Hickory Shad restoration in three Maryland rivers

F-57 Segment 15 Progress Report
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Need

Hickory Shad *Alosa mediocris* were historically abundant in many Chesapeake Bay tributaries (O'Dell et al. 1975, 1978). Populations declined similar to other Clupeid species during the 1970s (Minkkinen 1999). A moratorium was enacted on all Hickory Shad harvest in 1981. Recently, some upper Chesapeake Bay tributaries have experienced resurgence in Hickory Shad runs. The availability of Hickory Shad broodstock provided the opportunity to culture and stock this species to facilitate restoration in other Maryland tributaries. Few studies have been conducted on Hickory Shad. Funding obtained through Sportfish Restoration Act (F-57-R) has supported a Maryland Department of Natural Resources (MDNR) restoration project since 1999.

Previous work conducted under F-57-R yielded new Hickory Shad spawning strategy and life history information. Many Chesapeake Bay tributaries had historical Hickory Shad runs equal to or greater than that of American Shad *Alosa sapidissima* and it could be useful to develop spawning, culture and marking techniques for their restoration. These techniques have been refined and reintroduction of Hickory Shad to the target tributaries has progressed similar to MDNR American Shad restoration projects.

Objective

The objective for this project is to restore self-sustaining Hickory Shad populations to the project's target tributaries. Prior to project inception, the depressed native stocks in the Choptank River did not exhibit any evidence of spawning activity, according to exploratory sampling efforts in the early 1990s. This tributary supported spawning runs and active commercial and recreational fisheries in the past.

Expected Results and Benefits

Hatchery inputs are intended to provide adult spawners that will produce self-sustaining populations in the target tributary. These fish have tremendous value for stock assessment purposes at the larval, juvenile and adult life stages, since all stocked shad receive an otolith mark. Advanced juveniles were originally implanted with numeric coded wire tags (CWT, Northwest Marine Technologies, Shaw Island, Washington, USA). CWT use was discontinued in 2002 since Hickory Shad mortality was high due to tagging operations handling stress. Larval and early juvenile otolith marking is the primary identification method for hatchery reared Hickory Shad. Natural spawn culture techniques allow for the production of large numbers of larval and juvenile shad for stocking and assessment efforts.

Upper Bay and Potomac River Hickory Shad populations currently support active catch and release recreational fishing. Restoring shad stocks to tributaries that historically supported runs will increase fishing opportunities for anglers. Recreational fishing that targets Hickory Shad is beginning to occur in the Patuxent River and Choptank River. An indirect benefit of restoring shad populations to self-sustainable levels is the increased prey availability provided by both juvenile and adult shad for larger, more economically important recreational species such as striped bass, bluefish, and weakfish.

Approach

MDNR's American Shad hatchery based restoration project incorporated Hickory Shad into the project in 1996. The project continued over the next three years through various short-term funding sources. In 1998 it was determined that a long term funding source would be required, since it would take years of additional stocking and assessment to successfully support restoration. Federal Aid in Sport Fish Restoration funds was utilized to conduct this long-term effort.

The project consists of three sub-projects:

1. *Produce, mark and stock cultured Hickory Shad in the Choptank River.*
2. *A. "Assess the contribution of hatchery-produced fish on the resident/pre-migratory stock in the Patuxent River and Choptank River."*
   B. "Monitor the abundance and mortality of larval and juvenile shad using marked hatchery-produced fish".
3. *Analyze the contribution of hatchery origin Hickory Shad to the adult spawning population and monitor the recovery of naturally produced stocks.*

Location

Restoration efforts will focus on the Choptank River. The Choptank River watershed is rural-impacted by agricultural activities and low urban development. Choptank River efforts include the tributary Tuckahoe Creek.

Monitoring will occur in the Patuxent River. This river was an original target tributary and stocking began in 1996. The Patuxent River watershed is heavily urban-impacted, but has been the subject of numerous mitigation efforts due to its designation as a targeted watershed (i.e. sewage treatment upgrades). MDNR biologists observed that the Patuxent River composition of wild adults was stable and exceeded 80% for three straight years, so hatchery stocking was suspended in 2008. If this stable pattern of wild origin adult relative abundance continues over the next few years, despite lack of hatchery contributions to the juvenile stock, then the Patuxent River could be considered a self-sustaining population. Limited monitoring of adults and juveniles will continue in the Patuxent River in order to maintain trend data.

The Nanticoke River watershed is mostly farm-impacted in the middle and lower river. The upper Nanticoke River is urban and industrial-impacted. The Marshyhope Creek is a major tributary of the Nanticoke River. This creek was a previous restoration target tributary but it is no longer stocked by MDNR. MDNR amended the grant proposal to suspend stocking the Marshyhope Creek and devote all project resources towards stocking and monitoring in the Choptank River. This resulted in maximum stocking impact and more detailed analysis of assessment activities. This tributary has always been a secondary priority to stocking resources. Marshyhope Creek restoration will remain inactive due to finite resources and lack of observed impact from stocking efforts.

Sub-project 1.

"Produce, mark and stock cultured Hickory Shad in the Choptank River"

In 2014, MDNR staff produced, marked, and stocked Hickory Shad larvae and juveniles. Hickory Shad larvae were marked and stocked into the Choptank River (Figure 1). Early juvenile fish were first stocked as larvae into hatchery ponds and later transported to the river at approximately 30 days of age. Hickory Shad were produced through hormone-induced tank spawning utilizing Susquehanna River origin brood fish.

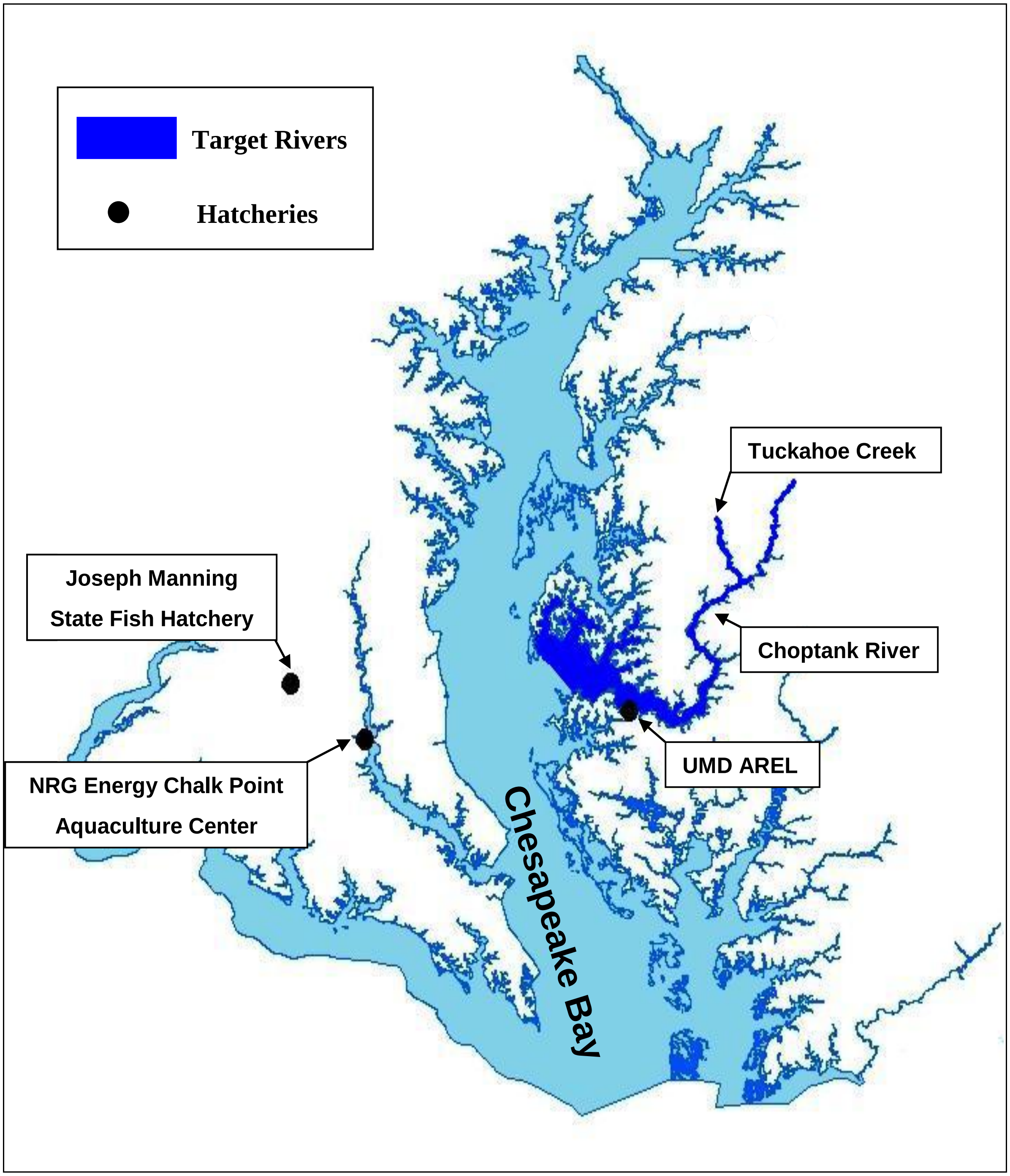

Figure 1. *2014 target tributary and culture sites for Maryland Department of Natural Resources shad restoration project. NRG Energy Chalk Point is a power company that cultures fish for the restoration effort. . The Horn Point Aquaculture and Restoration Ecology Laboratory (AREL), is a University of Maryland (UMD) facility that supplies culture ponds for the restoration effort.*

Materials and Methods

Broodstock Collection

Hickory Shad broodstock were collected from the Susquehanna River (Figure 1 and Table 1). Since the mid-1990s, Hickory Shad abundance increased in the upper Chesapeake Bay and its tributaries (ASMFC 1999).

Prior to 2005, Hickory Shad broodstock were collected by hook and line, either immediately downstream of Deer Creek or at Shure's landing, near the base of Conowingo Dam (Figure 2). In 2005, MDNR staff transitioned to boat electrofishing to collect Hickory Shad brood. The sample area was along the western shore of the Susquehanna River, from just downstream of Deer Creek at Rock Run Mill down to Lapidum boat ramp in the Susquehanna State Park (Figure 2). Electrofishing was used for its ability to efficiently collect larger numbers of Hickory Shad than could be collected by hook and line collection. Electrofishing for Hickory Shad broodstock requires less project staff and reduces handling stress. During brood collection, immobilized Hickory Shad were netted and placed into the electrofishing boat's hull-mounted live well (220L). The live well water was recirculated, oxygenated, and treated with various anesthetics to reduce stress and injury.

Hormone Induced Ovulation

Injections of Leutinizing Hormone-Releasing Hormone analog (LHRHa), a synthetic analog of gonadotropin-releasing hormone (GnRHa), stimulate pituitary release of endogenous gonadotropin. LHRHa induces gonadal maturation, ovulation and spawning (Mylonas et. al. 1995). In accordance with the Investigational New Animal Drug Permit (INAD #11-375), MDNR purchased pre-made 75µg hormone pellets for ovulation induction. LHRHa pellets are sold under the product name Ovaplant® and produced by Western Chemical Inc. (Ferndale, WA). When possible, Hickory Shad were implanted at the collection site on the Susquehanna River (Figure 2) to minimize additional handling stress. Males and females received an intramuscular (IM) implant of Ovaplant® into the dorsal musculature. Implants were administered through a spring-loaded 11-gauge syringe or a multiple dose Ralogun® (Intervet/Schering-Plough Animal Health, The Netherlands).

Figure 2. *2014 Maryland Department of Natural Resources Hickory Shad broodstock collection site on the Susquehanna River.*

Table 1. *Maryland Department of Natural Resources 2014 Hickory Shad broodstock collection data.*

Date	Females	Males
04/14/14	22	40
04/16/14	54	9
04/22/14	77	113
04/24/14	117	140
04/28/14	22	6
05/01/14	28	26
05/05/14	12	14
05/06/14	53	12
05/08/14	34	16

Egg Culture

Fish were placed into circular flow, insulated 3,785 L tanks at 4.0-6.0 ppt salinity and transported to Manning Hatchery (Figure 1). Dissolved oxygen (D.O.) was continuously monitored and regulated to saturation (approximately 10.0 ppm) with a Point Four oxygen monitoring system (Coquitlam, BC, V3K 6X9, Canada). Adults were netted into 3.05 m diameter natural spawn tank systems. A sex ratio of approximately 3:2 male: female is preferable in natural spawn systems but there are times when males are not sufficiently available to meet this ratio. Salinity was maintained at 2.0 ppt. A 25% water change was performed each day to maintain adequate water quality. Fish spawned naturally and eggs were automatically transported to an egg collection box through an airlift system.

Eggs were volumetrically measured (ml) and fertilization was determined 24 hours post spawn. Eggs were placed into modified McDonald hatching jars supplied by approximately 2.0 L/min water flow. Prophylactic treatments of formalin were administered in the morning and afternoon to control fungi. Eggs were exposed to a 600:1 treatment of formalin for approximately 17 min. Hickory Shad eggs began hatching at day four. In order to stimulate a simultaneous hatch, jars were removed from the egg bank, placed outdoors in sunlight for ten minutes and stirred occasionally. The rapid temperature change, lower oxygen content, concentrated hormonal influence and agitation stimulated simultaneous hatching. Hatching jars were then placed on benches beside 1.5 m (1,800 L) circular flow-through larval tanks that allowed water and larvae to flow from the hatching jars to the flow-through tanks. Water was supplied at approximately 2.0 L/min.

