Asia. Fuller et al. (1999) recorded this species from 8 US states, and it is now found in 12 states including New York (USGS 2010). Introductions have resulted from aquaculture escapes or aquaria releases. Concern has been expressed about this species' potential to have negative effects on native fishes and macroinvertebrates because of its broad environmental tolerance, low vulnerability to predation, flexible diet, and high reproductive potential (Logan et al. 1996, Page and Laird 1993). A monogenetic trematode has been introduced into Australia along with this species (Dove and Ernst 1998) but has not spread from its host.

The number of non-native fishes in the tidal portion of the Hudson River has increased substantially over the past several decades, some of which are inducing changes in the estuary (Daniels et al. 2005). For instance, the invasive *Ictalurus punctatus* (Rafinesque) (Channel Catfish) is outcompeting the native *Ameiurus catus* (L.) (White Catfish), and *Aplodinotus grunniens* Rafinesque (Freshwater Drum) is becoming increasingly abundant since *Dreissena polymorpha* (Pallas) (Zebra Mussel) became established in the estuary (Daniels et al. 2005). Known invasive

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species that appear in a new locality should be monitored because it is difficult to predict how the species will react in a complex ecosystem.

In New York, an Oriental Weatherfish population in Ball Creek (Chautauqua County) has been known since at least 2001 (New York State Museum, NYSM 53924, 55379, 57313). A second population in eastern Long Island, in the vicinity of Lake Ronkonkoma (NYSM 54195, 65640) has been known since at least 2003. Neither population has been studied. In 2010, two more populations were discovered in the Schoharie Creek drainage, Mohawk River, Schoharie County (NYSM 65919, 65922), and in a tributary to the Susquehanna River, Afton, Chenango County. Discovery of a population of Oriental Weatherfish in the Hudson Valley in April 2009 was the impetus for our study to determine how widespread the species has become in the Hudson Valley and to collect life-history data on this species. These data will be useful in determining whether the founding populations of Oriental Weatherfish exhibit attributes that suggest it may become invasive in the region. Most recently, a population was discovered in 2013 (NYSM 68732, 68734) in the Klyne Esopus Kill, a Hudson River tributary ≈6 km south of the mouth of Rondout Creek in Ulster Park, Ulster County.

Methods

Study area

The first specimen of Oriental Weatherfish collected in the Hudson Valley (NYSM 64681) was near the mouth of the Dwaar Kill in Ulster County, a tributary of the Wallkill River. The Dwaar Kill is a low-gradient stream with long stretches of sandy sediment and short, rocky riffles. Most of the areas we visited were 5–7 m wide and, unless impounded, less than 1.2 m deep. There were no game fishes present, and the most common large fishes were *Catostomus commersonii* (Lacepède) (White Sucker) and the exotic *Lepomis cyanellus (*Rafinesque) (Green Sunfish). The watershed is primarily rural with several large horse farms near the Dwaar Kill.

We sampled the Dwaar Kill at the location where the first specimen was collected, and at several sites upstream including tributaries in Ulster and Orange counties (Fig. 1). Later, we sampled 5 sites in the Wallkill River upstream and downstream of the mouth of the Dwaar Kill, 4 Wallkill River tributaries, and 2 sites on the lower Rondout Creek, recipient of flow from the Wallkill River and a direct tributary to the tidal Hudson River at Kingston, NY. Two of the Wallkill River tributaries were within 2 km of the mouth of the Dwaar Kill, one was the Shawungunk Kill mouth about 7 km downstream, and the last was the Klein Kill about 18 km downstream in New Paltz, NY.

