Are Blue and Flathead Catfishes Invasive in the Chesapeake Bay Watershed?

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Blue catfish (*Ictalurus furcatus)* and flathead catfish (*Pylodictis olivaris*) have become established in several major tributaries of the Chesapeake Bay since their deliberate stocking and sometimes unauthorized introduction in freshwater reaches of several rivers in Virginia and Maryland. Initial stocking of blue catfish occurred in the 1970s and 1980s in the freshwater reaches of the rivers, but since that time, this species has expanded rapidly into tidal riverine habitats such that they now are commonly found in oligohaline and mesohaline waters of Chesapeake Bay tributaries, including all Atlantic slope rivers of the Commonwealth. Flathead catfish were introduced to the James River, Virginia, *circa* 1965-1970, and now occur in several Chesapeake Bay rivers, including the James, York, Potomac, and Susquehanna rivers. Unlike blue catfish, flathead catfish are habitat specialists and are generally confined to nontidal and tidal freshwater and oligohaline habitats. Both species achieve a large size, are long lived, and include other fishes in their diet, thus they may potentially exert a negative effect on native aquatic species. Concern about the ecosystem-level effects of these two catfishes has prompted discussion of the invasiveness of blue and flathead catfishes and the need to mitigate, control, or eradicate these nonnative fishes from Chesapeake Bay tributaries. This document explores the implications of such a designation and reviews current knowledge of these nonnative catfishes in our region.

An invasive species is "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (National Invasive Species Council 2006). The National Invasive Species Management Plan (National Invasive Species Council 2008) further clarifies an invasive species as a nonnative species that may prey upon, displace or otherwise harm native species, or alter ecosystem processes. As such, the Mid-Atlantic Panel on Aquatic Invasive Species recognized blue and flathead catfishes as invasive species of interest in 2007 (R. Fernald, VDGIF, *pers. comm.*). Both species are considered invasive (i.e., "biologically harmful") elsewhere outside of their native range (central US drainages), including Georgia and North Carolina (Fuller et al. 1999; Pine et al. 2005). Not all introduced species that have the potential for ecological harm are necessarily targeted for management action, however. The question is one of degree of harm to the environment, the economy, or human health; in the case of these catfishes, the degree of current or potential harm to the environment and the economy must be determined prior to implementing a baywide management plan for blue and flathead catfishes. A considerable body of knowledge exists on these species in Chesapeake Bay rivers, collected principally by scientists at the Virginia Department of Game & Inland Fishes, Maryland Department of Natural Resources, Virginia Commonwealth University, and the Virginia Institute of Marine Science. Several publications and graduate student theses report on the distribution, dispersal, diet, trophic status, growth, recruitment, and population structure of these species. However, none of these studies was directed at the issue facing resource managers today and the data vary in their spatial and temporal coverages. Because scientific information to inform management decisions is somewhat limited, we will examine potential mechanisms that could lead to environmental harm and discuss critical knowledge gaps that warrant research.

Invasive catfish species share certain biological characteristics that are believed to enhance the likelihood of their establishment in new environments, including a diverse diet, adult trophic status as apex predators, long life span, large body size, high salinity tolerance, and parental care of young (Table 1; Morris and Whitfield 2009). Some of these characteristics may lead to environmental harm if native species or aquatic habitats are affected in a negative manner. Other biological characteristics such as tolerance for a wide range of environmental conditions may further enhance the spatial expansion of newly established nonnative populations. For instance, both blue and flathead catfishes can tolerate salinities near 14 ppt and can move into estuarine reaches of tidal tributaries (Schloesser et al. *in press*; Bringolf et al. 2005). (The high salinity tolerance of these catfishes is not unique: channel catfish, which are also nonnative in Atlantic slope rivers, also have a high salinity tolerance.) Blue catfish were observed to expand their range in Virginia tributaries when adult densities in tidal freshwater reaches were high and in years of high river flows or episodic flooding (Schloesser et al. *in press*). Further range expansion of blue catfish in other tributaries may ensue when similar conditions co-occur (high adult abundance, high river flows). Systematic increases in the range of newly established species accompanied by order-of-magnitude higher densities in new environments are a known characteristic of fish invaders (Morris and Whitfield 2009). In Maryland, angler redistribution appears to have aided the spread of blue catfish among tidal tributaries of the upper Bay. Currently, flathead catfish are not as abundant as blue catfish and thus, populations may not exhibit dispersive movements in response to environmental cues. Laboratory experiments indicate that dispersal of flathead catfish does not appear to be limited by estuarine salinities (Bringolf et al. 2005). In the Chesapeake Bay watershed, angler redistribution appears to play a major role in the dispersal of flathead catfish.