Hickory Shad feed on rotifers that are difficult to culture in the MDNR hatchery. Therefore, Hickory Shad larvae were marked and stocked into hatchery ponds or target tributaries prior to first feeding (<six days age). Prior to stocking, larvae were enumerated using a volumetric direct proportion procedure in which a columnar sample of water was collected with a 25.0 mm diameter PVC tube at random locations in the larval tank. Larvae were enumerated in this sample and the total number of larvae in the tank was estimated by extrapolation to the total tank volume.

Marking

All fish stocked into target tributaries were given an oxytetracycline (OTC) mark to identify recaptured fish as hatchery origin. OTC marks applied to larvae or juveniles will still be visible as adults. Larval marks were produced by immersion in a 300 ppm buffered OTC bath for six hours. D.O. content was monitored and regulated (>5.0 ppm) by a carbon air stone connected to a liquid oxygen delivery system. All water used at Manning Hatchery for OTC marking was softened before use (Culligan ion exchange system). Reliable marking can only take place in water with hardness below 20 mg/L and water hardness at Manning Hatchery routinely exceeds 200 mg/L. Samples analyzed from each group of OTC marked fish indicated that all fish stocked were successfully marked. Marks were verified by viewing larval otoliths with an ultraviolet microscope (Zeiss Axioskop).

Larval Stocking

Fish intended for larval stocking were given a larval immersion OTC mark at day one after hatch. Larval stocking was accomplished by placing marked larvae into boxes originally designed for shipping tropical fish. These containers consisted of an outer shell cardboard box, an inner insulating foam box, a black plastic trash bag to reduce stress of bright sunlight and a double thickness plastic fish transport bag. Larval culture tanks were drawn down to crowd the fish. Larvae were scooped out of the tanks and placed in the shipping bags/boxes, which were supplemented with salt (1.0 ppt) to mitigate stress. Each bag was filled with pure oxygen and sealed with electrician’s tape. Boxes were driven to the stocking river and the bags were placed into the water to temperature acclimate (~45 minutes). The bags were then opened and river water was slowly introduced to further acclimate larvae to river water chemistry. Bags were then emptied into flowing water to minimize predation.

Early Juvenile Stocking

Fish intended for early juvenile stocking were given OTC immersion marks at day one and three after hatch. After the second mark was administered, larvae were stocked into hatchery ponds for approximately thirty days. Manning Hatchery, NRG Energy, and the University of Maryland (UMD) Aquaculture and Restoration Ecology Laboratory (AREL) Horn Point provide grow out ponds to hold fish for the restoration effort (Figure 1).

The decision to take juveniles out of the pond is based on zooplankton density. Food availability is evaluated with a plankton net. Early juveniles are removed from culture ponds when food availability declines.

Juvenile fish tend to stress easily and direct netting from hatchery ponds into transport tanks is not recommended. Juvenile fish were concentrated with a seine and bucketed with pond water into the transport tank. A small one horse power water pump is used to create current within the seine net to orient shad into the water flow. This current serves two purposes. The current concentratates the shad to be easily bucketed and it separates fish from algae and detritus. Early juvenile survival increased in recent years due to the reduction of algae and detritus in the transport tanks. Early juveniles were transported in fish hauling tanks at 3.0-5.0 ppt. salinity and saturated D.O. to mitigate stress. Ponds at NRG Energy and AREL already have natural salinity of 6.0-8.0 ppt. Juvenile stocking was accomplished by quick-dumping juveniles through a 15.0 cm hose directly from the transport vehicle into the river.

For the past several years, MDNR biologists altered stocking procedures for early juveniles. A one-horsepower trash pump is carried on the stocking truck to temper juvenile shad before stocking. Fish are tempered until temperature and salinity in the tank are within one degree Celsius and 1.0 ppt salinity of the river value. Although this procedure adds a considerable amount of time that fish are aboard the transport tank, it is assumed this procedure increases the survival of early juvenile stocked shad by reducing stress.

Late Juvenile Stocking

Late juvenile Hickory Shad have not been cultured by MDNR since 2004 due to high fish mortality during long-term culture and CWT marking procedures.

Stocking Goals

Larval stocked fish can efficiently contribute large numbers of juveniles if survival is high. In 2014, Hickory Shad larvae were proposed for stocking in the Choptank River. The project developed stocking goals, which are based on past experience with larval survival. The stocking goal for the Choptank River was set at six million larvae.

Fish stocked as early juveniles survive extremely well and are young enough to successfully imprint to the stocked tributary. Stocking early juveniles can also mitigate the impacts of poor larval survival since post-stocking survival of this life stage is high. In 2014, Hickory Shad early juveniles were proposed for stocking in the Choptank River and its tributary, the Tuckahoe Creek. The project developed stocking goals, which are based on past experience with juvenile survival. The stocking goal for the Choptank River was set at 450,000 early juveniles.

Results and Discussion

Hickory Shad Production Summary

Hickory Shad tank spawn production statistics are contained in Table 2. Hickory Shad overall fertilization was 29.2% in 2014. Since the program's inception, the average fertilization rate was 50.5%. Excluding the elevated fertilization rate of 2012, the past several years' Hickory Shad egg fertilization rates (Figure 3) and shad larval production (Figure 4) have been lower than expected. A potential cause of decreased Hickory Shad larval production was clumping of viable eggs in hatching jars. Egg clumping reduces larval escapement from hatching jars, which reduces hatching success. The cause of Hickory Shad egg clumping has not been adequately investigated and is unknown. In 2015, Hickory Shad will be spawned and cultured at AREL in an attempt to determine whether water quality (i.e. pH, hardness, well water) may be a factor at Manning hatchery.

Egg de-adhesion techniques were investigated extensively over the past few years. Egg de-adhesion techniques were adapted from method's described for Atlantic Sturgeon (Mohler 2003). Eggs were treated with solutions containing fuller's earth and tannic acid. De-adhesion solutions containing 100-200 g of fuller's earth and 50-75 mg of tannic acid per gallon of water were used. Eggs were gently mixed in the de-adhesion solution for 20 minutes with a large feather. The egg de-adhesion solutions were effective one to two days after treatment, then eggs would clump together again. The agitation of eggs with a large feather in the hatching jars several times per day helped to minimize the clumping and caking of eggs prior to hatching.

Table 2. *Maryland Department of Natural Resources 2014 tank spawn Hickory Shad egg production.*

Total eggs produced	29,068,775
Overall fertilization	29.2%
Fertilized eggs produced	8,498,525
Total larvae produced	520,000

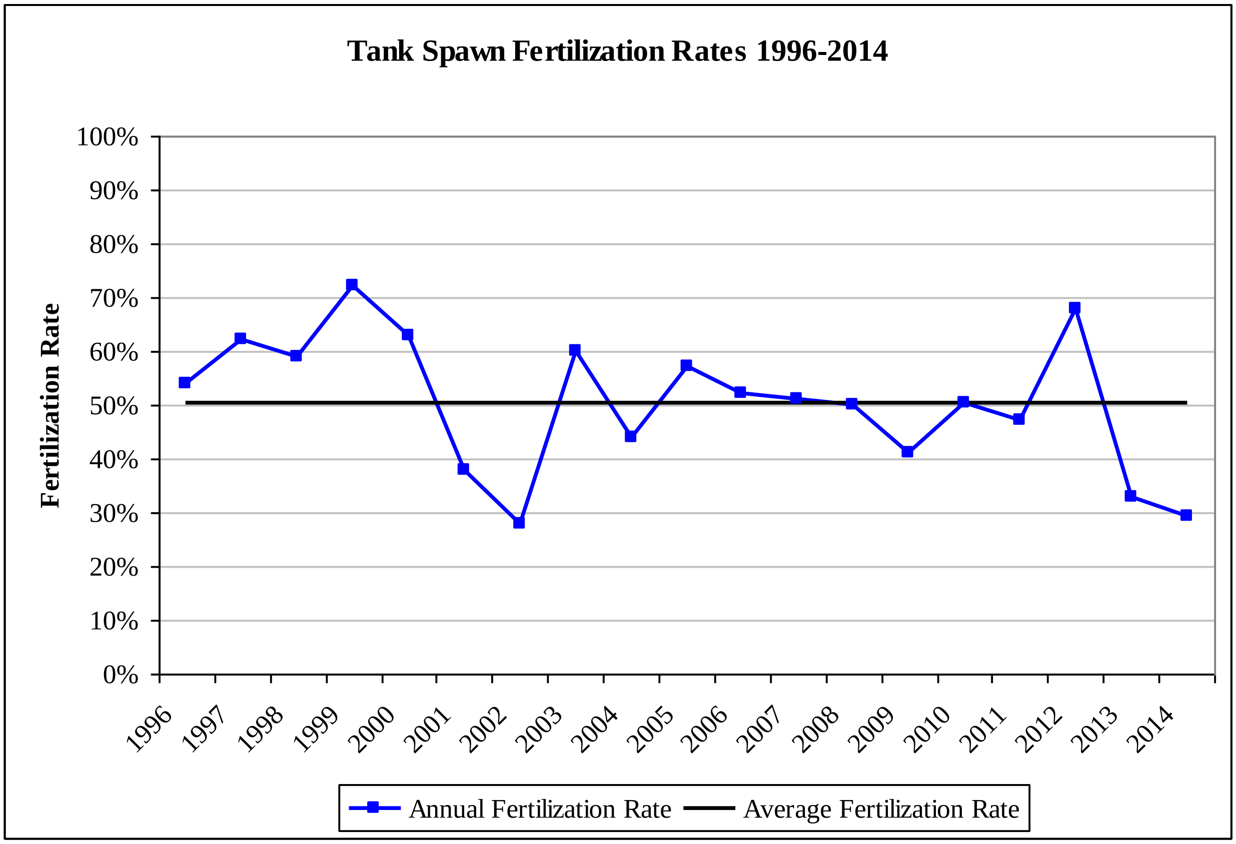

Figure 3. *Maryland Department of Natural Resources tank spawn fertilization rates for Hickory Shad, 1996-2014.*

Stocking

A summary of 1996-2014 Hickory Shad stocking production appears in Figure 4. In the early years of restoration efforts, larvae and late juveniles were the only life stages stocked into the target tributaries. In 2001, early juveniles were cultured in hatchery ponds and stocked 30 days later into the Patuxent River. In 2002, juveniles were cultured and stocked into the Patuxent River, Choptank River and Marshyhope Creek. Hickory Shad stocking was suspended in the Patuxent River in 2008 and Marshyhope Creek in 2010 to focus project resources towards stocking the Choptank River.

In 2014, Hickory Shad larvae were stocked as larvae at Red Bridges on the Choptank River. Hickory Shad early juveniles were stocked at the Denton boat ramp on the Choptank River, and Stony Point on the Tuckahoe Creek (Figure 5). Stockings are separated by event in Table 3. Historical Hickory Shad stocking production for all years by tributary is contained in Tables 4 through 9. Some larvae were stocked into the Patapsco River (1998-2001) to investigate fish passage issues. Additionally, excess marked larvae were stocked into the Chester River in years when the timing of culture and marking activities precluded stocking into the target tributaries. The Nanticoke River table identifies fish cultured and stocked by MDNR only. The state of Delaware also cultures and stocks shad for the mainstem Nanticoke River and those figures are not included in these data (Tables 4 through 9).

Hickory Shad larval stocking levels did not meet project goals in 2014. The factors that contributed to low larval production were 1.) Sub-average fertilization rates (Figure 3) and 2.) egg clumping in the hatching jars prior to hatch. Increased broodstock mortality was observed in hatchery broodstock spawning tanks this year. Factors that contribute to broodstock mortality prior to spawn include transport stress, excessive handling stress, and prolonged anesthesia in the shock boat holding tank. In years when broodstock are plentiful in traditional fishing areas, holding times in the livewell are greatly reduced. Excessive fishing time contributed to additional stress aboard the small livewell.

Early juvenile stocking goals were not met for 2014. There were several factors that contributed to reduced stocking numbers. High-flow events and lower than normal temperature conditions during April reduced the ability to collect large numbers of Hickory Shad broodstock below the Conowingo Dam, which reduced the number of eggs cultured at Manning Hatchery.

