

**Incorporating Land Use into Ecosystem Based Fisheries Management:
A case study using Alosines in non-tidal tributaries to the Bush River, Upper Chesapeake Bay**

A Final Independent Project Proposal by
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Introduction

Many species of anadromous fish inhabit Chesapeake Bay. Anadromous species, such as American Shad (*Alosa sapidissima*), Alewife (*Alosa pseudoharengus*) and Blue-Back herring (*Alosa aestivalis*) spawn in freshwater but live out most of their adult life in saltwater. All of these species are currently, or once were, very commercially and recreationally important (Pardue, 1983; Murdy, et. al, 1997; Gertsell, 1998; Boreman & Friedland, 2003; Chesapeake Bay Fisheries Ecosystem Advisory Panel, 2006). However, because of environmental impacts such as eutrophication of the bay mainstem, construction of dams blocking migration, and overfishing, populations of many of these species have experienced serious declines (Forester & Reagan, 1977; Murdy, et. al, 1997; Gertsell, 1998; Olney & Hoenig, 2001; Olney et. al., 2003; Limburg, 2003; St.Pierre, 2003).

American Shad, and Blueback Herring and Alewife (collectively referred to as River Herring), enter the bay every spring to spawn in freshwater tributaries. Because of the sheer number of fish in a spawning run, fisheries developed during pre-colonial times (Forester & Reagan, 1977; Pardue, 1983; Stier & Crance, 1985; Murdy, et. al, 1997; Gertsell, 1998). There is

evidence from abandoned fishing villages along the lower Susquehanna River, and its major tributary, the Juniata, that Native Americans took advantage of the annual spring shad runs since before the colonial era in North America (Gertsell, 1998). The migratory range of these species spanned nearly the full length of some of the major Chesapeake Bay tributaries. Prior to construction of large and small dams along the Susquehanna River (the Chesapeake's largest tributary) and its tributaries, American Shad migrated all the way to upstate New York into the headwaters close to present day Cooperstown (Gertsell, 1998; St.Pierre, 2003; Kocovsky et. al., 2009).

American Shad once supported the largest and most valuable fin-fishery in the Chesapeake Bay (Chesapeake Bay Fisheries Ecosystem Advisory Panel, 2006). River Herring also supported large fisheries as well for human consumption, fish meal, and bait for other types of fishing (Stier & Crance, 1983). Spring migrations prompted the development of major commercial fisheries for shad and herring in many of the Chesapeake's tributaries. For example, in the Susquehanna and James Rivers, major gill net fisheries were established in the mid-19th century (Gertsell, 1998; Olney et. al., 2003). In the Potomac River, haul seines were first used, and were gradually replaced by gill nets in the mid-19th century. All three of these fisheries played an important role in shaping regional commerce and culture (Mansueti & Kolb, 1953; Massman, 1961).

Serious declines took place in harvests of American Shad and River Herring during the second half of the 20th Century. The Chesapeake Bay fishery for American Shad has been in steady decline since a peak harvest of approximately 7,000,000 lbs in 1897 (Mansueti and Kolb, 1953; Forester & Reagan, 1977). The State of Maryland instituted a moratorium on American Shad in 1980, followed by the District of Columbia and Virginia in 1986 and 1992, respectively. All moratoria are still in effect. River Herring are still harvested in the Chesapeake Bay and its tributaries. However, from 1965 to 1985 harvests declined by 80% (Chesapeake Bay Fisheries Ecosystem Advisory Panel, 2006).

Ecosystem Based Fisheries Management: A Change in Paradigm

In addition to supporting valuable commercial fisheries, American Shad and River Herring served as important prey for higher trophic level species in the Chesapeake Bay ecosystem (e.g. Striped Bass [*Morone saxatilis*]), and may have played an important role as a predators of various species of zooplankton (i.e. copepods; Murdy et. al., 1997; Walter & Olney, 2003). In addition, field observations and mesocosm studies have shown that American Shad and River Herring provide important inputs of nutrients and carbon to freshwater streams during and after spawning (Durbin et. al., 1979; Freeman et. al., 2003). Estimates have shown that annual biomass of runs of American Shad in the non-tidal James River before dams were constructed in the 1870s exceeded 155kg/ha (Garman, 1992). Studies on the density of biomass of herring runs in New England Rivers have been found to exceed some Alaskan salmon runs. The effects of fishing pressure on River Herring have been shown to decrease nutrient and carbon influxes into these rivers by as much as 80% (Durbin et. al., 1979; Freeman et. al., 2003).