We used a Smith-Root backpack electroshocker to sample at about the same time of day (late morning–early afternoon) at each site. The Dwaar Kill and its tributaries, and the tributaries to the Wallkill River, were wadeable streams that we effectively sampled with the backpack shocker. The shocker was only effective in the shallow margins and backwaters of the Wallkill River and Rondout Creek. We determined the preferred habitat of the Oriental Weatherfish by visual observation of the catch among all available habitats. Once we defined the habitat for this species, we targeted our sampling in those areas. Fine-mesh dip-nets were used to collect young-of-the-year (YOY) Oriental Weatherfish. At each location, we sampled until we had collected 10–20 specimens, or until we had sampled all of the area available

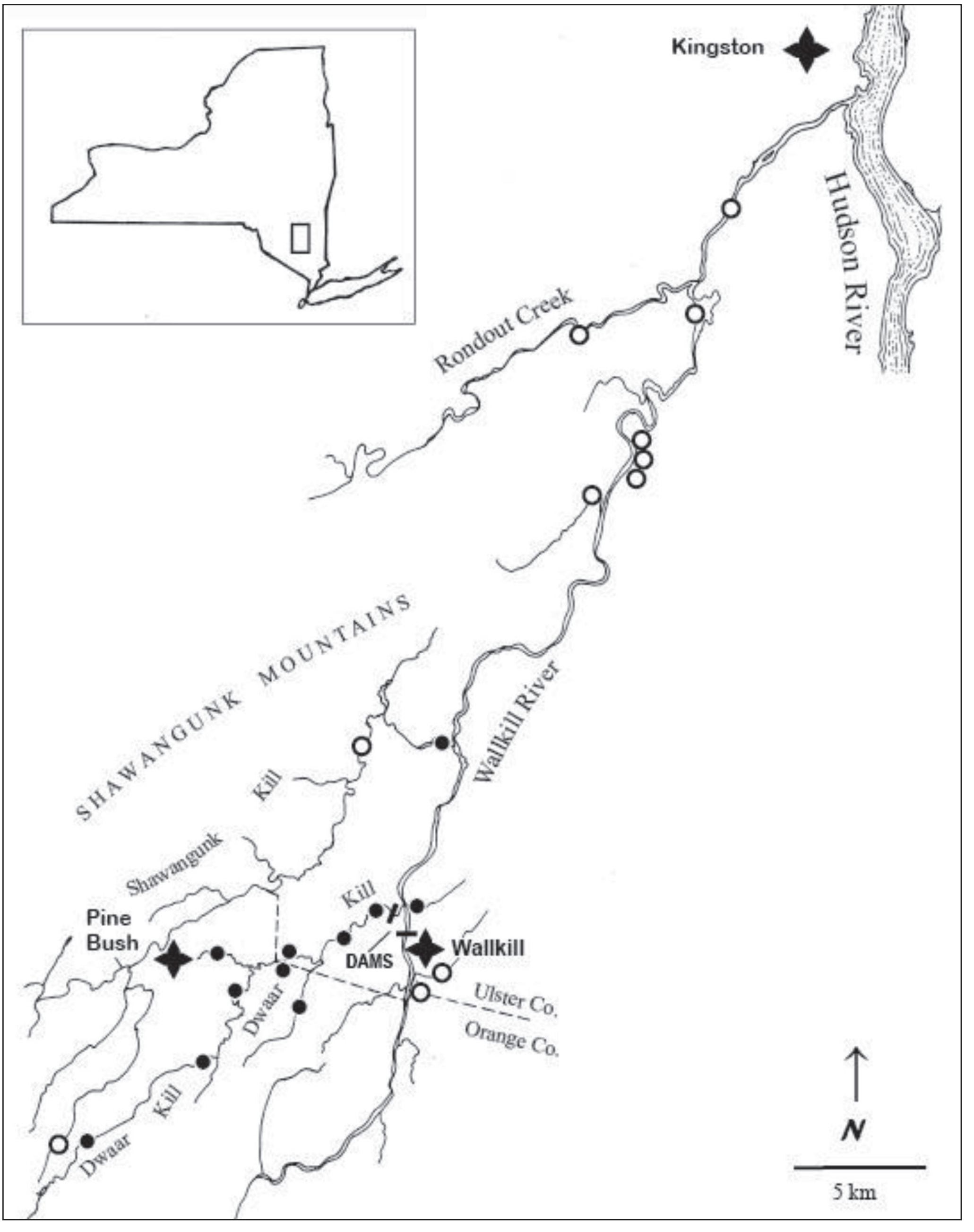

Figure 1. Map of the Dwaar Kill in Orange and Ulster counties, NY and its relationship to the downstream segments of the Wallkill River and Rondout Creek, Hudson River tributaries. Sites sampled are indicated by circles. Solid circles indicate presence of Oriental Weatherfish. Dams mentioned in the text are indicated by a line perpendicular to the stream.