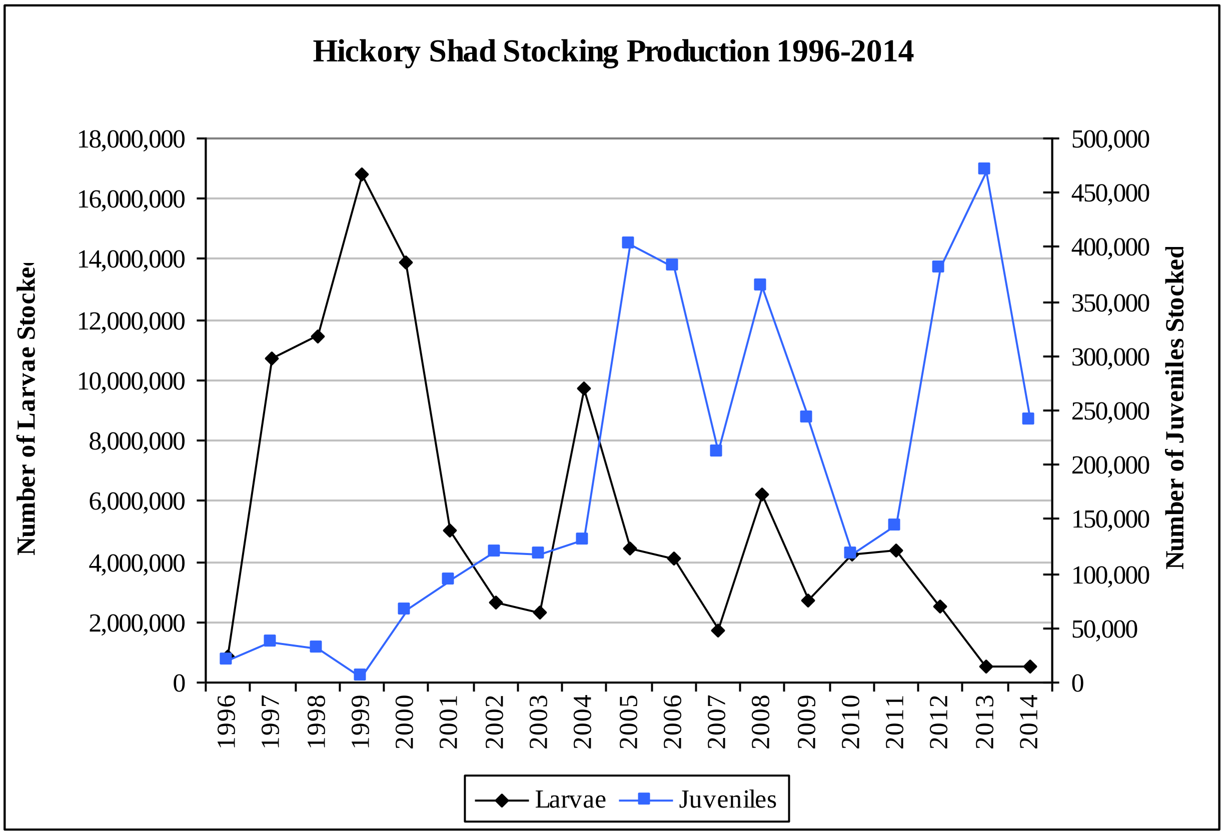

Figure 4. *Maryland Department Natural Resources annual Hickory Shad stocking production in all tributaries, 1996-2014. The juvenile category includes fish stocked as early juveniles (late June) and late juveniles (July/August). Fish were stocked into the Choptank River, Patuxent River, Nanticoke River, Patapsco River, and Chester River.*

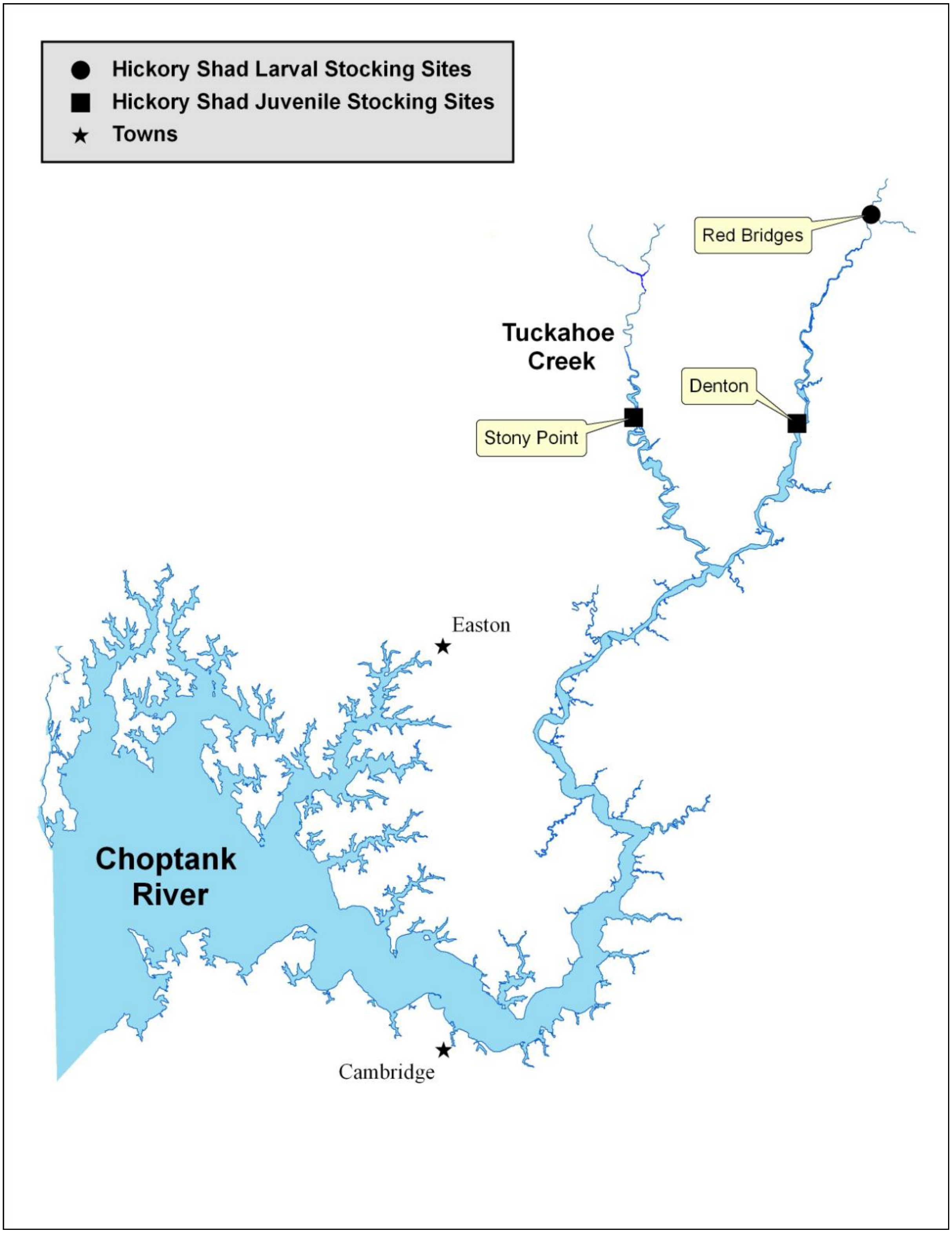

Figure 5. *Maryland Department of Natural Resources 2014 Choptank River Hickory Shad stocking sites.*

Table 3. *Maryland Department of Natural Resources 2014 Hickory Shad stocking events in the Choptank River and Tuckahoe Creek.*

Life stage	Date	Number stocked
Larvae	05/04/14	100,000
Larvae	05/15/14	130,000
Larvae	05/16/14	290,000
Early Juvenile	05/29/14	54,500
Early Juvenile	06/05/14	140,000
Early Juvenile	06/09/14	12,000
Early Juvenile	06/10/14	4,000
Early Juvenile	06/11/14	30,000

Table 4. *Historical stocking summary for larval and juvenile Hickory Shad in the Patuxent River since the inception of the restoration effort (1996-2007).*

Patuxent River Hickory Shad

Year	Larvae	Early Juveniles	Late Juveniles
1996	746,000	0	12,659
1997	5,118,000	0	35,982
1998	6,475,400	0	31,979
1999	8,106,000	0	4,601
2000	8,235,000	0	28,436
2001	1,380,000	53,500	20,238
2002	350,000	40,000	0
2003	395,000	35,000	0
2004	3,425,000	68,500	0
2005	1,160,000	120,000	0
2006	1,350,000	70,000	0
2007	520,000	36,500	0
Total	**37,260,400**	**423,500**	**133,895**

Table 5. *Historical stocking summary for larval and juvenile Hickory Shad in the Choptank River since the inception of the restoration effort (1996-2014).*

Choptank River Hickory Shad

Year	Larvae	Early Juveniles	Late Juveniles
1996	125,000	0	7,963
1997	5,571,000	0	0
1998	4,991,000	0	0
1999	8,719,000	0	0
2000	5,634,000	0	38,508
2001	1,158,800	0	19,907
2002	1,050,000	25,000	0
2003	700,000	34,500	0
2004	4,090,000	42,350	0
2005	2,430,000	177,000	0
2006	1,770,000	220,000	0
2007	1,080,000	149,500	0
2008	3,028,000	225,000	0
2009	1,953,000	120,000	0
2010	4,260,000	117,000	0
2011	4,399,000	143,750	0
2012	2,503,000	380,100	0
2013	560,000	471,000	0
2014	520,000	240,500	0
Total	**54,541,800**	**2,345,700**	**66,378**

Table 6. *Historical stocking summary for larval and juvenile Hickory Shad in Marshyhope Creek since the inception of the restoration effort (2001-2009).*

Marshyhope Creek Hickory Shad

Year	Larvae	Early Juveniles	Late Juveniles
2001	1,230,000	0	0
2002	300,000	26,000	17,247
2003	500,000	17,000	18,551
2004	500,000	14,000	5,482
2005	370,000	66,000	0
2006	750,000	70,000	0
2007	100,000	25,500	0
2008	2,209,000	140,000	0
2009	785,000	122,000	0
Total	**6,744,000**	**480,500**	**41,280**

Table 7. *Historical stocking summary for larval and juvenile Hickory Shad in the Nanticoke River since the inception of the restoration effort (2001-2006).*

Nanticoke River Hickory Shad

Year	Larvae	Early Juveniles	Late Juveniles
2001	1,230,000	0	0
2002	975,000	0	11,058
2003	625,000	11,500	0
2004	1,000,000	0	0
2005	450,000	40,000	0
2006	225,000	22,000	0
Total	**4,505,000**	**73,500**	**11,058**

Table 8. *Historical stocking summary for larval and juvenile Hickory Shad in the Patapsco River since the inception of the restoration effort (1997-2004).*

Patapsco River Hickory Shad

Year	Larvae
1997	1,695,000
1998	250,000
1999	825,700
2000	500,000
2001	0
2002	0
2003	0
2004	542,000
Total	**3,812,700**

Table 9. *Historical stocking summary for larval and juvenile Hickory Shad in the Chester River since the inception of the restoration effort (2003-2008).*

Chester River Hickory Shad	
Year	**Larvae**
2003	90,000
2004	200,000
2005	0
2006	0
2007	0
2008	602,000
Total	**892,000**

Sub-project 2

A." Assess the contribution of hatchery-produced Hickory Shad to the resident/pre-migratory stock in the Patuxent River and the Choptank River."

B. "Monitor the abundance and mortality of larval and juvenile Hickory Shad using marked hatchery-produced fish".

Materials and Methods

The Patuxent River was sampled weekly from 6 August, 2014 to 7 October, 2014. Sampling was precluded on 13 August, 10 September, and 1 October due to other commitments (Figure 6). The Choptank River was sampled weekly from 5 August through 16 October, 2014 (Figure 7).

A seine 61.0 meters in length, 3.1 meters deep, with 6.4mm mesh, was deployed by boat and pulled to shore by hand at established seine sites. Captured juvenile Hickory Shad were picked from the seine collection, placed in plastic bags, labeled, and put on ice. Upon return to the lab, the samples were frozen to -9 ^{o}C.

Samples were subsequently thawed and measured (FL and TL in mm). Both sagittal otoliths were removed from the Hickory Shad samples and mounted on 76.2 mm x 25.4 mm glass slides with Crystalbond 509 (Aremco Products, Ossining, NY). Mounted otoliths were lightly ground on 600 grit silicon carbide wet sandpaper and viewed under immersion oil and epi-fluorescent light at 400X magnification at 50-100 watts with a Zeiss Axioscop 20 microscope. The presence and location of OTC mark epi-fluorescence was recorded. Epi-fluorescence is a technique in which light in the wavelength of 490-515 nm is allowed to strike the specimen. The specimen then absorbs this light energy and emits light of a longer wavelength back through the microscope objective.