Potential Interactions Leading to 'Environmental Harm'

Nonnative catfishes in Chesapeake Bay tributaries may interact with native fish and shellfish in a negative manner as predators or competitors for resources. Blue catfish in these tributaries have a highly diverse diet and consume crustaceans, worms, bivalves (including native freshwater mussels), and fish, such as Atlantic menhaden, American shad, blueback herring, bay anchovy, and other blue catfish. The diet of flathead catfish tends to be dominated by fish and the onset of piscivory occurs at a smaller size (>200 mm TL; Chandler 1998) than for blue catfish. Because both species consume fish, and because several fish species (e.g., *Alosa* spp.) that use Chesapeake Bay tributaries are the subject of restoration or stock rebuilding efforts, blue and flathead catfishes have the potential to exert measurable 'ecological harm' to the ecosystem. Recent studies based on stable isotope analyses suggest that adult blue catfish and flathead catfish in these systems are novel apex predators that feed extensively on important fishery resources, including native, anadromous fishes (MacAvoy et al. 2009).

The extent of piscivory of these species and population-level effects are poorly understood, at least in Chesapeake Bay waters. In Atlantic coastal rivers in North Carolina and Georgia, predation by introduced flathead catfish has been associated with declines of some native fishes, with concomitant effects on recreational fisheries (Pine et al. 2005; Bonvechio et al. *in press*). Comparable studies of predation effects of introduced flathead catfish in tributaries of Chesapeake Bay are lacking. In addition, we do not know how piscivory of blue and flathead catfishes varies seasonally and regionally (freshwater vs oligohaline habitats). We also do not know if fish from shallow habitats in estuarine regions exhibit the same pattern of piscivory (because only a few samples from estuarine waters less than 4-feet deep have been collected for examination). Furthermore, ecosystem-level effects of piscivory must take into account the size dependency of this feeding behavior. In blue catfish, piscivory is strongly size-dependent such that the frequency with which fish are observed in the diet increases with increasing fish size (Table 2). If proportionately few individuals comprise the size class exhibiting piscivory (>60 cm FL), then predation mortality would not be as high as if the piscivorous size class comprised a major portion of the blue catfish population. Based on electrofishing surveys in the freshwater reaches of the James River in 2010 when 6,725 catfish were measured, about 46% of the population was <31 Whacm, 47% was between 31 and 61 cm, and about 7% of the population exceeded 61 cm fork length. However, it should be noted that electrofishing is not an effective gear for sampling large catfishes (>61 cm), which may be in deeper waters, hiding under woody debris, or otherwise unavailable (or invulnerable) to the electric field. Clearly, a better understanding of the size structure of blue catfish populations is warranted, as is investigation of the size structure in the estuarine reaches of these tributaries. The latter habitats have been sampled only by bottom trawl, which is also ineffective at capturing large (>61 cm) catfishes.