(often in very small streams). We preserved specimens in 10% formalin in the field, transported them to the laboratory, catalogued them, and deposited them in the New York State Museum fish collection.

Laboratory procedures

We measured the total length (TL in cm) of each preserved specimen, weighed them to the nearest 0.1 g, and recorded the presence of external sex-specific characteristics. We kept very small specimens intact because they were difficult to find, but we dissected larger individuals. We removed ovaries and eggs from all females and weighed the fish again to obtain the ovary weight by subtraction. We examined the ovaries with a dissecting microscope (30x), classified the sizes of all eggs present, and categorized each female that had not spawned by the number of size classes present. We used an ocular micrometer to measure the diameters of a small sample of eggs from a subsample of 4 females and classified the eggs as large (average of 0.72 mm), medium (0.55 mm), and small (0.43 mm). We categorized very tiny oocytes (<0.1 mm) as primary oocytes. We weighed a sample (to the nearest 0.01 g) of the largest eggs from the females that had not spawned prior to capture, counted the eggs, and recorded the estimated total number of large eggs in the ovary.

To evaluate diet composition, we removed the anterior end of the intestine and extracted the contents. We identified food items to broad taxonomic categories (e.g., Order) and counted them.

Sex

Males are smaller than females, and breeding males are distinguished by the development of modified anterior pectoral fin rays (Breder and Rosen 1966, Urquhart and Koetsier 2011). Mature males also have a raised keel running along the body from under the dorsal fin to the caudal peduncle (Okamoto 1922, Vladykov 1935; Fig. 2). This keel seems to function as a clasping device. Males clasp females by bending their bodies around the female (see photograph in Kawanabe and Mzuno 1989). Females that had mated had mating abrasions on both sides of their bodies dorsal to the vent (Fig. 2) that were probably caused by the horny ridges on the males. We assumed that females without abrasions had not recently mated.

Results

We collected 111 Oriental Weatherfish in the Dwaar Kill including 35 females, 55 males, and 21 YOY, and we collected 8 specimens in two other tributaries of the Wallkill River.

Distribution

Oriental Weatherfish were present throughout the Dwaar Kill drainage (Fig. 1), from the headwaters near Circleville to the Bates Lane Bridge, in Wallkill. We collected specimens in 3 unnamed tributaries—on Rt. 52 east of the Dwaar Kill (designated T4 in Moore 1937), in Pine Bush west of the Dwaar Kill (T5), and in a very small undesignated tributary 0.2 km north of the Orange/Ulster County border. The species occupies a beaver pond in tributary T4, and potentially occupies a private impoundment downstream of Bates Lane, both of which were inaccessible to electrofishing with a backpack shocker.

Outside of the Dwaar Kill drainage, we collected Oriental Weatherfish in an unnamed stream tributary to the Wallkill River (T23) whose mouth was about 0.1 km upstream of the mouth of the Dwaar Kill. We also collected specimens in the mouth of the Shawangunk Kill, ≈7 km downstream (north) of the mouth of the Dwaar Kill.

Habitat use

All but 3 of the specimens collected (97.3%) were found in silty backwaters. The substrate was typically layered with dead leaves and sticks and occasionally