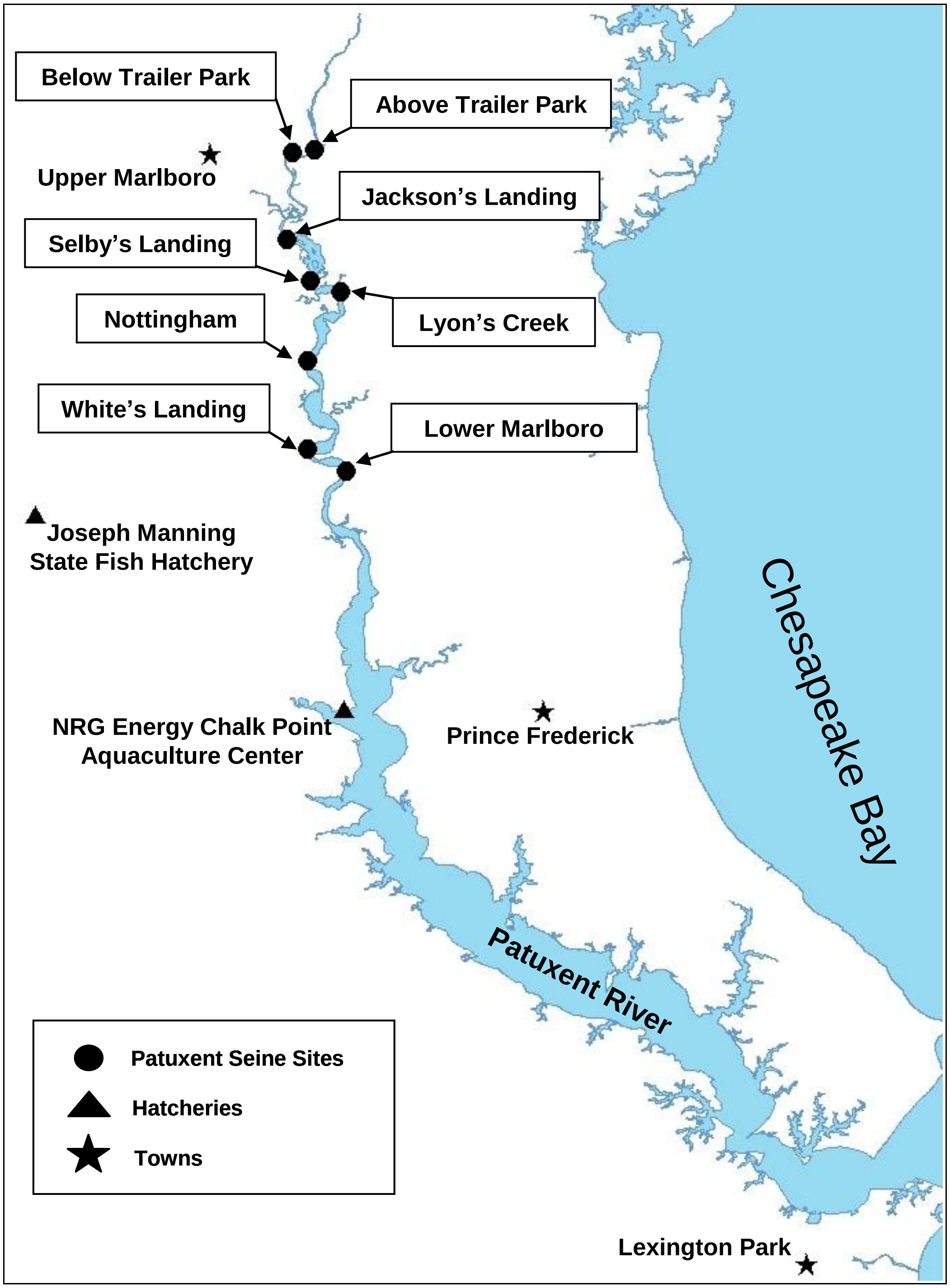

Figure 6. *Maryland Department of Natural Resources Patuxent River juvenile Hickory Shad survey seine sites sampled in 2014.*

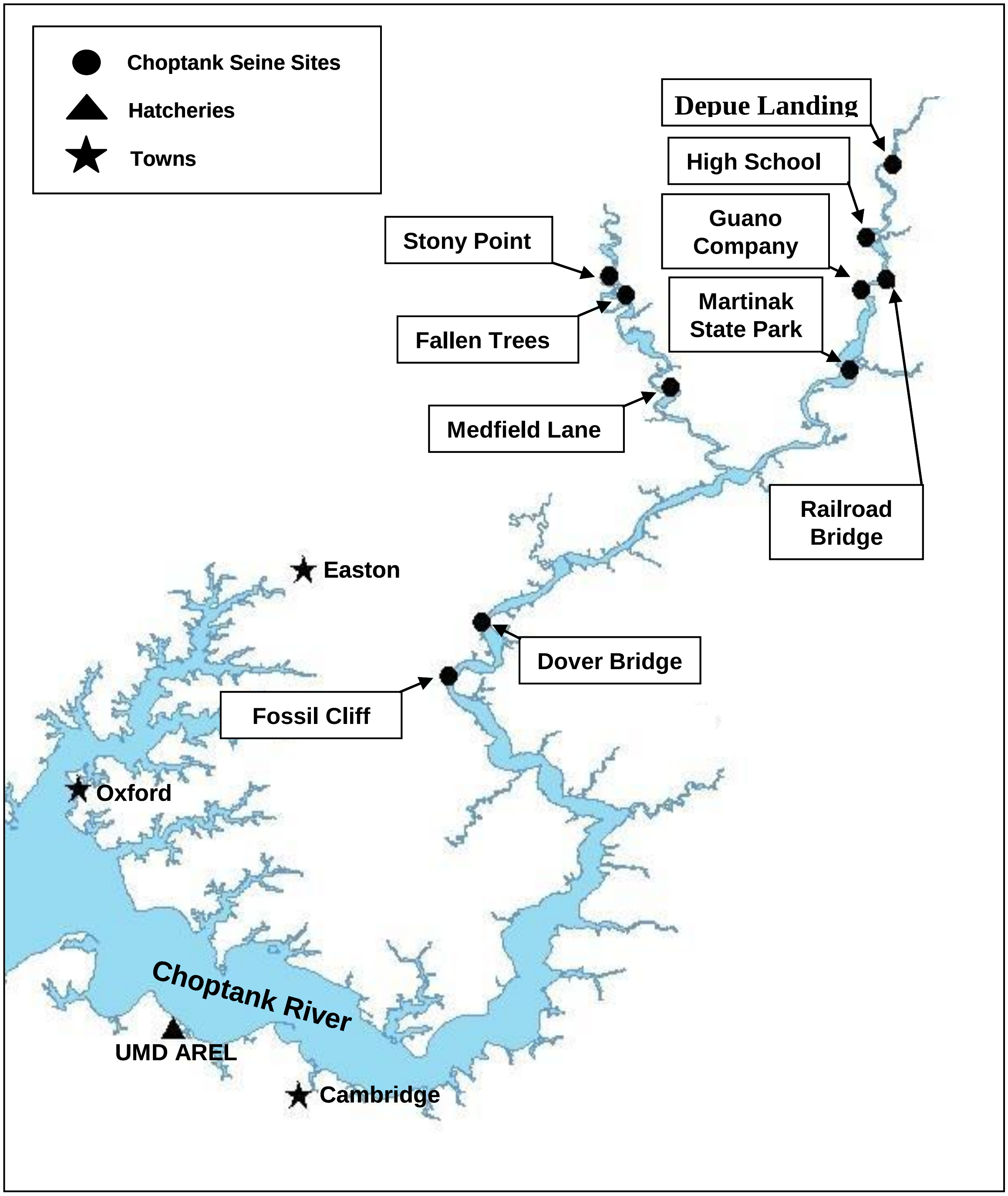

Figure 7. *Maryland Department of Natural Resources Choptank River juvenile Hickory Shad survey seine sites sampled in 2014.*

Results and Discussion

Juvenile Hickory Shad are difficult to recapture with seine gear. Collections are extremely limited and variable. Hickory Shad were typically found at seine sites with minimum shallow shoreline (below 0.5 meters) and slope rapidly to deeper water (>3.0 meters). During the summer seine survey season, juvenile Hickory Shad are generally larger in size than American Shad and are more likely to avoid sampling gear. Until juvenile Hickory Shad are captured in sufficient numbers, calculation of abundance estimates and larval survival will not be possible. Currently, adult Hickory Shad assessment is a better indicator of restoration progress (Sub Project 3).

Patuxent River

The 2014 summer seine survey collected 52 wild origin Hickory Shad juveniles in the Patuxent River (Table 10). This is the most Hickory Shad juveniles (27%) collected in one year since the inception of the survey. Due to the highly variable catch rate of Hickory Shad juveniles, the adult Hickory Shad assessment is a better indicator of restoration progress (Sub Project 3).

Table 10. *1998-2014 Maryland Department of Natural Resources Hickory Shad summer juvenile recaptures in the Patuxent River. Hatchery origin includes larvae, and 30-day early juveniles.*

Year	Wild origin	% Wild origin	Hatchery origin
1998	18	78.3%	5
1999	0	0.0%	0
2000	15	39.5%	23
2001	22	62.9%	13
2002	0	0.0%	0
2003	0	0.0%	0
2004	27	79.4%	7
2005	36	87.8%	5
2006	2	66.7%	1
2007	37	100.0%	0
2008	9	100.0%	0
2009	0	0.0%	0
2010	21	100.0%	0
2011	6	100.0%	0
2012	0	0.0%	0
2013	0	0.0%	0
2014	52	100%	0

Choptank River

Nineteen Hickory Shad juveniles were collected during the summer seine survey in the Choptank River in 2014 (Table 11). Wild Hickory Shad juveniles were captured in all but three years of the survey (1998-2014). Even though few juveniles are captured each year, natural recruitment is occurring. Due to the highly variable catch rate of Hickory Shad juveniles, the adult Hickory Shad assessment is a better indicator of restoration progress (Sub Project 3).

Table 11. *1998-2014 Maryland Department of Natural Resources Hickory Shad summer juvenile recaptures in the Choptank River. Hatchery origin includes larvae, and 30-day early juveniles.*

Year	Wild origin	% Wild origin	Hatchery origin
1998	7	41.2%	10
1999	1	100.0%	0
2000	1	50.0%	1
2001	12	92.3%	1
2002	1	100.0%	0
2003	1	100.0%	0
2004	15	100.0%	0
2005	26	86.7%	4
2006	4	100.0%	0
2007	6	100.0%	0
2008	0	0.0%	0
2009	19	90.5%	2
2010	0	0.0%	0
2011	5	83.3%	1
2012	0	0.0%	0
2013	0	0.0%	1
2014	9	47.4%	10

Sub-project 3.

Estimate the contribution of hatchery origin Hickory Shad to the adult spawning population and monitor recovery of naturally produced stocks.

Objectives

Patuxent River and Choptank River spawning ground surveys commenced in 1999 to collect adult Hickory Shad. Restorative stocking of Hickory Shad began in 1996 on these targeted rivers. Three quantifiable population variables were identified to evaluate restoration progression and relative abundance of adult Hickory Shad spawning stocks in the targeted tributaries. A fourth objective is to evaluate the population status of Hickory Shad spawning stocks from brood source tributaries.

1) *Estimate catch-per-unit effort (CPUE) in each target river using geometric mean.*
2) *Estimate the contribution of hatchery produced fish to the adult spawning populations*
3) *Estimate the frequency of virgin and repeat- spawning.*
4) *Monitor the viability of the Susquehanna River as a Hickory Shad brood source through analysis of virgin and repeat- spawning compositions.*

Methods and Materials

Sampling was conducted at historical Hickory Shad spawning areas described by anecdotal data and concentrated in river reaches where shad were encountered during previous sampling efforts (Table 12, Figure 8). The survey was conducted with a Smith-Root electrofishing boat model SR18-E (Vancouver, WA). The Patuxent River was sampled weekly from 11 March to 10 June and the Choptank River was sampled 19 March to 5 June during day time hours coinciding with high tides. Each survey was accomplished with three people, one person piloting the boat and two people netting shad from the bow. Each river was sampled in an upstream to downstream direction with constant voltage applied to the entire reach. Total shock time (s) was recorded for calculating relative abundance (CPUE). Water temperature (°C), dissolved oxygen (ppm), and conductivity (µS/cm) were obtained using a YSI Pro 2030 water quality meter (Yellow Springs, OH) and a Secchi disk was used to quantify turbidity (cm).

Adult Hickory Shad are sampled in areas that display similar physical characteristics in each river. The survey reach on both rivers generally includes the lowermost areas near the salt wedge to the uppermost areas just below the fall line. In the Patuxent River, this includes the area from the wastewater treatment plant located north of the intersection of Bayard Road and Sands Road (4500 block of Sands Road) to approximately 2.44 miles upstream just above the

Patuxent River 4H Center. In the Choptank River this area extends from the Route 313 Bridge in Greensboro, Maryland to approximately 1.28 miles upstream (Table 12, Figure 8).

In each of the targeted rivers, it is likely that shad utilize tidal freshwater areas downstream of our collection sites, but increasing river width and depth reduces capture efficiency with electrofishing gear. Anecdotal evidence indicates that substantial spawning habitat and fish movement also exists upstream of currently sampled stream reaches, but sampling upstream habitat is limited by electrofishing boat access.

Table 12. *Maryland DNR 2014 adult Hickory Shad electrofishing survey starting and ending coordinates for target tributaries.*

River	Starting latitude/longitude	Ending latitude/longitude
Patuxent River	38° 53’ 08.24” N 76° 40’ 29.53” W	38° 51’ 05.09” N 76° 41’ 33.04” W
Choptank River	38° 59’ 11.91” N 75° 47’ 11.29” W	38° 58’ 36.79” N 75° 48’ 06.79” W

A sub-sample of no more than 20 Hickory Shad was collected per day for age, otolith, and coded wire tag (CWT) analysis. All other observed shad were counted to calculate CPUE. Fish collected were measured for total length (TL; mm), fork length (FL; mm) and sex was determined. Scale samples were taken for age estimation and spawning mark analysis, and otoliths were extracted to identify hatchery OTC marks. All hatchery origin Hickory Shad are marked with OTC, which allows for collection of data on hatchery contribution to the juvenile abundance estimate and the adult spawning stock. Shad scales were cleaned, mounted between glass slides, and age was estimated and spawning attempts were counted using a microfiche reader. Two biologists interpreted the scales independently. In cases where biologists disagreed on an age estimate, a consensus age was used as the final age. Scales were aged using methods described by Cating (1953). Otoliths were processed using methods described for juvenile fish in Sub-project 2.