Because of the overarching value that fish play in their ecosystems, many scientists and managers believe that it's prudent for the management of fisheries to take an ecosystem-based approach. Fisheries management, not just in the Chesapeake Bay but throughout the world, frequently uses a single species approach. This means that management decisions on fisheries are made according to the current status of each individual fish population. The interconnectivity of fish species, their prey, their predators, and environment are often not taken into effect (Pitcher, 2001).

There are attempts to engage other sectors into the management of fisheries, such as land management. For example, fisheries biologists with the State of Maryland Department of Natural Resources (MD DNR) have been developing numeric thresholds, or reference points for impervious surface (ISRPs) for various anadromous and semi-anadromous species of fish such as Striped Bass, White Perch, and Yellow Perch (Uphoff et al., 2009). This approach mimics the establishment of biological reference points (BRPs) which are numeric limits on parameters such as total fishing mortality (F). BRPs are venerable components of single species fisheries management used to direct utilization of populations by both the recreational and commercial fishing industries (Fuiman & Werner, 2002).

Issues such as increases in impervious cover in watersheds are currently viewed as externalities in terms of fisheries management. Research into their effects may help internalize these factors helping to predict the effects of social issues such as development of watersheds and population growth on management of natural resources.

Background on Indices for Assessing Ecological Integrity

When assessing the health of a lotic body of water (i.e. stream or river), it is important to assess the overall health at the watershed scale. It is widely accepted that varying degrees of different land use types can have negative effects on the health of a watershed. Assessments of diversity and abundance of in-stream organisms such as macroinvertebrates and fish have shown to decline with increases in proportions of impervious surface (i.e. man-made surface) in relation to total area of a watershed. Percentages of impervious surface above 10% and densities of agriculture above 30% have shown to cause decreases in aquatic health (Bilkovic, 2000; Bilkovic et. al., 2001; Allan, 2004). With increases in impervious surface, streams experience increases in peak flow (Figure I) causing scouring and erosion, and increases in contaminant runoff (Booth et. al, 2002; Allan, 2004). Increases in agricultural cover lead to increased runoff of nutrients and other contaminants used in cultivation (Boesch et. al., 2001; Allan, 2004).

Most of the work performed on land use effects in streams has been focused on non-tidal, freshwater systems. This had led to the development of indices of biotic integrity (IBI) and sampling protocols known as rapid bioassessment to quickly, but effectively assess aquatic health (Barbour et. al., 1999). The development of these indices is based on the observed habitat requirements (e.g. dissolved oxygen, bottom substrate) for stream organisms (Karr, 1991). Karr (1991) argued that incorporation of IBI scores is an effective way to evaluate local surface water quality and should be integrated into any jurisdiction's assessment regime as a means of complying with the Federal Water Pollution Control Act of 1972 (Clean Water Act; P.L. 92-500). IBI scores are based on the total sum of different organisms based on their sensitivity to pollution. Some orders are more sensitive to changes in water quality and habitat (e.g. order Ephemeroptera [mayflies]) than others who are more pollution tolerant (e.g. order Diptera [chironomids]). If more mayflies are present than more pollution tolerant species within a

stream reach, than the reach may be scored as containing good water quality (Karr, 1991; Barbour et. al., 1999).

Similar to the IBI is the concept of a habitat suitability index (HSI). Like an IBI, an HSI takes into account observed values for habitat requirements for a species. However, these models were not designed to assess habitat based on presence of organisms, but rather abiotic parameters that are necessary for habitat for specific species. This concept has been applied throughout a variety of ecosystems, especially in aquatic systems (Pardue, 1983; Stier & Crance, 1985; Ross et. al., 1997; Bilkovic, 2000; Bilkovic et. al, 2001). In a series of publications in the