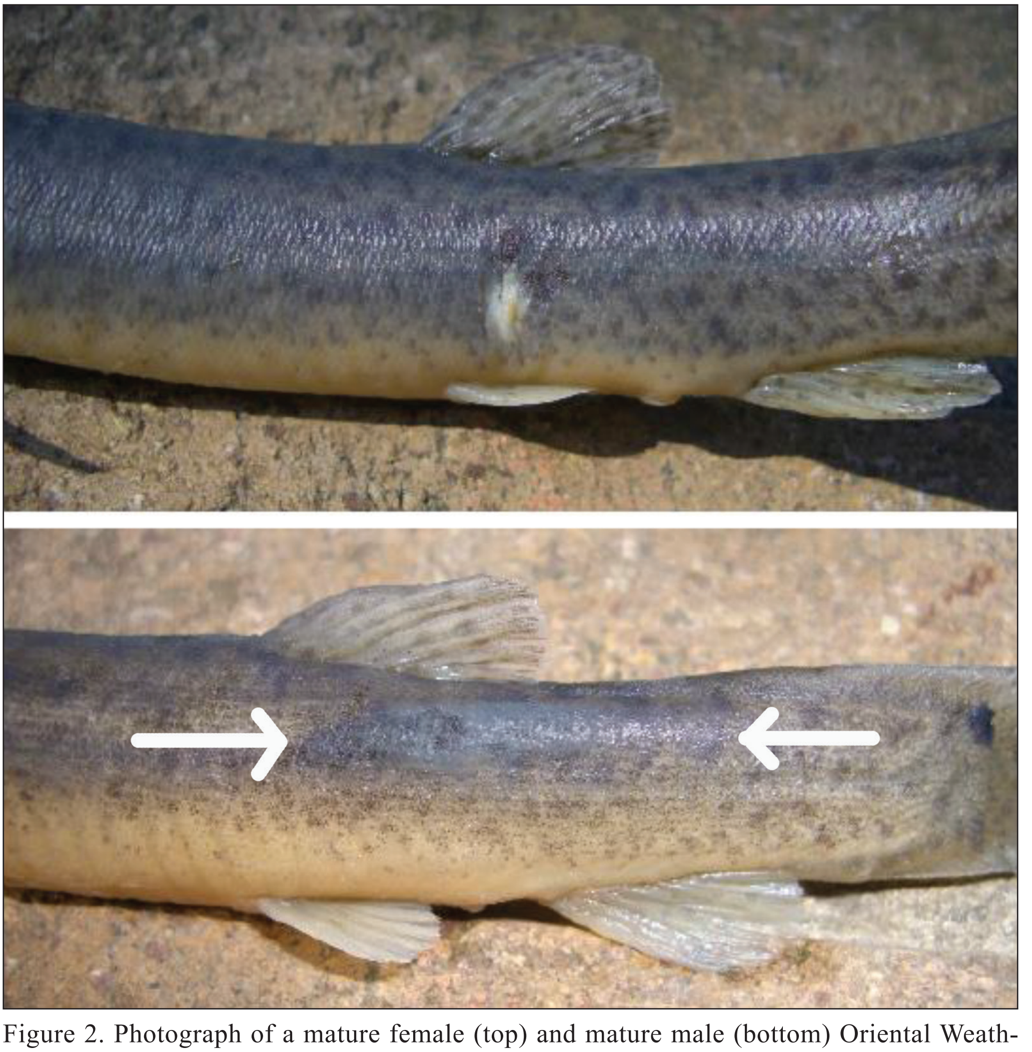

Figure 2. Photograph of a mature female (top) and mature male (bottom) Oriental Weatherfish from the Dwaar Kill, Hudson Valley, NY. Note the raised ridge on the posterior body of the male (between the two arrows: appears to be a light area) and the abraded (light) area anterior and dorsal to the vent in the female. The female has a similar abrasion on the other side of the fish.

contained vascular plants. The 3 specimens collected in rocky habitats were taken during high water. No Oriental Weatherfish were collected over sand.

Sex

A few male specimens had a second keel that extended from behind the operculum to below the dorsal fin, but this anterior keel was never contiguous with the posterior one (Vladykov 1935). This secondary keel is hard and sharp, and appears to be made from dermal elements. Most of the adult females we collected (86.7%) had spawning scars on their sides.

Size and age

Mean TL of males was 11.3 cm (range = 9.6–14.9), whereas mean TL of females was 13.2 cm (range = 9.7–16.0). Based on length frequency (Fig. 3), mature males were in their second summer (age 1) and mature females were in their second or third summer (ages 1 or 2).