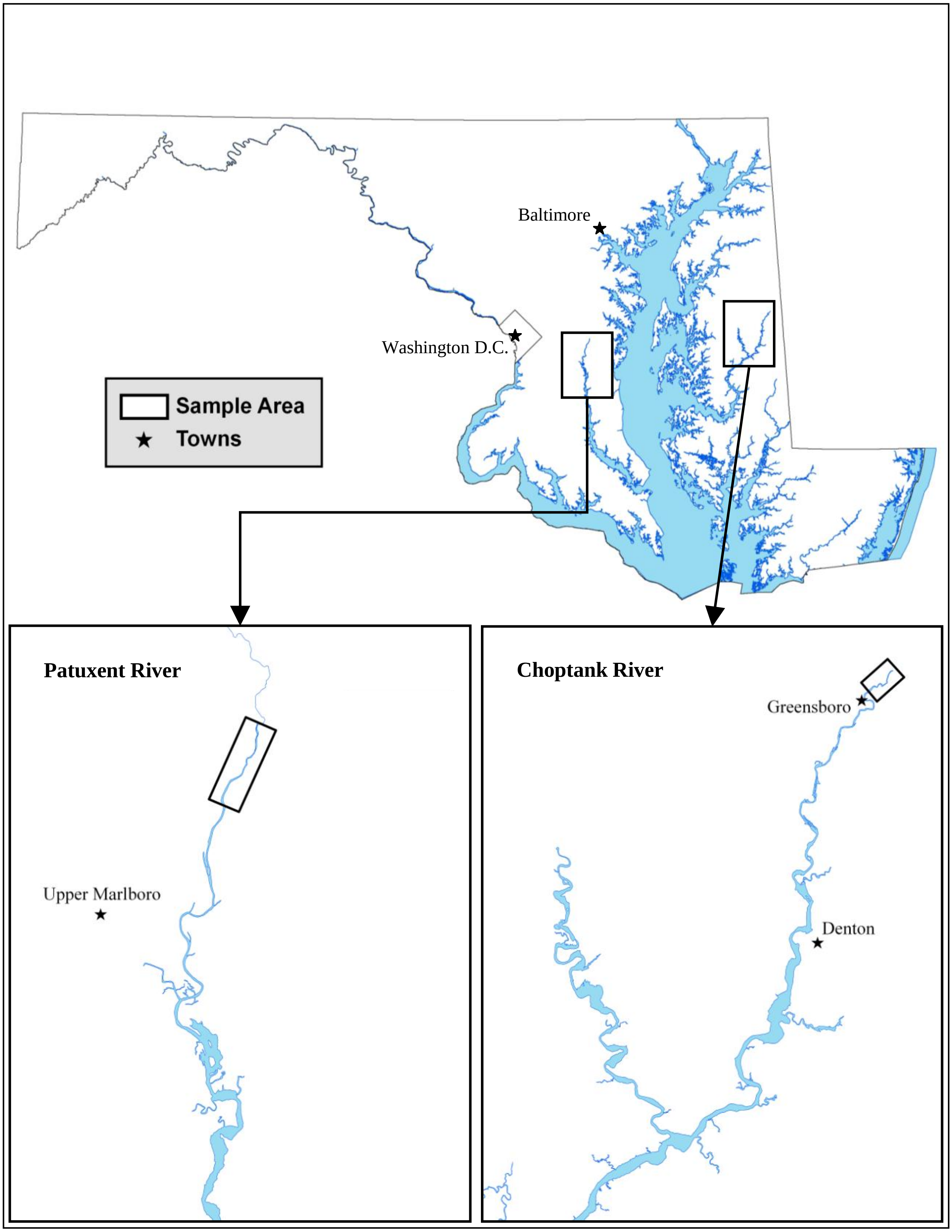

Figure 8. *Maryland DNR adult Hickory Shad electrofishing survey starting and ending locations sampled in 2014.*

Catch Per Unit Effort Analysis

Relative abundance was omitted in reports prior to 2008 due to changes in sampling protocol and the overall nature of sampling these highly turbid rivers. Beginning in 2008, attempts were made to standardize CPUE data and apply those results to evaluate restoration progression. Data were standardized using the number of shad encountered per day divided by the shock time in minutes applied to the river the day of sampling. Since the number of sampling days is different each year, the mean CPUE is calculated to obtain an annual CPUE. In years prior to standardization, estimates were developed using the best available information to back-calculate CPUE. Shock times (effort) for four Choptank and Patuxent river sample dates were not recorded. Those dates occurred in 2002, 2003, and 2005. To generate CPUE data for those dates, the shock time for that year was averaged based on distance covered and which biologist was piloting the boat. In 2002 and 2003, the average shock time for all sample days was used, due to insufficient boat crew data. Adult sample data are unavailable prior to 1999 and any data prior to 2001 are deficient of the necessary catch and effort data to obtain a standardized CPUE. Standardization of CPUE advanced in 2011 with the implementation of bracketing CPUE data. Before 2011, data were collected starting the first week of April and lasting until the CPUE reached zero at the end of the spawning run. Protocol implementation calls for two CPUE zeros at the beginning and end of the survey season to better understand how long fish remain in the spawning area each year.

The geometric mean (GM) has been adopted by this project as the preferred index of relative abundance to evaluate stock status and restoration progress. The GM is calculated from the $\log_e(x+1)$ transformation, where x is the number of Hickory Shad encountered per shock time (mins.). One is added to all catches in order to transform zero catches because the log of zero does not exist (Ricker 1975). The one is then subtracted to better represent the GM data. Since the $\log_e$-transformation stabilizes the variance of catches (Richards 1992), the GM estimate is more precise than the Arithmetic Mean (AM) and is not as sensitive to a single large sample value. The GM is almost always lower than the AM (Ricker 1975). The GM is presented with 95% confidence intervals (CI), which are calculated as antilog ($\log_e(x+1)$) mean ± 2 standard errors), and provide a visual depiction of sample variability. Because CI for each target tributary is calculated using small sample sizes, this results in a large amount of variability about the mean. Differences among annual GM were tested using a two-way analysis of variance (ANOVA) on the $\log_e(x+1)$ transformed data. Geometric means were considered significant at the $p<0.05$ level.

Origin Composition (Hatchery vs. Wild)

The percentage of hatchery versus wild origin Hickory Shad adults sampled on the spawning grounds provide insight into the impact of stocking larval and juvenile shad to the adult population. The presence of adult hatchery origin fish on the spawning grounds early in restoration may stimulate annual natural reproduction, something that has not occurred in decades prior to the restoration efforts. As restoration efforts continue, a transition from a high proportion of hatchery origin fish to a high proportion of wild fish year after year indicates natural reproduction events leading to successful recruitment to adulthood. Identifying shifts from predominantly hatchery origin adults to a wild origin population indicates a substantial effect upon the adult spawning stock population. This variable is sensitive to small sample sizes.

Virgin and Repeat-Spawning Compositions

A third estimator uses analysis of virgin and repeat-spawning compositions. Through examination of Hickory Shad scales, the number of times a fish embarks on an annual spawning run during its lifetime can be determined. The composition of virgin and repeat-spawn frequency observed on the spawning grounds provides additional insight to population stability and recruitment. Low levels of virgin-spawners may indicate problems associated with juvenile recruitment to the adult stock or poor spawning success. Conversely, a high level of virgin-spawners usually indicates successful recruitment of individual year classes to the adult spawning stock. A substantial contribution of virgin-spawners and several repeat-spawning classes utilizing the spawning grounds year after year is indicative of a stable spawning stock.

Results

Patuxent River Hickory Shad Spawning Stock

A total of 98 Hickory Shad were observed on the Patuxent River in 2014. Fifty-eight Hickory Shad were retained for length, otolith, and scale analysis. Surveys were conducted from 11 March to 10 June, when water temperatures were between 5.5° and 21.6°C (Figure 9). A majority (90%) of the Hickory Shad were observed between 7 and 21 April. Only five shad were observed in the Patuxent River once water temperature reached 15.6°C on 15 May.

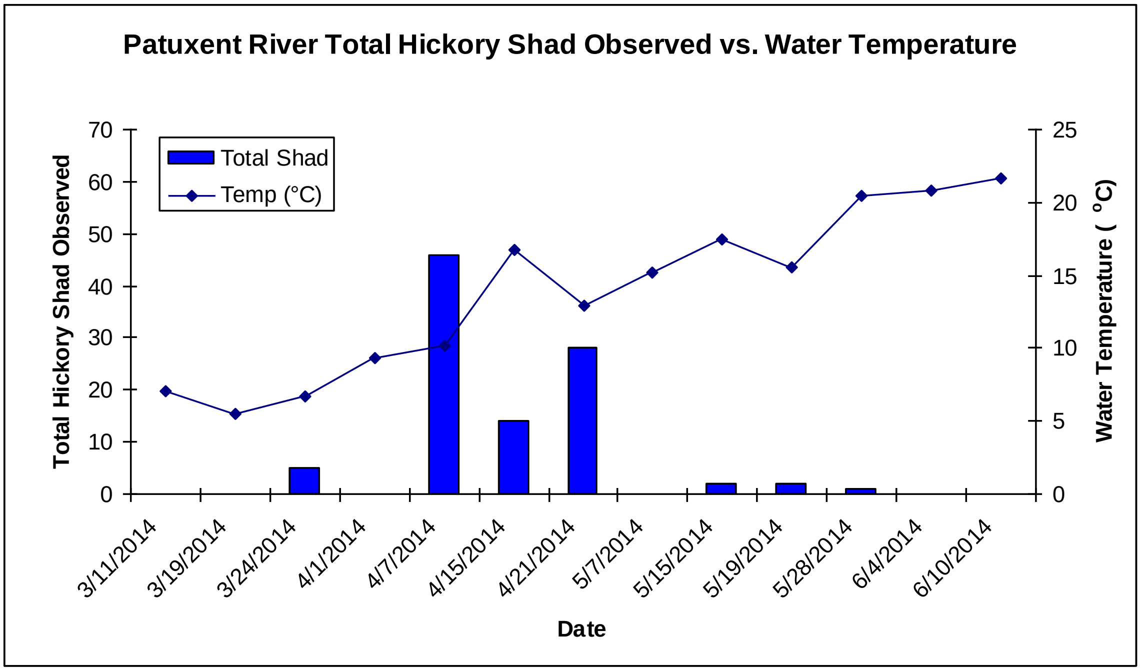

Figure 9. *2014 Maryland DNR electrofishing collections and observations of adult Hickory Shad in the Patuxent River.*

Similar to 2013, the first two and the last two sampling dates of the season yielded no adult Hickory Shad (Figure 10), which successfully bracketed the beginning and the end of the spawning run per standardized protocol. In years prior to 2013, the end data were bracketed, but the beginning of the sampling season was initiated after shad were already in the river.

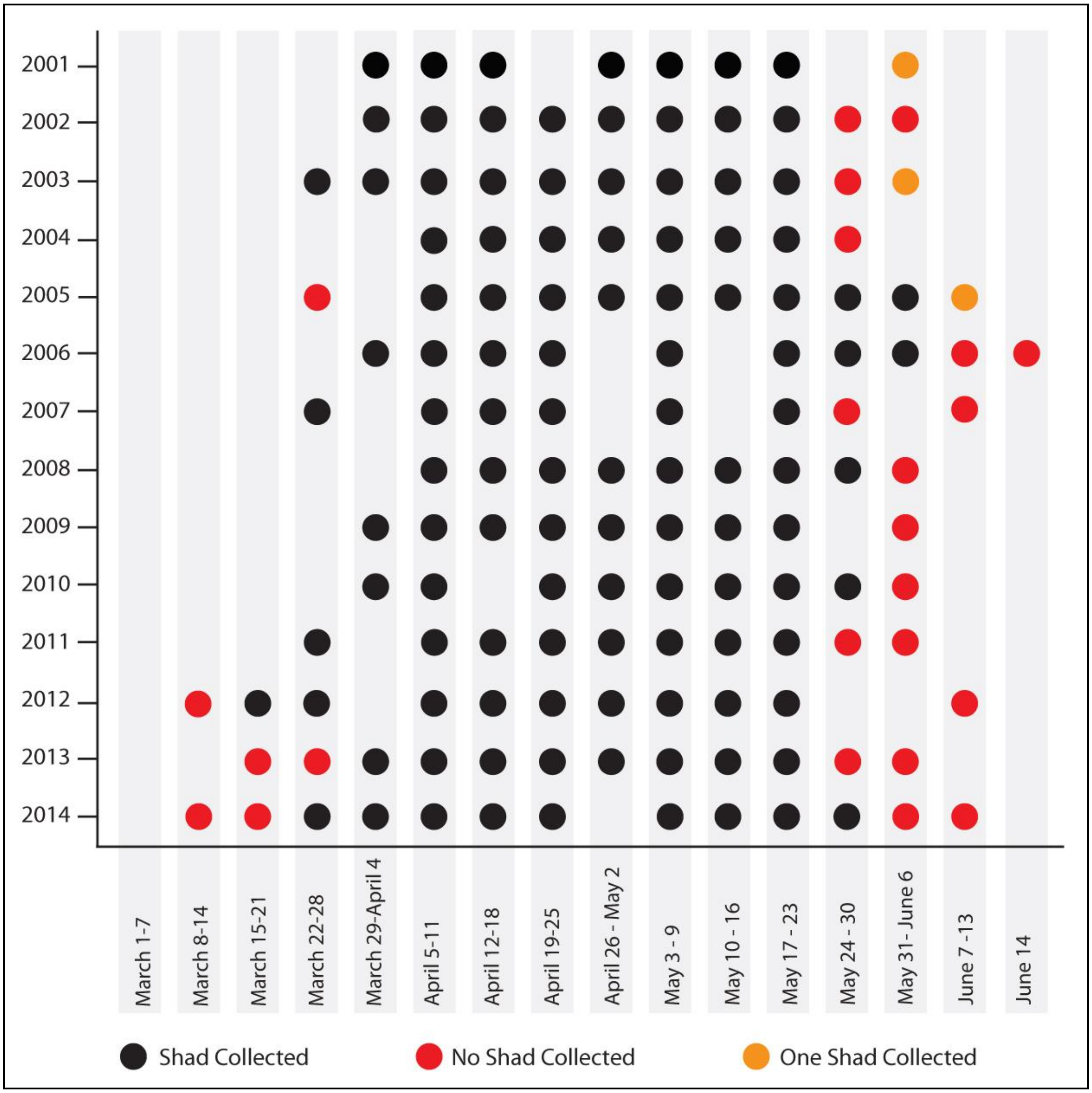

Figure 10. *2001-2014 Maryland DNR Patuxent River Hickory Shad sample dates sorted by seven day increments, with corresponding zero, one, or more than one total shad number.*