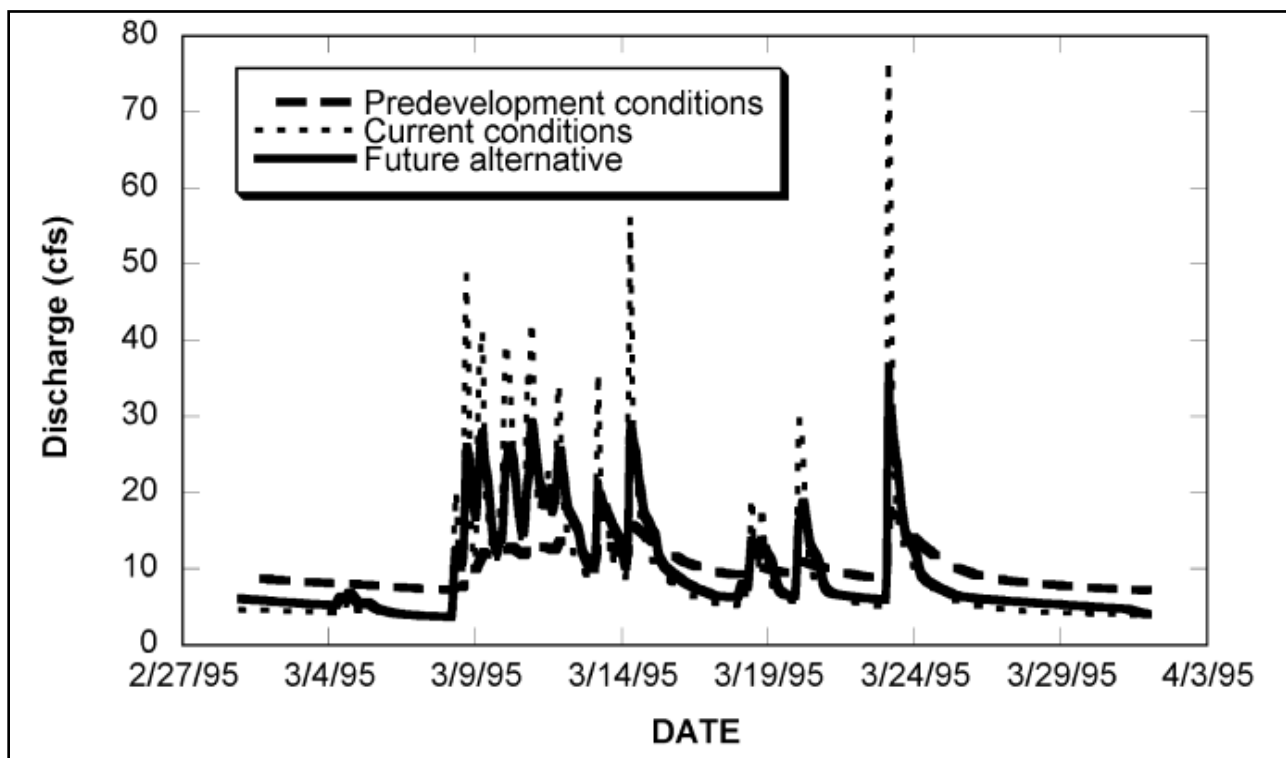


Figure 1 - Hydrograph developed for Des Moines Creek, King County, WA. The hydrograph shows the change in discharge over time between various landscape scenarios featuring predevelopment watershed conditions, current watershed conditions (urbanized), and future alternative conditions (restored landscape) (Booth et. al., 2002).

1980's, the U.S. Fish and Wildlife Service (USFWS) developed HSI models for several species of fish (see Figure II for example an HSI for River Herring). These models used empirical data collected from extensive literature reviews to evaluate and identify various areas as essential fish habitat (EFH) (Pardue, 1983; Stier & Crance, 1985). An example model can be found in

Figure II. EFH is defined by the Sustainable Fisheries Act of 1996 as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity (P.L. 104-297)."

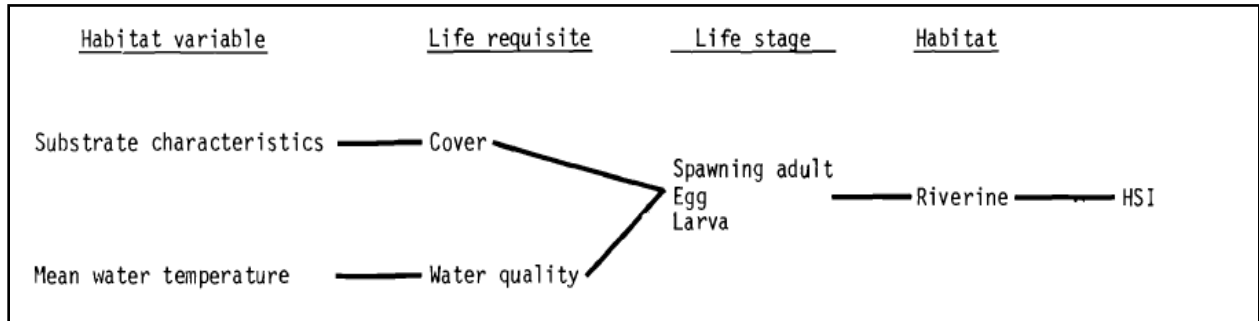


Figure II – Example HSI model used to assess riverine habitat for River Herring (Pardue, 1983).