Feeding habits

We examined 94 Oriental Weatherfish stomachs, of which 61 were empty. We broadly grouped stomach contents into 10 taxa (Table 1); a total of 688 food items were classified. Snails comprised 14% of the total food items, Chironomidae (midges) comprised 56%, and Simuliidae (blackflies) comprised 21%. By occurrence, snails were found in 58% of the Oriental Weatherfish that contained food and chironomid midges were seen in 68%.

There were apparent differences in food habits by location (Table 1). Fish from the Pine Bush site fed predominantly on snails and chironomids. Fish from the

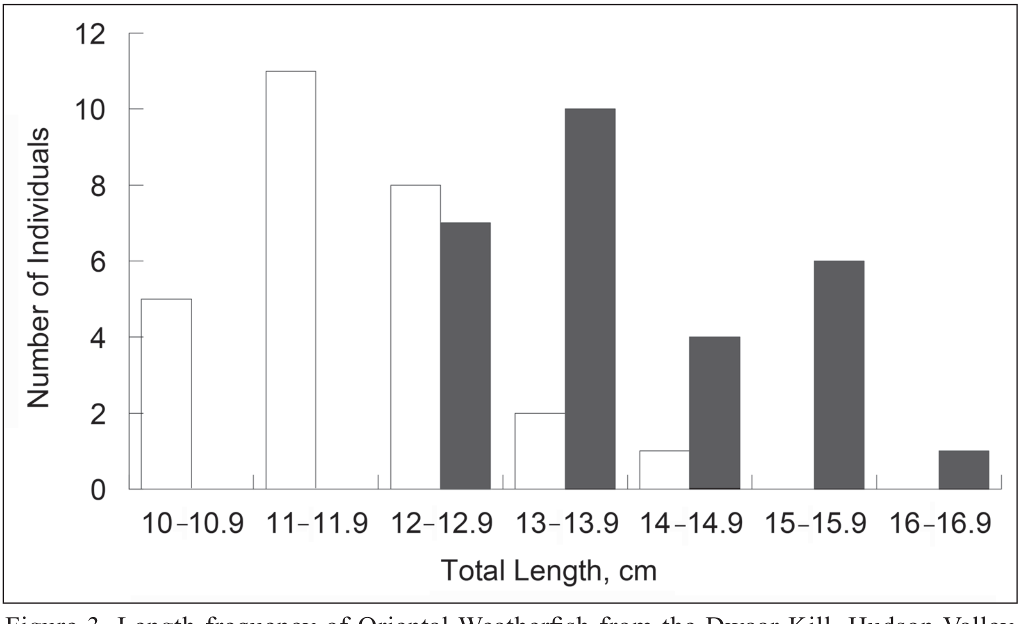

Figure 3. Length frequency of Oriental Weatherfish from the Dwaar Kill, Hudson Valley, NY in 2009. Total length of males is represented by open bars and females by shaded bars.

unnamed tributary on Rt. 52 consumed a wider variety of food items (10 taxa compared to 2) and many more chironomids than snails. Fish from the Bates Lane site ate mostly amphipods. Many of the fish caught later in the summer had empty guts.

Fecundity

Ovary weight varied between 4–19% of total body weight. Not coincidently, the largest female caught (15.2 cm TL) had ovaries weighing 19% of total body weight and exhibited no scarring from mating. Average percent ovary weight was lowest in late June–early July, but the decrease was relatively small (Fig. 4).

The total oocytes ready to spawn in unmated females (determined by lack of mating abrasions) ranged from 150–18,000. The number of large oocytes was roughly correlated (R^2 = 0.74) with body size (Fig. 5). Most females (68%) had small, medium, and large oocytes in their ovaries; 7 females had only small and medium oocytes, and 3 had only small oocytes. One female had 4 sizes of oocytes—small, medium, large, and tiny primary oocytes visible in her ovaries.