Patuxent River Hickory Shad CPUE

During the thirteen weeks from 11 March to 10 June 2014 when Hickory Shad were surveyed on the Patuxent River, the mean relative abundance (GM) was calculated as 0.14 fish/min (Figure 11). The 2014 value is similar to those from 2010-13 (0.22 fish/min average), which are lower than those observed in 2001-2009 (0.59 fish/min average).

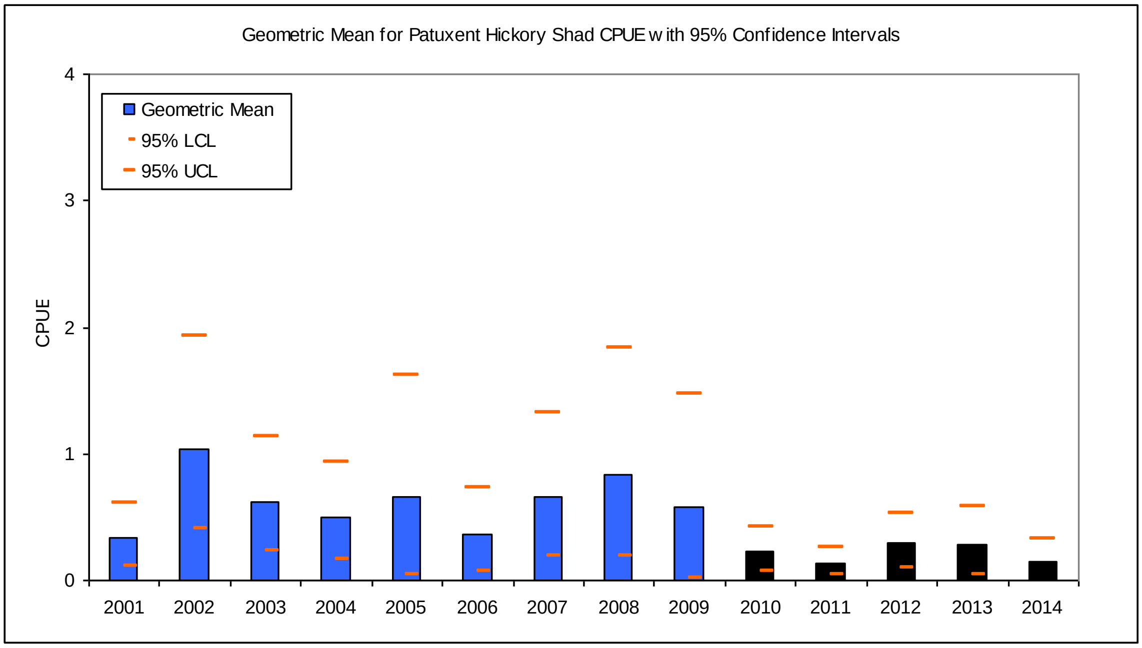

Figure 11. *2014 Maryland DNR electrofishing survey, Patuxent River Hickory Shad geometric mean (GM with 95% confidence intervals) for sample years 2001-14. Years 2011-2014 represent the implementation of new sample protocol.*

Patuxent River Hickory Shad Origin Composition (Hatchery vs. Wild)

In 2014, 58 Hickory Shad from the Patuxent River were retained for origin composition analysis using otolith OTC mark interpretations. Of those 58 samples, 57 otoliths were successfully analyzed and origin was determined. The samples comprised five hatchery origin (9%) and 52 wild origin (91%) (Figure 12). For purposes of this project, a wild component maintained at >80% for three consecutive years or more is considered a successfully restored population. A trend of high (>80%) wild component persisted on the Patuxent River from 2003-08, which led to the decision to discontinue restorative stocking in 2008. Years 2009-2011 were transition years when hatchery adults were still recruiting to the spawning populations without hatchery inputs and not considered during analysis. 2014 has continued the trend for the return of a wild component greater than 80%. Origin composition will be a less valuable tool to determine population in out years post-stocking. CPUE and spawning attempt analysis will be a more valuable indicator to determine population strength in the future.

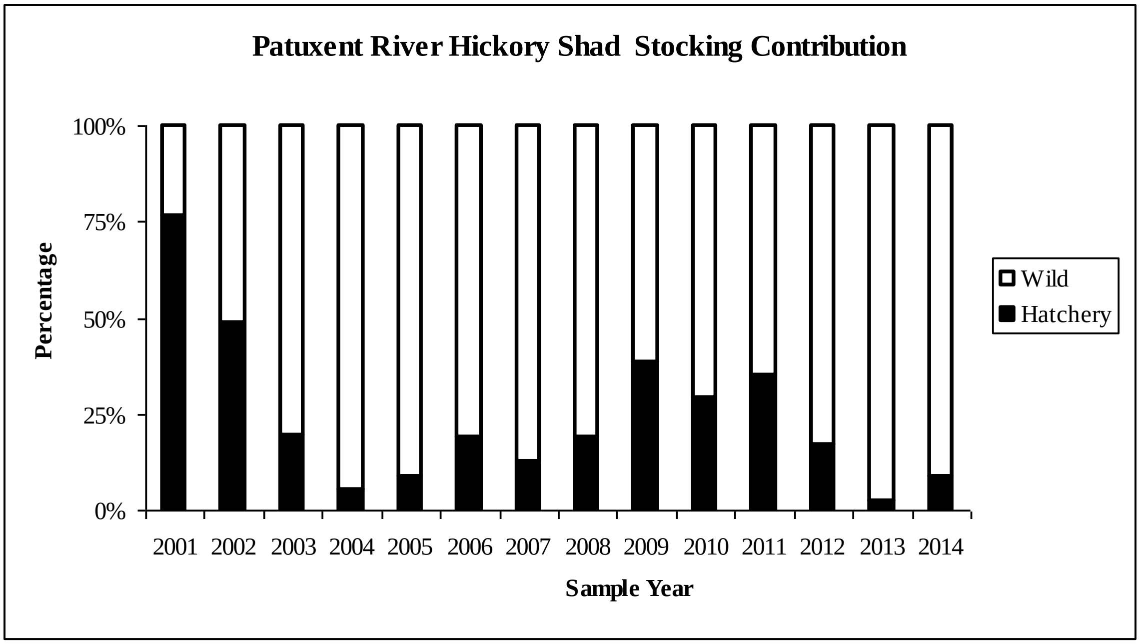

Figure 12. *Adult Hickory Shad origin composition on spawning grounds of the Patuxent River from the years 2001-2014.*

Patuxent River Hickory Shad Virgin and Repeat-Spawning Compositions

A total of 58 Hickory Shad scale samples were collected in 2014. All of the 58 scale samples collected were successfully analyzed and used to determine the annual spawning attempt composition. The 2014 sample population consisted of 36% virgin-spawners, 40% second-time spawners, 21% third-time spawners, and 2% fourth- time spawners and 2% fifth-time spawners (Table 13).

Table 13. *2014 Maryland DNR electrofishing survey. Patuxent River Hickory Shad spawning attempt composition for sample years 2002-14.*

		Spawning Attempts					
Sample Year	**Sample Size (n)**	**1 Virgin Spawners**	**2**	**3**	**4**	**5**	**6**
2002	204	87 (43%)	26 (13%)	71 (35%)	17 (8%)	3 (1%)	
2003	85	28 (33%)	11 (13%)	26 (31%)	19 (22%)	1 (1%)	
2004	59	24 (41%)	6 (10%)	15 (25%)	11 (19%)	3 (5%)	
2005	103	66 (64%)	2 (2%)	18 (17%)	13 (13%)	4 (4%)	
2006	93	41 (44%)	27 (29%)	17 (18%)	2 (2%)	4 (4%)	2 (2%)
2007	99	48 (48%)	14 (14%)	20 (20%)	11 (11%)	5 (5%)	1 (1%)
2008	127	30 (24%)	43 (34%)	35 (28%)	13 (10%)	6 (3%)	
2009	65	7 (11%)	20 (31%)	26 (40%)	10 (15%)	2 (3%)	
2010	55	17 (31%)	12 (22%)	15 (27%)	11 (20%)		
2011	38	8 (21%)	8 (21%)	8 (21%)	12 (32%)	2 (5%)	
2012	88	44 (50%)	26 (30%)	16 (18%)	2 (2%)		
2013	87	56 (64%)	27 (31%)	1 (1%)	2 (2%)	1 (1%)	
2014	58	21 (36%)	23 (40%)	12 (21%)	1 (2%)	1 (2%)	

Patuxent River Hickory Shad Spawning Stock Discussion

Electrofishing survey results for 2014 indicate a Patuxent River spawning stock that is exhibiting an inter-annual variation pattern. Prior to 2007, while stocking was occurring, the GM values varied without trend at an average of 0.59 fish/min (2001-2007; Figure 11). This was followed by a post-stocking adjustment period from 2008-2009. Starting in 2010 (2010-2014), three years post-stocking, the GM values continued to vary without trend, but at a much lower level (0.22 fish/min). Project biologists believed this decline in CPUE was potentially associated with increased turbidity levels, which led to lower catch rates. However, correlation analysis resulted in no correlation between CPUE and Secchi values. It seems this population is maintaining itself naturally, at a lower abundance than when stocking was occurring, and may be indicative of a population that has been restored. This is supported by the origin contribution data, which was initially used to deem this population restored.

Analysis of origin composition data of the Patuxent River Hickory Shad spawning stock represent a classic pattern of stocking effects on a nearly extirpated population (Figure 12). Before restorative stocking began in 1996, the spawning grounds were comprised of low numbers of a wild Hickory Shad remnant population and/or strays from other river systems. In 1999, the first documented hatchery origin adult Hickory Shad returned to the Patuxent River spawning grounds. After several cohorts of hatchery origin Hickory Shad successfully recruited to the adult migratory population, hatchery adults began to dominate the spawning grounds. The 2001-02 sample populations demonstrate this increased hatchery component on the spawning grounds. The 2003 survey represents the year in which the transition occurred from a hatchery dominated sample population to a wild dominated sample population. This transition to a wild dominated population was hypothesized to be triggered by progeny of hatchery origin adults returning to spawn. Because wild origin Hickory Shad dominated the overall adult catch from 2003-09, project biologists believed this population may have expanded enough to minimize the effects of hatchery inputs, and was considered restored.

Examination of the virgin and repeat-spawning data can be used to evaluate stability in a spawning stock and can aid in the prediction of a stock decline or expansion. A stable Hickory Shad spawning stock consists of a substantial contribution from several spawning classes. However, there are several factors that can impart variability in these distributions, including maturity schedules of males (3-4 years) and females (5-6 years), timing of the spawning run, inter-annual spawning, annual recruitment of wild fish, number of fish stocked annually and recruitment of stocked fish. It may be possible to remove some of the variability from these distributions by evaluating male and female distributions separately, but there are already small sample size concerns when combining the males and females in these distributions. This is especially true when looking at fish making their fifth and sixth spawning attempt. Rarely are there five fish in these age categories, which are needed to evaluate these distributions statistically (i.e. chi-square analysis). These small sample sizes lead to uninformative gaps in the time series (2011-2014). However small sample sizes, the spawning population for the Patuxent River demonstrate virgin spawners up to and including fifth time spawners since 2002, which represents a spawning population with numerous cohorts.