Finally, catfish predation on native species such as American shad, blueback herring, alewife, and blue crabs is likely to be spatially confined to habitats where these species co-occur with catfishes. Habitat-specific assessments of fish and crustacean communities would help elucidate the potential for impacts of catfish predation mortality. Such studies of the trophic relations among catfishes and native fishes are hampered by the need to discern whether ingestion of fish is due to directed predation on fish (piscivory) or from scavenging of fish carcasses, a behavior known to occur in blue catfish as evidenced by the appearance of hard parts (spines, scales) from large adult fish (such as carp or American shad) in the stomachs of small blue catfish. Teasing apart these two behaviors will be important in the accurate assessment of 'harm' to native species.

Competition between native species and blue or flathead catfishes is not well documented. Native white catfish populations in the estuarine portions of the James and Rappahannock rivers decreased in abundance during the time of increasing abundance of blue catfish (Schloesser et al. *in press*). Similarly, white catfish populations declined in the Piankatank River after the introduction of catfish in this system. The co-occurrence of observed trends may or may not represent a cause-and-effect phenomenon, and the nature of any potential interactions between native and nonnative catfishes (competition, predation, both) in Chesapeake Bay tributaries is unexplored.

Potential Economic Harm

As bycatch, blue catfish interact with fisheries operating in Chesapeake Bay tidal tributaries and may negatively affect economic interests. For example, in the Potomac River, blue catfish are bycatch in gillnet fisheries, and due to their high abundance, may severely reduce gear efficiency for target species (AC Carpenter, Potomac River Fisheries Commission, *pers. comm*.). We suspect similar interactions may be occurring in gillnet fisheries in the James River. The amount and economic value of foregone harvest of the target species are currently unknown, but may represent significant local effects.

Critical Knowledge Gaps

Critical gaps exist in our knowledge of blue and flathead catfishes in Chesapeake Bay tributaries such that currently, it is not possible to unequivocally demonstrate 'ecological harm' associated with these nonnative fishes. However, ecological impacts associated with invasive catfishes, including blue catfish and flathead catfish, have been documented elsewhere (e.g., Pine et al. 2005; Bonvechio et al. *in press*). The following gaps (some of which were identified by Fabrizio et al. 2010) pose significant sources of uncertainty in our knowledge of the ecological consequences of nonnative catfishes, and hence, our ability to develop scientifically based policy advice.

Zoogeographical studies

- Determine colonization rates of down-estuary sites by blue catfish in coastal tributaries; identify proximal stimulus for down-estuary range expansion of blue catfish; investigate effect of population density on colonization rates and range expansion
- Determine migration and movement patterns of blue and flathead catfishes in tidal tributaries, especially movements associated with spawning and colonization (dispersal into estuarine reaches)
- Investigate site fidelity of trophy-sized blue catfish
- Investigate effect of population density in freshwater habitats on abundance of blue catfish in lower reaches (mesohaline areas 6-14 ppt)
- Identify critical nursery areas in estuarine reaches of the coastal tributaries
- Determine salinity tolerance of all life stages (eggs, larvae, juveniles, adults)

Population dynamics

- Assess temporal changes in biomass and fish community composition for major tidal tributaries of the Bay; provide information to EcoPath models (see below)
- Determine biomass, growth, and recruitment of blue and flathead catfishes in major tidal tributaries of the Bay
- Develop sampling design and methods to permit estimation of abundance (density) in freshwater and estuarine reaches; calibrate methods using estimate of population abundance derived from mark-recapture study (such a study could also provide estimates of survival)
- Determine level of removal (harvest) necessary to reduce population densities in tidal tributaries; estimate exploitation rates of the commercial and recreational fisheries for blue and flathead catfish and evaluate these relative to necessary harvest levels
- Determine fecundity, maturity schedules, and spawning frequency for these species in tidal tributaries