Young of the year

YOY Oriental Weatherfish were difficult to capture. Early in the season, we only found the very small YOY in leaf detritus at the very edges of a silty backwater. We collected larger YOY Oriental Weatherfish in the same habitats as the adults, but we found them in shallower water closer to the shoreline.

Table 1. Food habits of *Misgurnus anguillicaudatus* (Oriental Weatherfish) from 3 locations in the Dwaar Kill, a Hudson River tributary, NY. Data were collected in early summer 2009. % = percent of a given food item out of the total number of food items, occurrence = the percent of individuals with food in their stomach that had that food item, X = indicates presence of algae.

Location	Pine Bush		Rte. 52 tributary		Bates Lane	
	%	Occurrence	%	Occurrence	%	Occurrence
Prey category						
Trichoptera	2.0	9.1	1.0	11.1		
Coleoptera			1.2	11.1		
Megaloptera			1.4	16.7		
Diptera						
Chironomidae	62.0	63.6	54.6	83.3		
Simuliidae			33.4	22.2		
Terrestrials	8.2	9.1	1.0	16.7	3.3	33.3
Amphipoda					96.8	100.0
Isopoda			1.8	22.2		
Decapoda			<1.0	5.5		
Gastropoda	31.0	81.8	5.3	55.6		
Pelecypoda	4.1	36.4	1.8	16.7		
Algae	X	9.1			X	33.3
# Fish examined	12	28	12			
# Empty	1	10	7			
# Food items	245	434	31			

Discussion

We report the first record of Oriental Weatherfish in the Dwaar Kill and describe basic biological attributes of the specimens captured. The Oriental Weatherfish has colonized at least 20 km of the Dwaar Kill mainstem (plus several tributaries), and

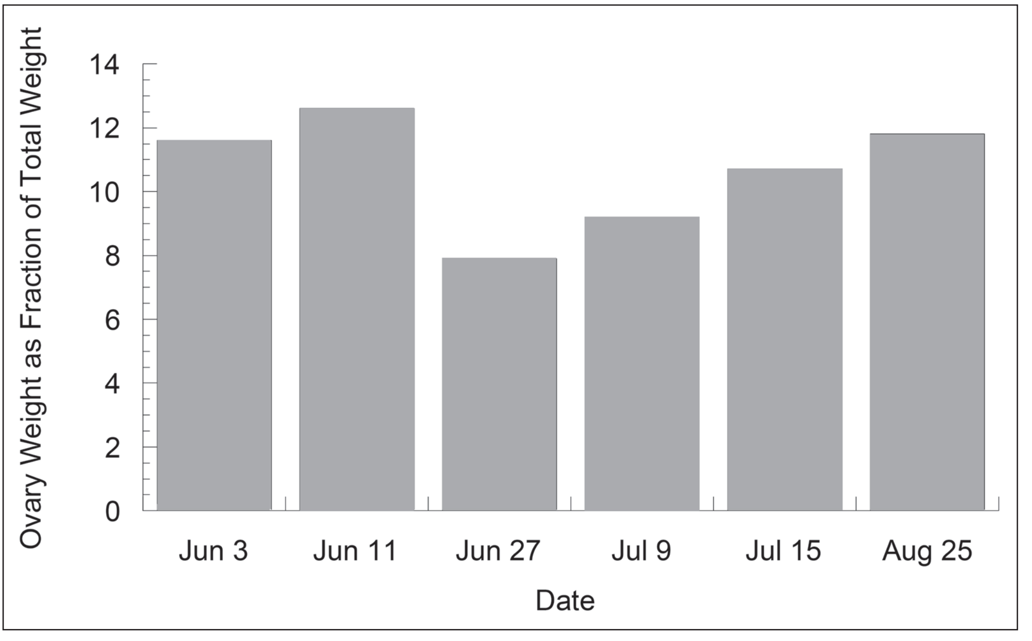

Figure 4. Average ovary weight (as percent of total weight) of scarred female Oriental Weatherfish from the Dwaar Kill, Hudson Valley, NY in 2009.