Patuxent River Hickory Shad Management Implications

Overall, the Hickory Shad stocking effort in the Patuxent River was successful. The stocking effort resulted in the formation of a stable population. The adult electrofishing survey was able to capture stability in the data. During stocking years (2001-2007), the relative abundance varied without trend. After completion of the stocking program there was a transition period from 2008 to 2009 when hatchery individuals were still recruiting to the spawning stock. From 2010 to 2014, the relative abundance varied without trend, but at lower levels compared to those during stocking years. Because stable populations exist, there is no longer a reason to stock and survey the Patuxent River every year for Hickory Shad. Some data collection is still appropriate to maintain trend data, and we recommend sampling every three years.

Choptank River Hickory Shad Spawning Stock

A total of 166 Hickory Shad were observed in the Choptank River in 2014, of which 85 Hickory Shad were retained for length, otolith, and scale analysis. Surveys were conducted from 19 March to 5 June when water temperatures were between 5.9° and 21.6°C (Figure 13). A majority (93%) of the Hickory Shad were observed between 7 and 21 April. Only five total shad were observed in the Choptank River once water temperature reached 17.3°C on 15 May.

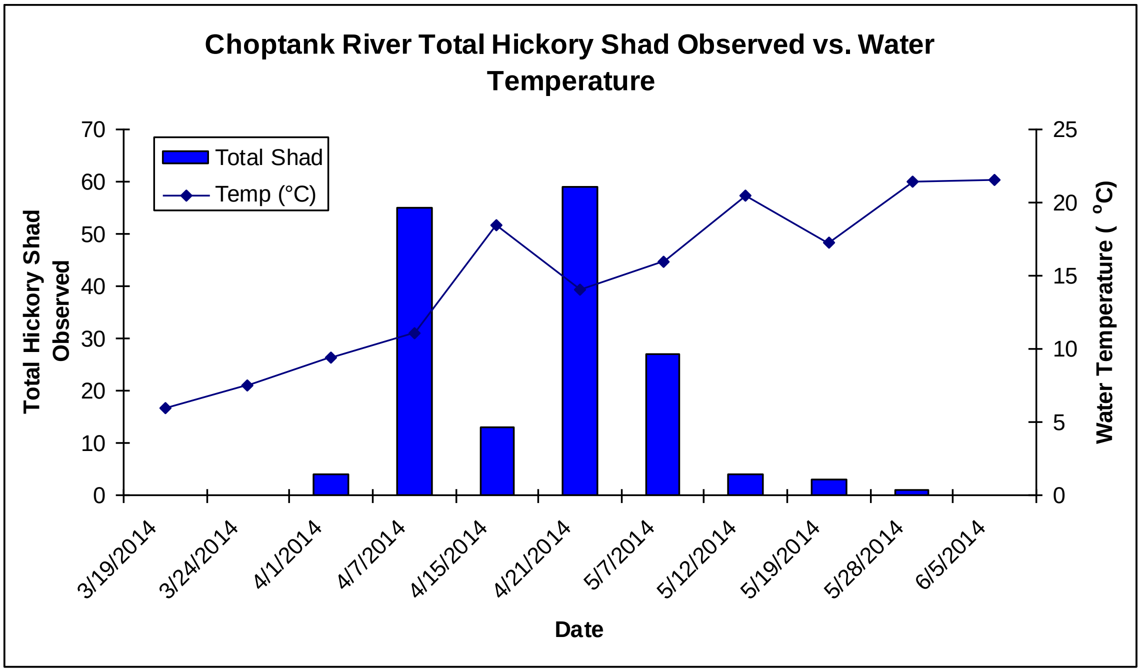

Figure 13. *2014 Maryland DNR electrofishing collections and observations of adult Hickory Shad in the Choptank River*.

Starting in 2011, MDNR implemented a protocol that requires two CPUE zeros at the beginning and end of the Hickory Shad survey season to better understand how long fish remain on the spawning grounds each year. In 2013, the first two sample trips and the last sampling date of the season yielded no adult Hickory Shad, which successfully bracketed the beginning and the end of the spawning run per the new protocol. In 2014, the first two survey dates both resulted in a CPUE of zero, fulfilling the requirements of the protocol (Figure 14).

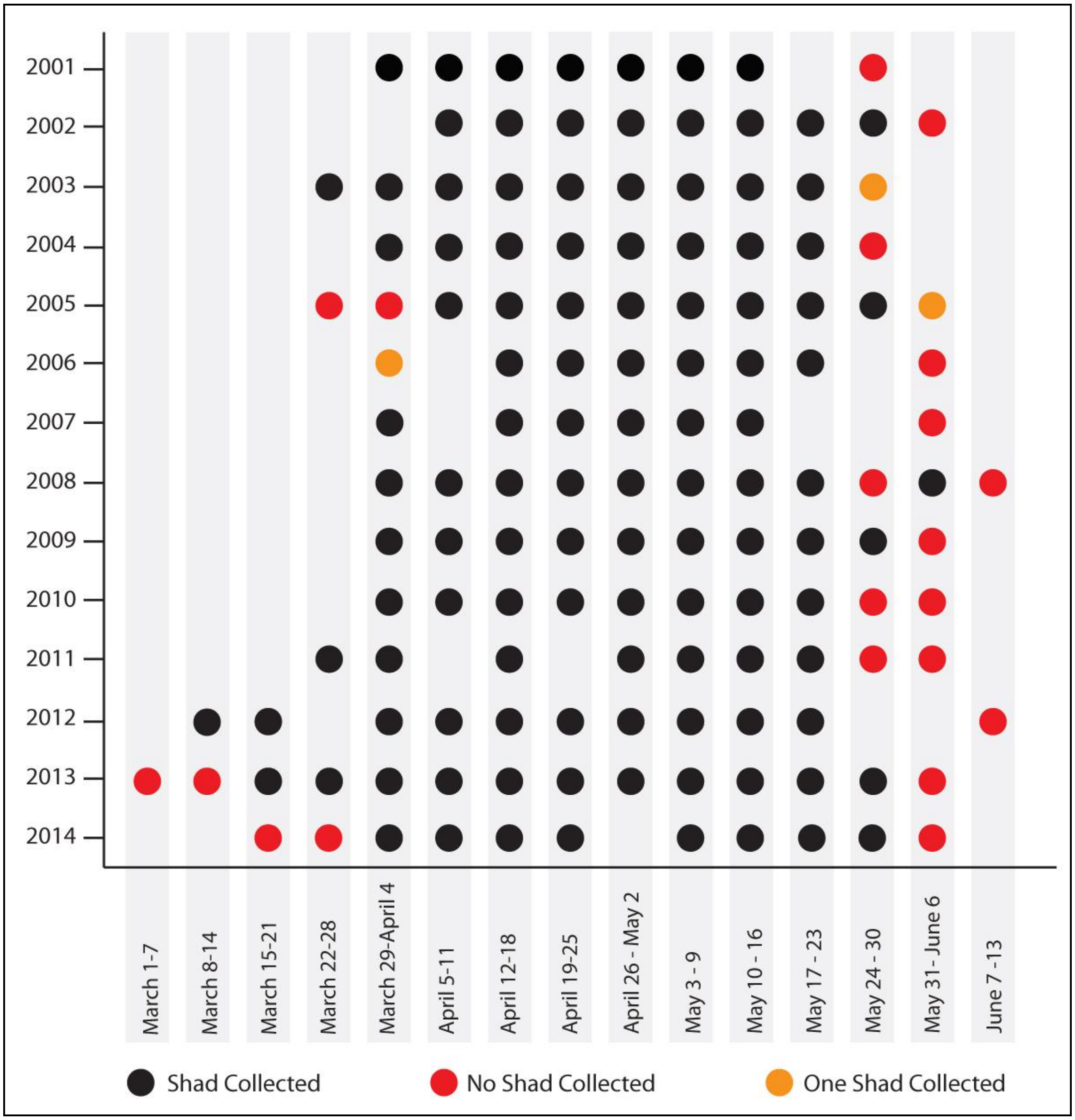

Figure 14. *2001-2014 Maryland DNR Choptank River Hickory Shad sample dates sorted by seven day increments, with corresponding zero, one, or more than one total shad number.*

Choptank River Hickory Shad CPUE

During the eleven weeks from 19 March to 5 June 2014 when Hickory Shad were surveyed on the Choptank River, the mean relative abundance (GM) was calculated as 0.51 fish/min (Figure 11). The 2014 value is similar to those across the time series (2001-2014; 0.68 fish/min average).

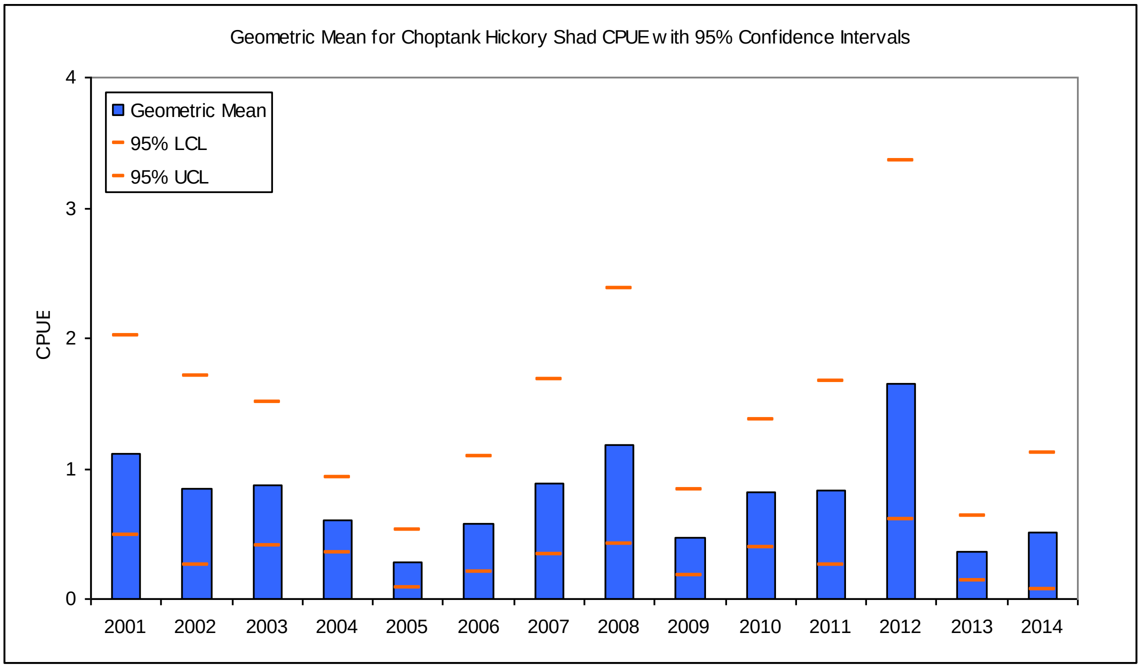

Figure 15. *2014 Maryland DNR electrofishing survey, Choptank River Hickory Shad geometric mean (GM with 95% confidence intervals) for sample years 2001-14. Years 2011-2014 represent the implementation of new sample protocol.*

Choptank River Hickory Shad Origin Composition (Hatchery vs. Wild)

In 2014, 85 Hickory Shad adults from the Choptank River were retained for origin composition analysis, and 84 otolith samples were successfully analyzed to determine origin. The sample comprised 22 hatchery origin (26%) and 62 wild origin (74%) (Figure 16).

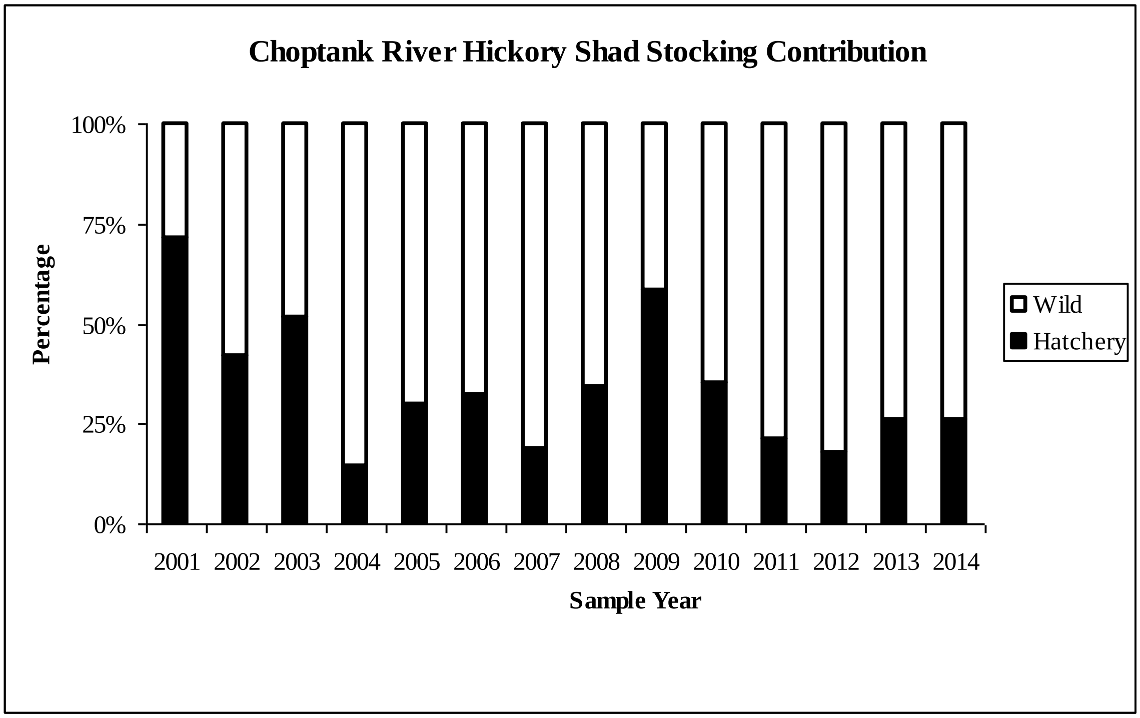

Figure 16. *Maryland DNR adult Hickory Shad origin composition on spawning grounds of the Choptank River from the years 2001-2014.*

Choptank River Hickory Shad Virgin and Repeat-Spawning Compositions

A total of 85 Hickory Shad scale samples were collected in 2014. All were successfully analyzed to determine the annual spawning attempt composition. The 2014 sample population consisted of 42% virgin-spawners, 25% second-time spawners, 26% third-time spawners, and 7% fourth-time spawners (Table 14).