Community-level effects

- Determine nature of interaction between blue catfish and flathead catfish and native fishes such as white catfish and blueback herring.
- Determine trophic status of blue and flathead catfishes with adequate seasonal, regional, and fish size considerations; investigate size-dependent feeding habits and relate these to habitat (e.g., salinity regime, depth); explore the use of bioenergetic models to understand consumptive needs of nonnative catfishes; use Ecopath models to determine population-level effects of predation by nonnative catfishes; evaluate the impact of catfish predation on native species (river herring, American shad, white catfish, blue crabs, and freshwater mussels) relative to the impact of other predators (e.g., striped bass); evaluate the prevalence of scavenging (relative to predation)

- Determine the role of blue and flathead catfishes in nutrient cycling in the system (consider catfish as predator and prey)
- Determine the effect of natural or man-made impediments that concentrate predators (i.e., catfishes) and prey (i.e., native migratory fishes); such impediments include dams, the base of rapids (e.g., James River rapids), and constricted reaches below the fall line; this non-random distribution of predators and prey may constitute an inordinately large proportion of the total predation mortality on native species; determine sources of mortality on key native fishes in order to evaluate effect of catfish consumption (e.g., bycatch mortality, predation by native fishes, etc.)
- Determine extent of blue catfish bycatch in gillnet and other fisheries; assess economic impact of foregone harvest
- Determine economic and societal values of trophy fishery for blue catfish in the James River
- Investigate the relationship between size and concentrations of toxic substances in blue and flathead catfishes (e.g., Hg, PCBs); investigate human consumption risks for all sizes of catfishes

Control

- Identify blue and flathead catfish refugia and likely dispersal mechanisms
- Assess feasibility of removal strategies including development of fishery on small individuals (see bullet on contaminants)

We suggest that future action and support by the Fisheries Goal Implementation Team should be focused on obtaining information to address these scientific needs.

Table 1. Predictors of invasiveness for blue and flathead catfishes (adapted from Morris and Whitfield 2009). Propagule pressure refers to the density of individuals introduced, the number of introduction events, and the frequency of introductions. In addition to the predictors shown in the table, short distance to native source, young age at maturity, large egg diameter, and long reproductive season have been identified as additional predictors of invasiveness, however, none of these apply to the two catfishes.

Predictor	Blue catfish	Flathead catfish	Reference
High propagule pressure	?	?	Marchetti et al. 2004a Marchetti et al. 2004b Colautti 2005 Jeschke & Strayer 2005 Jeschke & Strayer 2006
Prior invader	X	X	Kolar & Lodge 2002 Marchetti et al. 2004a Marchetti et al. 2004b Ribeiro et al. 2008
Large native range	X	X	Marchetti et al. 2004a Marchetti et al. 2004b
Environmental tolerance	X	X	Kolar & Lodge 2002 Marchetti et al. 2004a Marchetti et al. 2004b Vila-Gispert et al. 2005
Long life span	X	X	Marchetti et al. 2004a
Large body size	X	X	Marchetti et al. 2004b Colautti 2005 Duggan et al. 2006 Ribeiro et al. 2008
High adult trophic status	X	X	Marchetti et al. 2004b
Broad diet	X		Kolar & Lodge 2002 Ruesink 2005
Fast growth		X	Kolar & Lodge 2002
High fecundity	X		Jeschke & Strayer 2005 Jeschke & Strayer 2006 Vila-Gispert et al. 2005
Parental care	X	X	Marchetti et al. 2004a Marchetti et al. 2004b Jeschke & Strayer 2005 Jeschke & Strayer 2006

Table 2. Proportion of blue catfish stomachs containing fish species; number of non-empty stomachs examined is given in parenthesis. Data for the James River provided by VDGIF (B. Greenlee); data for the James, York, and Rappahannock rivers combined are from Schloesser et al. (*In Press*); data for the Potomac River are from MDDNR (M. Groves).

Size class (fork length)	James River (2002)	James, York and Rappahannock rivers (2004 – 2007)	Potomac River (2008-2010)
<30 cm	0 (52)	0.10 (765)	--
30-60 cm	0.05 (92)	0.28 (265)	0.21 (108)
>60 cm	0.48 (61)	--	0.41 (108)

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