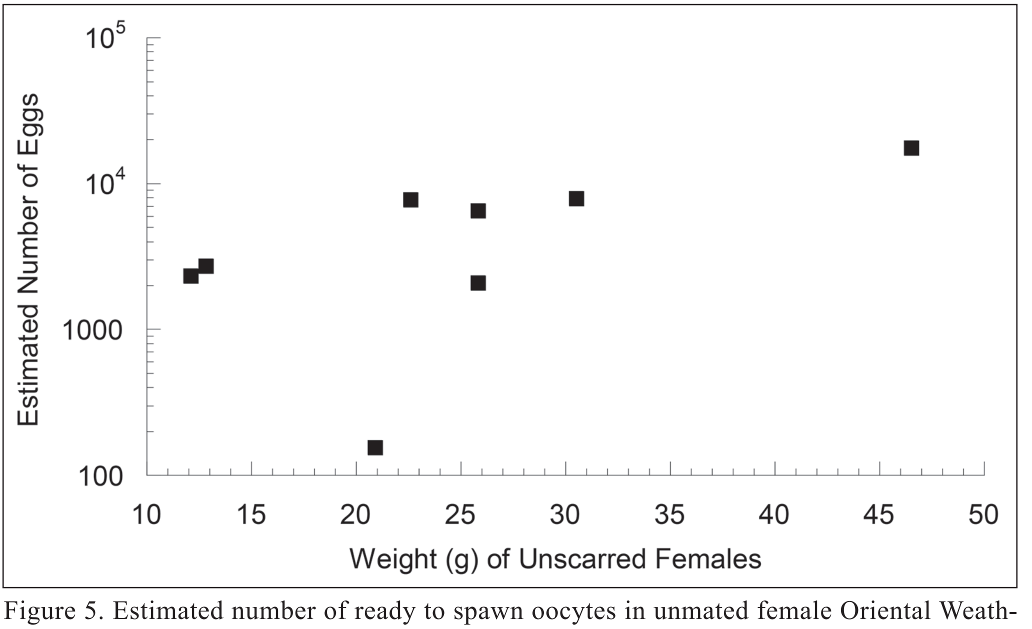

Figure 5. Estimated number of ready to spawn oocytes in unmated female Oriental Weatherfish from the Dwaar Kill, Hudson Valley, NY in 2009.

records indicate its presence in at least 8.5 km of the Wallkill River (Fig. 1), suggesting that there is a well-established population there. We found no records of sampling in the Dwaar Kill for the last 29 years. The most recent record of a fish collection was 1981 (D. Carlson, New York State Department of Environmental Conservation, Watertown, NY, pers. comm.) and no Oriental Weatherfish were noted in that report. If sampling did not include electrofishing or failed to target shallow silty margins, the species could have been overlooked. Regardless, enough time has elapsed between sampling efforts to allow Oriental Weatherfish to take up residence throughout the system. For example, Schultz (1960) recorded them in 16 km of a stream in Michigan and estimated entry into the system as sometime 9–21 years prior to the study.

Dams may limit the upstream distribution of Oriental Weatherfish in the Hudson River watershed. No Oriental Weatherfish were collected upstream of the dam on the Wallkill River in Wallkill (Fig. 1). The dam near the mouth of the Dwaar Kill (Fig. 1) should have prevented this species from moving upstream; it appears the introduction of Oriental Weatherfish into the Hudson River watershed occurred in the Dwaar Kill. The sources of previously described Oriental Weatherfish introductions include aquaculture (Hawaii; Fuller et al. 1999) and the pet trade (Michigan; Schultz 1960). There are no known aquaculture operations in the Dwaar Kill watershed. It seems likely that Oriental Weatherfish were introduced into the Dwaar Kill via an aquarium release.

The results of our study indicate that Oriental Weatherfish prefer silty backwaters and stream margins. Schultz (1960), Logan et al. (1996), and Tabor et al. (2001) also observed Oriental Weatherfish primarily in silty-mud substrates. Additionally, Logan et al. (1996) and Tabor et al. (2001) mentioned that Oriental Weatherfish were often associated with aquatic vegetation. Our sample sites were largely devoid of vegetation.