Table 14. *2014 Maryland DNR electrofishing survey. Choptank River Hickory Shad spawning attempt composition for sample years 2002-14.*

		Spawning Attempts					
Sample Year	**Sample Size (n)**	**1 Virgin Spawners**	**2**	**3**	**4**	**5**	**6**
2002	217	73 (34%)	41 (19%)	84 (39%)	17 (8%)	2 (1%)	
2003	92	19 (21%)	13 (14%)	37 (40%)	20 (22%)	2 (2%)	1 (1%)
2004	83	29 (35%)	16 (19%)	27 (33%)	8 (10%)	3 (4%)	
2005	64	30 (47%)	11 (17%)	7 (11%)	7 (11%)	9 (14%)	
2006	80	49 (61%)	14 (18%)	13 (16%)	1 (1%)	2 (3%)	1 (1%)
2007	80	31 (39%)	25 (31%)	19 (24%)	4 (5%)	1 (1%)	
2008	131	53 (40%)	49 (37%)	23 (18%)	4 (3%)	2 (2%)	
2009	62	9 (15%)	15 (24%)	27 (44%)	11 (18%)		
2010	122	50 (41%)	42 (34%)	21 (17%)	9 (7%)		
2011	137	65 (47%)	19 (14%)	27 (20%)	21 (15%)	4 (3%)	1 (1%)
2012	166	70 (42%)	62 (37%)	30 (18%)	4 (2%)		
2013	123	50 (41%)	43 (35%)	21 (17%)	7 (6%)	2 (2%)	
2014	84	35 (42%)	21 (25%)	22 (26%)	6 (7%)		

Choptank River Hickory Shad Spawning Stock Discussion

Since 2001, adult Hickory Shad relative abundance on the Choptank River has exhibited a pattern similar to the Patuxent River during years that it was stocked. During this time, the Hickory Shad GM values in the Choptank River varied without trend at an average of 0.68 fish/min (2001-2014; Figure 15). Despite relatively stable relative abundance, restoration has never been considered complete on the Choptank River and stocking has continued.

Origin composition patterns for Choptank River spawning stock follow a similar pattern exhibited by the Patuxent River. After a brief dip in the wild component in 2009 (Figure 16), the population responded by reverting to a wild dominated spawning population from 2010-2014, marking the fifth year in a row where the majority of adults spawning in the Choptank River were wild origin fish. The average wild contribution of adult Hickory Shad in the Choptank River over the last four years is 77.25%. Because wild origin Hickory Shad dominated the overall adult catch from 2004-2014 (with the exception of 2009), project biologists believe this population has expanded to the point where the effects of hatchery inputs are minimal.

Examination of the virgin and repeat-spawning data can be used to evaluate stability or instability in a spawning stock and can aid in the prediction of a stock decline or expansion. A stable Hickory Shad spawning stock consists of a substantial contribution from several spawning classes. However, there are several factors that can impart variability in these distributions, including maturity schedules of males (3-4 years) and females (5-6 years), timing of the spawning run, inter-annual spawning, annual recruitment of wild fish, number of fish stocked annually and recruitment of stocked fish. It may be possible to remove some of the variability from these distributions by evaluating male and female distributions separately, but there are already small sample size concerns when combining the males and females in these distributions. This is especially true when looking at fish making their fifth and sixth spawning attempt. Rarely are there five fish in these age categories, which are needed to evaluate these distributions statistically (i.e. chi-square analysis). Although the samples sizes of Hickory Shad collected from the Choptank River are larger than those collected from the Patuxent River, they are still small and can lead to uninformative gaps in the time series. Regardless of sample size, the Choptank River spawning population for indicates virgin spawners up to and including fourth time spawners since 2002, which represents a spawning population with numerous cohorts.

Choptank River Hickory Shad Management Implications

Overall, the Hickory Shad stocking effort in the Choptank River was successful. The stocking effort resulted in the formation of a stable population. The adult electrofishing survey was able to capture stability in the data. Wild origin adult Hickory Shad now dominate the spawning population and there are numerous cohorts returning to spawn each year as described (Table 14). During the stocking program (2001-2014), the CPUE varied without trend over the time series. Because a stable population exists, there is no longer a reason to survey the Choptank River every year.

The relative abundance of Hickory Shad in the Choptank River corresponds similarly to the Patuxent River during the years that it was stocked. The Patuxent River population has remained relatively stable since 2009 in the absence of stocking. Furthermore, because wild origin Hickory Shad dominated the overall adult catch from 2004-2014 (with the exception of 2009), project biologists believe this population has expanded to the point where the effects of hatchery inputs are minimal. Consequently, stocking is no longer necessary to sustain a population. If stocking were discontinued, there is no indication that the Choptank River

Hickory Shad population will react differently than the self-sustaining Patuxent River population. Data collection is still appropriate to maintain trend data. A three-year survey interval will be implemented in future year..

Susquehanna River (Brood Source) Hickory Shad Spawning Stock

The Susquehanna River Hickory Shad population has been the sole brood source for restoration efforts since the inception of the project. This population declined along with other Chesapeake Bay Hickory Shad stocks during the 1970s, but experienced resurgence during the 1990s as a dominant year class appeared in 1993. This year class provided a sufficient source of broodstock adults when they began to return as spawning adults in 1996 (Minkkinen et.al. 2000). Strong and stable Hickory Shad spawning runs have occurred since 1996, and have been stable enough to support broodstock collection and a large catch-and-release recreational fishery.

Analysis of spawning attempt data reveals a spawning stock that naturally recruits several spawning classes to the spawning grounds annually (Table 15). This pattern has occurred for several years, as 4+ substantial spawning classes recruit every year. Even though we are able to collect larger samples sizes of Hickory Shad from the Susquehanna River, they are still relatively small and lead to uninformative gaps in the time series.

Table 15. *2014 Maryland DNR brood fish collections. Susquehanna River Hickory Shad spawning attempt composition for sample years 2004-14.*

		Spawning Attempts						
Sample year	**Sample Size (n)**	**1 Virgin Spawners**	**2**	**3**	**4**	**5**	**6**	**7**
2004	80	25 (31%)	11 (14%)	17 (21%)	20 (25%)	6 (8%)	1 (1%)	
2005	80	14 (18%)	10 (13%)	22 (28%)	25 (31%)	7 (9%)	2 (3%)	
2006	178	58 (33%)	29 (16%)	48 (27%)	29 (16%)	11 (6%)	3 (2%)	
2007	139	29 (21%)	26 (19%)	40 (29%)	23 (17%)	17 (12%)	3 (2%)	1 (1%)
2008	149	24 (16%)	37 (25%)	50 (34%)	29 (19%)	7 (5%)	2 (1%)	
2009	118	13 (11%)	19 (16%)	54 (46%)	20 (17%)	11 (9%)	1 (1%)	
2010	240	59 (25%)	72 (30%)	73 (30%)	25 (10%)	10 (4%)		1 (0.4%)
2011	216	67 (31%)	65 (30%)	57 (26%)	19 (9%)	6 (3%)	2 (1%)	
2012	200	72 (36%)	64 (32%)	45 (23%)	15 (8%)	4 (2%)		
2013	193	73 (38%)	62 (32%)	41 (21%)	15 (8%)	2 (1%)		
2014	100	41 (41%)	19 (19%)	30 (30%)	10 (10%)			

Overall Restoration progress:

Restoration efforts demonstrated positive results to Patuxent and Choptank River Hickory Shad populations. Evidence of population expansion since the pre-restorative period is not indicated statistically since data are unavailable prior to the initial stocking of these tributaries. Relative abundance estimates using adult CPUE data while stocking and post-restorative stocking indicate a population without trend during stocking years and a stable population at a lower level following several years of not stocking in the Patuxent River. The Choptank River shows the same trends during the years of stocking. The lack of Hickory Shad juvenile recaptures prevents a complete assessment of the restoration effort, but trend data using adult electrofishing surveys demonstrate a pattern similar to American Shad efforts.

The Patuxent River Hickory Shad population is considered restored. Relative abundance significantly declined since stocking was suspended in 2008. However, data from 2012-2014 indicate a pattern of stability in the absence of hatchery inputs. In addition to relative abundance estimates, repeat spawning analyses indicate a healthy spawning population, which includes consistent virgin spawners each year since 2009. In the future, Hickory Shad analysis in the Patuxent River will depend more upon CPUE estimates and repeat spawning analysis. Since termination of hatchery contributions in 2008, there will be no way to estimate the contribution of hatchery produced fish to the adult spawning populations. Adult sampling should continue every three years to maintain trend data.

This stable pattern of relative abundance and repeat spawning data has continued since 2009 despite lack of hatchery contributions to the juvenile stock, therefore the Patuxent River should be considered a self-sustaining population.

The Choptank River restoration demonstrates a very similar pattern, but this tributary continued to receive annual hatchery contributions until 2014. As stated previously, the lack of Hickory Shad juvenile recaptures precludes complete assessment of the restoration effort. Data analysis from the adult recapture survey indicates that wild contributions steadily increased each year from a low of 26% in 2001 to a high of 75% in 2014. Wild contribution exceeded 75% since 2011. Virgin spawners now substantially contribute to the spawning population and the relative abundance estimates vary without trend since CPUE was standardized. This static pattern of relative abundance and spawning attempt data has continued since 2010, therefore the Choptank River is considered a self-sustaining population. All analyses indicate that the Choptank River would not appreciably benefit from additional hatchery inputs and we propose to suspend stocking in this tributary. Future CPUE trends will be invaluable to evaluate the impacts of suspended stocking in the Choptank River, compared to the Patuxent River stocking cessation in

2008. Adult sample collection will occur every three years to maintain trend data.

Based on this analysis, we propose to amend the 2015 scope of work to explore other target tributaries within Maryland that historically supported Hickory Shad populations. These tributaries include the Northeast Creek, Chester River, and the Pocomoke River. The Marshyhope Creek, a tributary to the Nanticoke River was an original target tributary of the project. Therefore, we also propose to reassess that tributary to determine if stocking is warranted. This amendment will not change the total project budget since substantial resources will be required to assess tributaries during Hickory Shad spawning runs.

Literature Cited

ASMFC (Atlantic States Marine Fisheries Commission). 1999. Amendment 1 to the interstate fishery management plan for shad & river herring. Fishery Management Report No. 35, Washington, D.C.

Cating, J.P. 1953. Determining age of Atlantic shad from their scales. Fishery Bulletin 85, Fishery Bulletin of the Fish and Wildlife Service, Volume 54.

Mohler, J. W. 2003. Culture manual for the Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus. U.S. fish and Wildlife Service, Hadley, Massachusetts. 70 pp.

Minkkinen, S. P., B. Richardson and R. Morin. 1999. Assessment of alosid stocking and natural reproduction in a restoration setting, 1998 report pursuant to Federal Aid #NA86FA0330.

Minkkinen, S. P., B. Richardson and R. Morin. 2000. American shad and hickory shad restoration, 1999 report to Federal Aid in Sport Fish Restoration Act grant #F-57- R.

Mylonas, C., Y. Zohar, B. Richardson and S. Minkkinen. 1995. Induced spawning of wild American shad Alosa sapidissima using sustained administration of gonadotropin-releasing hormone analog (GnRHa). Journal of the World Aquaculture Society 26(3):240-251.

O'Dell, J., J. Gabor and J. Mowrer. 1975. Survey of anadromous fish spawning areas for Chester River drainage in Queen Anne's County. Project AFC-9-2. Maryland Department of Natural Resources. Annapolis, Maryland.

O'Dell, J., J. Gabor and J. Mowrer. 1978. Survey of anadromous fish spawning areas for Potomac River drainage, Upper Chesapeake Bay drainage. Project AFC-9-1. Maryland Department of Natural Resources. Annapolis, Maryland.

Richards, A.R.1992. Incorporating Precision into Management Trigger Based on Maryland’s Juvenile Index. National Marine Fisheries Service, Woods Hole, MA 02543

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191:382 p.

Stence, C., M. Baldwin, M. Bowermaster, J. Schuster. 2011. Hickory shad restoration in three Maryland rivers. 2011 report to Federal Aid in Sport Fish Restoration Act grant #F-57-R.