Project Proposal

For my independent project I am proposing to examine the effects of geomorphic parameters (e.g. sediment size, sinuosity), total watershed impervious cover, and hydrographic parameters (e.g. current velocity, dissolved oxygen) on habitat for American Shad and River Herring in the non-tidal reaches of the Bush River, a coastal plain tributary of the Chesapeake Bay. The Bush River is being chosen as the study site because the Maryland Department of Natural Resources (DNR) has historically conducted surveys on the presence or absence of anadromous clupeid (i.e. species of shad and herring) eggs and larvae in this system. DNR noticed variability in abundance of eggs and larvae in their samplings for some subwatersheds of the Bush between 1973 and 2008, and wanted to examine whether or not this was attributed to changes in physical parameters (e.g. geomorphological and hydrographic parameters) of the non-tidal tributaries. They decided to contract a study to Chesapeake Environmental Management, Inc. (CEM) to conduct stream reach geomorphological and physical habitat surveys in various subwatersheds of the Bush River in 2008 to assess the status of in-stream habitat. Data collected by the contractor did indicate that in-stream habitat for fish was degraded in both watersheds and they attributed this loosely to changes in landuse, especially increases in impervious surface (MD DNR, 2008).

The data collected by CEM in the Bush subwatersheds requires further statistical analysis to assess if changes in land use have had a negative effect on habitat for specifically for anadromous clupeids. Analysis and incorporation of the data collected on stream geomorphology, flow, and water quality into preliminary HSIs for American Shad and River Herring will help DNR in their management efforts, effectively internalizing factors that would have been traditionally ignored in fisheries management. These HSIs will be recommended as preliminary management tools because data required to make solid conclusions about EFH may be missing. DNR may want to develop HSI specific habitat sampling surveys to more fully develop delineation techniques for shad and herring habitat. In addition, sampling conducted for presence/absence of fish eggs and larvae was done using coarse examination for anadromous clupeids. Other species of clupeids (e.g. Gizzard Shad [*Dorosoma cepedianum*]) may have made up significant proportions of the eggs and/or larvae observed as. However, HSI models have not been developed for other clupeid species in lotic systems.

HSI models developed by USFWS for American Shad have been refined by other studies over the past 25 years. These studies include research conducted mainly on American Shad (*Alosa sapidissima*) in Chesapeake Bay tidal and non-tidal tributaries of the coastal plain in Virginia and the piedmont region in Pennsylvania (Bilkovic, 2000; Bilkovic et. al., 2001; Kocovsky et. al., 2008; Kocovsky et. al., 2009). Research on non-tidal reaches has also been applied in the Delaware River for American Shad (Ross et. al., 1997). Background literature on River Herring habitat requirements is somewhat limited relative to American Shad with original models developed by USFWS (Pardue, 1983), and later refined by Carline et. al. in 1994.

The goals for this project are as follows:

- 1) Infer through application of an HSI and other statistical analyses that land use does or does not affect the quality of habitat for alosines in these two watersheds.
- 2) Develop preliminary HSIs for American Shad and River Herring that MD DNR can use in their habitat mapping and species management efforts.

This project incorporates concepts from a large amount my coursework while attending Johns Hopkins. Courses of particular utility include Hydrology & Water Resources; Geological Foundations for Environmental Science; Landscape Ecology; Wetlands Ecology & Management;

Chesapeake Bay: Ecology & Management; and Fisheries Ecology, Science, & Management. This project also merges my two main areas of interest: watershed management and fisheries management.

My mentor is Robert Murphy, Director of Ecosystem Solutions, Inc., a private non-profit research consultant group located in Edgewater, MD and adjunct faculty in the Johns Hopkins University Krieger School of Arts and Sciences. Professor Murphy has a strong background in aquatic and fish ecology, and has performed research in estuarine and freshwater systems. He completed his graduate work at the Chesapeake Biological Laboratory (University of Maryland) under the advisement of Dr. Dave Secor. He has a strong background in quantitative analysis of ecological data (univariate and multivariate statistics) that will be helpful with my analyses. Professor Murphy is author or co-author of several publications in fish ecology and estuarine habitat restoration. Professor Murphy teaches two courses as part of the Johns Hopkins environmental studies program, including Chesapeake Bay: Ecology & Management, and Fisheries Ecology, Science, & Management.