The Oriental Weatherfish is a batch-spawner in captivity (Suzuki 1976), releasing a fraction of available eggs at any one time and spawning several times per season. Suzuki (1983) reported 1815–15,524 eggs per spawning, a range very similar to data from presumably unmated females we collected in the Dwaar Kill (Fig. 5). Females in Suzuki's (1976) studies were 2–3 years old and 17–25 g body weight, which closely resembles the findings for the Dwaar Kill specimens.

Most Hudson Valley Oriental Weatherfish exhibited 3 visible size-classes of oocytes. Suzuki (1983) also reported 3 size categories, but with different size ranges than we describe in our study. Suzuki (1983) reported egg size-classes 0.05–0.2 mm diameter, 0.25–0.5 mm, and 0.55–0.85 mm. The latter two size categories are similar to the range of oocyte sizes that we measured from specimens collected in the Dwaar Kill. Presence of multiple egg sizes in unmated fish and correspondence of egg number and size to Suzuki's (1983) data strongly suggests that Oriental Weatherfish in the Hudson Valley are also batch spawners.

Despite a substantial fecundity, we rarely captured YOY Oriental Weatherfish. We collected the smallest specimens in piles of leaves in <2 cm of water on the margin of a silty backwater. The very low catch of YOY may indicate poor recruitment or that the YOY Oriental Weatherfish inhabit areas not sampled effectively with electrofishing or dip-netting.

Oriental Weatherfish appear to be generalist benthic macroinvertebrate-feeders. Feeding is probably nocturnal, and the fish select items based on gustation associated with the barbels (Watanabe and Hidaka 1983). Food items ingested suggest that they fed in the silty backwater habitats where they were usually captured. Few riffle inhabitants were among the items consumed (Table 1). We hypothesize that the Oriental Weatherfish is a non-selective benthic feeder and the variation in macroinvertebrates consumed from site to site reflects the variation in prey availability.

Invasive potential in the Hudson Valley

Oriental Weatherfish has spread throughout the Dwaar Kill and into the mainstem Wallkill River (Fig. 1) during the last 20–30 years. Within the Dwaar Kill, it occupies all appropriate habitats accessible to sampling.

There is nothing preventing Oriental Weatherfish from entering the tidal Hudson River (31.4 km NNE of the nearest documented location) and, indeed, it may have done so already. Our 2013 collection of this species from the Klyne Esopus Kill recorded some individuals from tidal freshwater habitat but within the stream banks. If this newly discovered population was derived by dispersal from the Wallkill River, this species has already moved through the tidal estuary. We have no data on whether tidal wetlands would be suitable habitat. However, large areas of silty substrates are available in the Hudson Estuary, chironomid midges and other macroinvertebrates that Oriental Weatherfish consume are present in abundance, and Oriental Weatherfish can breathe air through the large intestine (McMahon and Burggren 1987); therefore, they can tolerate periods of anoxia and dewatering.

In the streams sampled, few vertebrates occupy the silty, leafy backwater habitat. The vertebrates that occupy the backwaters of the Wallkill River are mostly YOY White Sucker, *Ameiurus natalis* (Lesueur) (Yellow Bullhead), and *Etheostoma olmstedi* Storer (Tessellated Darter) (R.E. Schmidt, unpubl. data), and these species are found elsewhere and do not appear to be especially abundant in the backwaters. The native *Umbra pygmaea* (DeKay) (Eastern Mudminnow) preferentially occupies Wallkill River backwater habitats and is at the northern end of its range there (Smith 1985). Eastern Mudminnows may compete for food with Oriental Weatherfish.

On the other hand, vertebrates are abundant in the tidal freshwater marshes. This fauna is dominated by killifishes (Fundulidae) but can seasonally include YOY Cyprinidae, Moronidae, Centrarchidae, and other fishes. Oriental Weatherfish could be a serious competitor with native tidal Hudson River fishes if their populations become much more dense than what we observed in stream habitats. There are few data available that are useful in determining whether this concern is justified.

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