Project Development and Implementation Schedule

September 2010: Secured Robert Murphy as advisor and began developing research ideas

October 2010: Met with Dr. Eileen McGurty to discuss project ideas

October – November 2010: Continued to refine research ideas with Robert Murphy. Discussed project ideas with MD DNR. MD DNR provides data, which is organized by Matt Robinson

December 15th, 2010: Draft project proposal submitted to Dr. McGurty and Professor Murphy

January 15th, 2011: Final project proposal submitted to Dr. McGurty and Professor Murphy. Project implementation begins.

January 15th – March 15th, 2011: Data analysis and HSI development

March 15th – April 15th, 2011: Write draft paper

May 7th, 2011: Submit final paper

Methods

Assessing Land Use Change in the Bush and Corsica Watersheds

Land use data for the Bush River watershed (1984-2006) was compiled as raster image files by US Geological Survey (USGS) staff at the Chesapeake Bay Program Office, Annapolis, MD as part of the Chesapeake Bay Land Cover Dataset (CBLCD). Data on areal cover for various land use types will be loaded into ArcGIS 9.3 (ESRI, Inc., Redlands, CA). Proportions of each land use type will be examined using ArcGIS Spatial Analyst (ESRI, Inc., Redlands, CA) for 1984, 1992, 2001 & 2006 (years available in the CBLCD). Only those portions of the subwatersheds upstream from the geomorphic survey reaches will be assessed in order to provide a more accurate picture of the effects of land use on the stream reaches surveyed. This deviates somewhat from the methods of Bilkovic et. al. (2002), because that particular study looked only at land use within a 100 m buffer of the stream. Bilkovic et. al. (2002) cited Large & Petts (1994) and Phillips (1996) who contended that land use within that distance from the stream had the greatest effect on stream functions. However, as a relatively developed watershed, the Bush River contains an extensive stormwater drainage system (Figure V displays drainage system within the Bynum Run subwatershed). Therefore stormwater runoff outside the 100 m buffer could affect stream functions as much as runoff within the buffer.

Total impervious cover for each subwatershed will be assessed using impervious surface coefficients developed by USGS. Total cover of pasture and cropland will be calculated as well. These numbers will be merged into one total areal cover figure for agriculture. Table I below displays changes in land use in the Bynum Run subwatershed between 1984 and 2006. Figure IV displays the results of using ArcGIS Spatial Analyst to examine changes in land use as well as the percent change in impervious surface.

Collection of Stream Geomorphological Parameters, Water Quality Data, and Presence/Absence of Clupeid Eggs and Larvae

Data on stream geomorphology and physical habitat was collected by CEM, Inc. in 2008 for several subwatersheds in the Bush River, Harford County, MD. CEM, Inc. utilized the 1994 stream channel reference site field techniques developed by the U.S. Department of Agriculture

Forest Service (Harrelson et. al., 1994). Stream reaches surveyed varied from 500 – 1000 ft in length were chosen by CEM, Inc. based on the location of MD DNR ichthyoplankton survey sites in each subwatershed, as well as accessibility.

MD DNR conducted surveys for presence or absence of anadromous clupeid larvae and eggs in 1973, 2005, 2006, 2007, & 2008 using stream drift nets. Water quality measurements were taken during the surveys including temperature, pH, specific conductivity and dissolved oxygen (DO). Measurements were taken using a hand held YSI model 55 (YSI, Inc., Yellow Springs, OH).

Landuse Category	Percent Change
Developed Open Space	7%
Low Intensity Urban	6%
Medium Intensity Urban	3%
High Intensity Urban	0%
Deciduous Forest	-5%
Evergreen Forest	-1%
Pasture Hay	-6%
Cultivated Crop	-6%

Table I – Percent change in various landuse categories between 1984 & 2006 for the Bynum Run watershed (tributary to the Bush River). Percent change was calculated using spatial analyst in ArcGIS. Landuse data was retrieved from the USGS Chesapeake Bay Landcover Dataset.

Statistical Analysis

Using SysStat software (SysStat Software, Inc, Chicago, IL), a suite of multivariate techniques will be used to relate presence/absence of clupeid eggs and larvae, watershed landuse, water quality data and stream geomorphic characteristics. Data collected by DNR in 2008 (ichthyoplankton, water quality and stream geomorphic characteristics) will be compared to 2006 landuse characteristics of each catchment upstream from the geomorphic survey site. It is highly unlikely that significant changes in landuse took place in each watershed between 2006 and 2008. An example analysis of changes in landuse between 2001 and 2006 in the Bynum Run watershed (subwatershed to the Bush River) showed virtually no change (Figure III). Therefore it's safe to assume that there will be no or negligible changes in landuse between 2006 and 2008, allowing comparison of 2006 land use data to all other data collected in 2008.

An exact assessment of which statistical techniques will be used is uncertain until after preliminary assessments of data are complete.

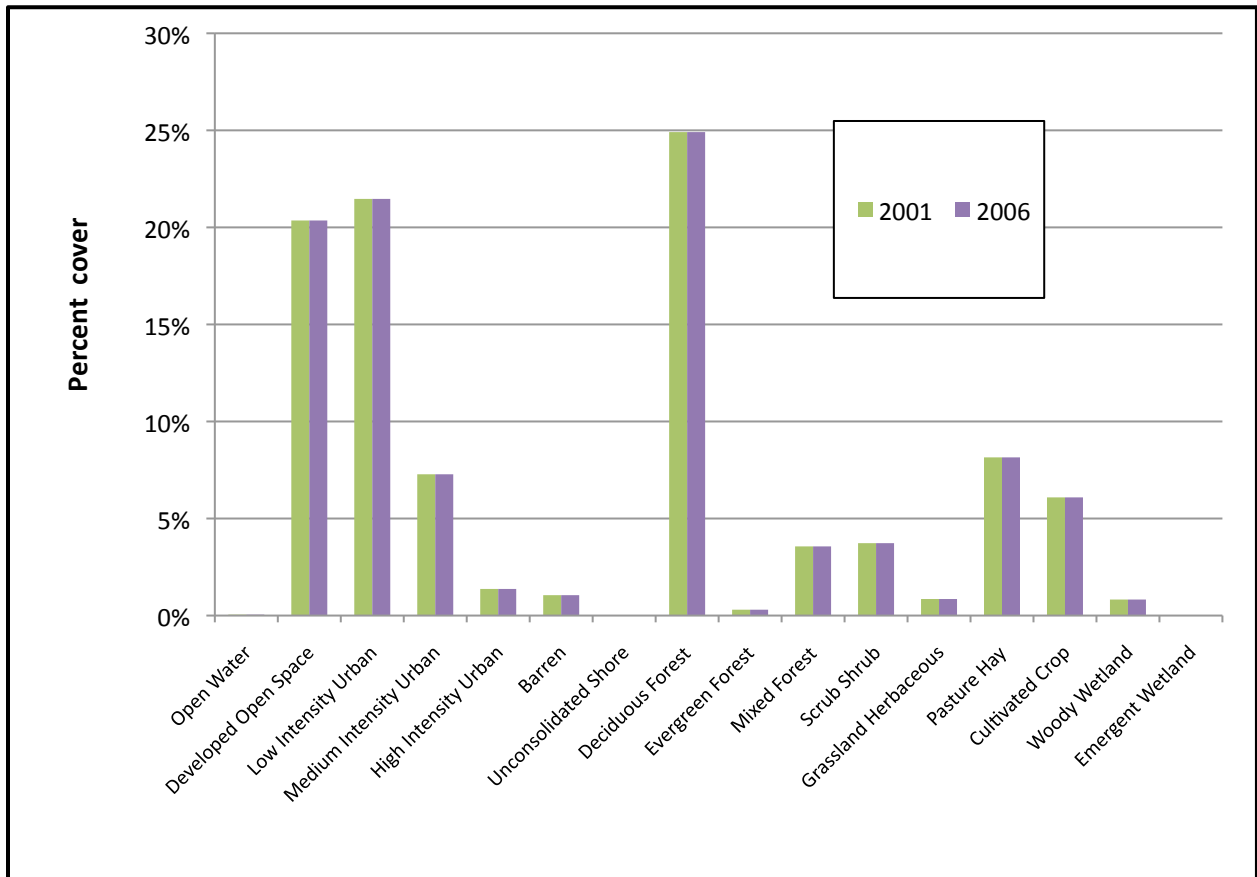


Figure III –Percentages of various landuse types between 2001 & 2006 for Bynum Run catchment upstream from geomorphic survey point.

Developing Preliminary HSIs

HSIs for American Shad were developed using methods developed by Pardue 1983; Stier & Crance, 1985; Bilkovic, 2000; Kocovsky et. al., 2008, & Kocovsky et. al., 2009. HSIs for River Herring were developed using methods developed by Pardue, 1983 and Carline et. al., 1994.

Data requirements include: