Tracking terrapins through genetic analysis: Multilocus assignment tests shed light on origin of turtles sold in markets

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ABSTRACT

Diamondback terrapins (*Malaclemys terrapin*) are currently sold for human consumption in many large cities in the United States. Some Asian cultural groups utilize large numbers of terrapins, both regionally and world-wide, as a protein source. Terrapin populations face many prevalent problems including predation by both native and non-native predators, and anthropogenic disturbances (such as habitat destruction, roadkill, and bycatch in blue crab traps). The additional anthropogenic dilemma of terrapins sold in fish markets is particularly troubling when added to the long list of widespread disturbances. Terrapin harvesting is restricted in each state throughout the Atlantic and Gulf coastal range of the species; however, enforcement of these restrictions is weak. The objective of our study was to determine the origin of terrapins sold in New York City's Fulton Fish Market. In 2004, we collected blood samples from 63 individual terrapins confiscated from illegal sellers in the Market. Some of these terrapins were released off the coast of Maryland, based on the belief that the terrapins were originally harvested in the Chesapeake Bay. In this study, we used microsatellite DNA variation to test the hypothesis that *M. terrapin* collected in the Market are from the Coastal Mid-Atlantic terrapin metapopulation. We extracted DNA from blood samples, performed PCR, and screened each turtle at 12 polymorphic microsatellite DNA loci developed for bog turtles (*Glyptemys muhlenbergii*). Statistical analyses relied on assignment tests to determine the most likely region of origin for each terrapin to the metapopulation and subpopulation level. Many of the terrapins were assigned to the Chesapeake Bay metapopulation (or subpopulations in Maryland); however, some terrapins were assigned to the Coastal Mid-Atlantic or the Coastal Carolina region. Rules and regulations (and the enforcement of these rules) need to be improved to adequately protect terrapins from direct harvest.

CHAPTER 1: INTRODUCTION

Diamondback terrapins (*Malaclemys terrapin*) are the only emydid turtle that inhabit brackish water such as coastal marshes, estuarine bays, lagoons, and creeks. Terrapins live along the east coast of the United States from Cape Cod, Massachusetts to Corpus Christi, Texas. Some prevalent problems faced by terrapins are predation by native and non-native predators (Draud et al. 2004; Feinberg & Burke 2003; Seigel 1980) and anthropogenic disturbances (such as habitat destruction, roadkill (Wood & Herlands 1997), bycatch in blue crab traps (Bishop et al. 1983; Davis 1942; Roosenburg et al. 1997), and demand by humans).

The demand for turtles can be summarized into five categories, which include food (both meat and eggs), Traditional Chinese Medicine (TCM), pets, decoration, and release during religious ceremonies (Compton 2000). Of all of these trade sectors, the highest demand for turtles comes from food and TCM. TCM beliefs include that turtle soup should be consumed during the winter to warm the consumer’s blood and that turtle jelly detoxifies the body to the extent that it can cure cancer (Lau 2000). In addition, turtles are commonly kept as pets, typically when they are small hatchlings. For example, terrapins have been documented for sale in pet markets in Taiwan (Chen 2000). Furthermore, turtle shells are commonly used to make decorations for the home and the human body. Tourist areas often sell items such as turtle shell masks for wall decorations and belts or shoes for accessories. Turtles are also commonly released during Buddhists’ religion ceremonies, especially in Southeast Asian temple ponds (Compton 2000). Releases are a concern because species are being released into areas where they do not originate. The effect of the introduced species of turtles on existing types of amphibians is unknown and may be detrimental. Although many turtles are used for TCM, pets, decoration, and religious releases, the direct harvest of terrapins for the food industry is becoming an increasing problem in the United States and worldwide.

In the late 1800s and early 1900s, many people considered terrapins a gourmet delicacy, typically served as terrapin stew (Carr 1952). In the early 1920s, terrapins were being sold for $90 a dozen (Carr 1952). Due to this gourmet status, terrapins were hunted to the extent that their populations were nearly depleted along the coast from New York to Virginia. By the late 1920s, terrapin populations slowly began to rebound due to the effects of Prohibition (sherry made up a large portion of terrapin stew) and the Great Depression (middle class people were no longer able to afford terrapin meat) (Conant 1964). Nevertheless, more than 80 years later, terrapin populations have not rebounded to the level of pre-"gourmet delicacy status".

Currently some Asian cultural groups utilize very large numbers of wild caught turtles, both regionally and world-wide (Compton 2000). The United States' involvement in this trade is not limited to export; large but almost completely undocumented numbers of native turtles, especially red eared sliders (*Trachemys scripta*) and terrapins are sold for food in large cities in the United States. In order to protect native terrapin populations, the food industry must be analyzed to determine the extent of terrapin presence. Furthermore, terrapins that are confiscated from a fish market should not be returned to the wild prior to determining the most likely region of origin. If terrapins are returned to the incorrect location, new genes could be introduced to the population or gene frequencies could be altered.

In 2004, 63 diamondback terrapins were confiscated from the Fulton Fish Market in New York City, where the turtles were being marketed for sale as a fish species. It was assumed that the market terrapins came mostly or entirely from Maryland (J. P. Green, pers.

comm.), in part because Maryland permitted a large legal terrapin harvest and had existing market connections due to the thriving shellfish industry. In response to this assumption, some of the market terrapins were released in Maryland. This project has two goals: (1) to discuss the state rules and regulations concerning terrapin harvest and (2) to determine the actual origin of the market terrapins. Previous research has designated specific ranges along the East and Gulf coasts where six different terrapin metapopulations exist (Hart 2005) (Figure 1) and microsatellite DNA markers have been developed for the bog turtle that also amplify for terrapins (King & Julian 2004) (Table 1). From this information and blood samples from the terrapins sold in the Fulton Fish Market in NYC, it was possible to genotype these animals and analyze their genetic makeup to determine the origin of each terrapin.

CHAPTER 2: THE POLICY

Definition of the Policy Problem

Currently, each state throughout the terrapin range has different rules and regulations in place that protect or exploit terrapins (Table 2). This chapter aims to synthesize the terrapin harvest regulations for each of the states in the six metapopulations based on the most recent information available as of April 2007. Admittedly, many of the rules and regulations regarding terrapin harvest have changed since the samples were collected in 2004 (necessary early regulations will be discussed briefly in Chapter 3). We then discuss the human ecology of the market terrapin issue to show the various parties that are involved with this issue. Finally, we outline the policy alternatives and provide recommendations for future improvements to regulations.

Legal Mandates

Northeast Atlantic

The take of diamondback terrapins from Massachusetts' waters is prohibited by the Division of Marine Fisheries (Anon. 2006f). The state lists terrapins as a threatened species and it is thus illegal to disturb, harass, hunt, fish, trap, or take adults, young, or eggs by any means.

Terrapins are considered an endangered species by the state of Rhode Island (Brennessel 2006). The take of terrapins (including eggs and nests) is prohibited and thus it is illegal to buy, sell, or in any way traffic any terrapin or part thereof, either living or dead according to the Division of Fish and Wildlife (Lapisky 2006). The only exception to this rule is for purposes of science or education, where a permit is required for take.

In Connecticut, terrapins are considered a state-regulated species (May 2005). In the past, open season for terrapins was from August 1 to April 30 and take of up to five terrapins between 4 to 7 inches was allowed. In May 2005, the Connecticut Department of Environmental Protection closed the open season for terrapin collection and it has not reopened since.

Coastal Mid-Atlantic

In New York, there is no official status listing for terrapins (Brennessel 2006). Since 1990, the terrapin open season has been from August 1 to April 30 (Anon. 1990). A diamondback terrapin permit is required for take and only terrapins that are between 4 and 7 inches are allowed to be harvested. The sale of terrapins is not allowed from May 5 to July 31, unless the turtle was killed and processed for consumption before May 5.

Terrapins are considered a species of special concern in New Jersey (Brennessel 2006). A permit is required, by the Division of Fish and Wildlife, for possession of terrapins (McHugh 2004). The permit allows the take of terrapins from November 1 to March 31, which coincides with terrapin hibernation season. The size limit is a plastron length of five inches and terrapins may not be taken by traps, pots, seines, or any other type of net.

In Delaware, terrapins are designated as a species of greatest conservation need (Brennessel 2006). The open season is from September 1 to November 15 (Anon. 2006h). The take of terrapins is limited to four per day and it is illegal to use a dredge for the purpose of capturing terrapins. Take or possession of eggs is also not allowed. It is, however, legal to raise terrapins in private ponds.

In Virginia, terrapins are listed as an S4 species, which means that they are apparently secure in the state, most likely with over 100 populations (Brennessel 2006). However, the Department of Game and Inland Fisheries does not allow take of any size terrapin for the food or pet trade (Anon. 2006j).

Chesapeake Bay

Maryland, like Virginia, considers terrapins an S4 species (Brennessel 2006). In 2006, terrapin open season was from August 1 to October 31 according to the Department of Natural Resources (Anon. 2006a). The harvested terrapins had to be between 4 to 7 inches in carapace length and the trapper had to hold a commercial diamondback terrapin permit. On April 9, 2007, the North Carolina General Assembly issued a ban on the commercial trapping of terrapins (Pelton 2007a).

Coastal Carolina

In North Carolina, terrapins are considered both a species of special concern and an S3 species (Brennessel 2006). An S3 species is defined as being uncommon, but believed to have more than 20 populations in the state. The take, possession, collection, transportation, purchase, or sale of five or more terrapins per year is prohibited.

In South Carolina, terrapins have no status listing but the commercial take or possession of terrapins is prohibited (Brennessel 2006). No more than two terrapins per person may be possessed for a noncommercial purpose (i.e. pets) (Anon. 2006g). In addition, South Carolina's Department of Natural Resources no longer has the authority to grant permits to individuals that allow them to harvest and market terrapins.

In Georgia, terrapins are considered both a special concern animal and an S3 species (Brennessel 2006). No harvest of terrapins is permitted because terrapins are protected under non-game laws. It is also illegal to keep terrapins as pets in Georgia.

South Florida

In Florida, terrapins have no specific status listing; however, they are still protected by the Fish and Wildlife Conservation Commission (Anon. 2006b). No person is allowed to buy, sell, or possess for sale any terrapin in the state of Florida (Brennessel 2006). In addition, no person is allowed to possess more than two terrapins for personal use (i.e. pets) unless authorized by educational or scientific permit.

Gulf

In Alabama, terrapins are considered a species of special concern and also a protected species (Brennessel 2006). According to the Department of Conservation and Natural Resources, it is unlawful to take, capture, kill, possess, sell, or trade terrapins for food or pets (Anon. 2006e). The only exception is that a scientific collection permit can be issued to individuals or organizations for conservation research.

In Mississippi, terrapins are considered a species of special concern and an S2 species, which means that terrapins are rare and generally 6 to 20 populations occur in the state (Brennessel 2006). Commercial traffic of terrapins is illegal without a captive propagation permit, which allows the capture of sixteen animals per year or a small game hunting and fishing license which allows the capture of four terrapins per year.

Terrapins are listed as a species of special concern and a game animal in Louisiana (Brennessel 2006). The terrapin season is closed from April 15 to June 15 (Anon. 2005). It is illegal to take terrapins by fish or blue crab traps. A reptile and amphibian collector's or wholesale/retail dealer's license is required for the sale, barter, or trade of terrapins and a fishing license is required for collection.

In Texas, the status of the terrapin population is unknown and thus it is not officially listed (Brennessel 2006). Nonetheless, it is illegal to possess more than ten terrapins without a nongame collection or dealer permit. A nongame collection permit allows an individual to collect as many terrapins as they desire, another permit is required for sale or trade of terrapins, and a hunting license is required for actual collection.

Human Ecology

Before recommendations can be made concerning policy changes, it is important to understand the human ecology of the market terrapin issue. The biophysical ecology is everything involved in the issue except humans (Figure 2). In this case, the biophysical ecology would thus be the market terrapin issue. The human ecology of the constituents involves the people who affect or are affected by the market terrapin issue. In this case, the stakeholders include the terrapin watermen (who actually harvest and sell the terrapins), the consumers (who purchase the terrapins), and the public. The scientific community includes academic institutions such as Duke University or Hofstra University. The US Geological Survey is a government organization that studies the market terrapin issue. In addition, non-governmental organizations such as the Terrapin Institute in Maryland and the Wetlands Institute in New Jersey are involved in the study of terrapin conservation.

The institutional ecology involves the government organizations that are involved with managing terrapin harvests and this varies slightly by state. In Maryland, the Terrapin Task Force has the authority to suggest possible management plans to protect the terrapin population (Anon. 2000). State organizations such as the State Fisheries Agencies, the Department of Environmental Protection, or the Department of Natural Resources have the authority to write management plans (Anon. 2006g; Lapisky 2006; May 2005). The state general assemblies then have the authority to turn management plans into rules and regulations (Brennessel 2006). The final rules and regulations are enforced by Marine Patrol Officers, Natural Resource Police, or Environmental Conservation Police (Anon. 2006d).

Policy Alternatives

Many possible policy alternatives are currently in use by the various states and were briefly outlined in the legal mandates section. For example, one option would be to establish no take of terrapins or at least limited harvesting seasons. The limited seasons can be designed to avoid nesting season, which occurs from late May to early August, when the female terrapins are easy to find since they are on land searching for suitable nesting substrate. New Jersey avoids nesting season by having open season during the part of the year when terrapins are hibernating, approximately November 1 to March 31. When terrapins hibernate, they burrow into the mud at the bottom of the marsh and are more difficult to find. Moreover, there can be size restrictions about what size the terrapins must be in order to be legally captured. Some states require terrapins to be between 4 and 7 inches in carapace (top shell) length and others require terrapins to be larger than 8 inches in carapace length. In addition, some states require that fishermen hold permits (including fish, hunt, scientific, educational, or terrapin-specific permits) in order to harvest terrapins. Gear restrictions (such as no hand collection, net capture, or crab trap capture) are also sometimes used to keep watermen from harvesting large numbers of terrapin at one time in a specific area.

However, many of these policy alternatives are not working well. In Maryland during 2006, the open season was from August 1 to October 1 (Brennessel 2006). The terrapins are still relatively easy to capture at this time because the females just finished nesting, and males and females are still swimming around the top layer of the salt marshes and sunning themselves on the banks. Maryland also decreased the required size of harvest terrapins from 6 to 10 inches to 4 to 7 inches. This decline in size led to a larger number of terrapins that could be captured. Male terrapins are smaller than female terrapins. Females can reach about 12 inches in length and males only reach about 8 inches in length (Brennessel 2006). The new size requirements allow both male and juvenile female terrapins to be captured. This caused the number of terrapin watermen to increase from ten in 2005 to thirty-four in 2006 because with the 4 to 7 inch size limit there were more legal size terrapins to be captured.

Another negative outcome of Maryland's new regulations was that a terrapin waterman started a terrapin farm prior to the new regulations coming into effect in August 2006 (Pelton 2006). He used a bulldozer to dig four large ponds in his backyard where he could raise terrapins. He purchased 2,500 terrapins from Maryland watermen prior to regulations being announced in August 2007.

A potential option that should be considered is petitioning the World Conservation Network (IUCN) and the Endangered Species Act (ESA) to change the status of terrapins to threatened or endangered. According to the IUCN's website, diamondback terrapins are listed as Lower Risk, but Near Threatened (Anon. 2006c). However, the Tortoise and Freshwater Turtle Specialist Group has not assessed diamondback terrapins since 1996. Considering that terrapins were close to qualifying for Vulnerable status in 1996, if assessed now there is a good chance that terrapins would be listed as Threatened or Endangered. Many other turtle species in the Emydidae family are listed as endangered such as bog turtles (*Glyptemys muhlenbergii*), yellow blotched sawback turtles (*Graptemys flavimaculata*), ringed map turtles (*Graptemys oculifera*), Alabama red-bellied turtles (*Pseudemys alabamensis*), and aquatic box turtles (*Terrapene coahuila*).

The Endangered Species Act (ESA) lists diamondback terrapins as a federal species of concern (Anon. 2006i). This means that terrapins may or may not be listed in the future and that at this time there is insufficient information to support listing. Although it is a popular option to attempt to get a species designated as threatened or endangered by the IUCN or the ESA, a designation alone is not enough to sufficiently protect a species. Other management practices also need to be improved to thoroughly protect terrapins.

Recommendations

States need to establish no take or reasonable take limits for their terrapin populations. These take limits need to be determined using the smallest, most at-risk terrapin subpopulation as the model for management. The take of terrapins may be appropriate in some cases as long as take does not exceed the level at which the subpopulation can remain sustainable. Moreover, the open season for all states should definitely avoid the nesting season. During nesting season, fertile females venture on land to find suitable nesting habitat. If the reproductively most valuable females are all taken, then the population will not be able to survive. Further, the size minimum for capture of terrapins should be 8 inches or longer. The 4 to 7 inch range used currently by many states allows the take of many reproductive males and juvenile females. By taking 8 inch or larger terrapins, only large, old females will be targeted. In effect, this would mean more meat will be provided by this size turtle, so fewer individual terrapins will need to be harvested.

In addition, states need to establish rules and regulations for terrapin farms. Turtle farming is a complicated issue. Turtle die-offs are common in sea turtle farms (Jacobson 1996). If farming begins without considering possible health problems and preventative medication, then die-offs are almost inevitable. This has been an issue in the green sea turtle farm in the Cayman Islands. If all the terrapins in the farm in Maryland die, regulations allow the owner to replace the dead turtles with live turtles captured from the wild. Furthermore, microsatellite DNA analysis cannot be used to determine whether terrapins came from wild or farm populations and thus there would be no way to tell if market terrapins were obtained legally. Regulations need to be developed that, at the very least, insist on the use of preventative medicine in terrapin aquaculture and disallow the capture of wild terrapins as replacements or additions to the aquaculture population.

The recommendations presented here do not represent the absolute solution to managing diamondback terrapin harvests, but they do provide a point at which to move forward. Effective rules and regulations need to be created and enforcement of regulations needs to be improved. Many states only have a handful of natural resource police and these law enforcing individuals are responsible for all species covered by the fishing and hunting regulations of that state. Much is known regarding individual terrapin subpopulations. But, management will be most beneficial to the largest number of terrapins if it is done at the metapopulation level which would require that states work together to create terrapin harvest management plans.

CHAPTER 3: THE SCIENCE

Materials and Methods

Tissue Collection and DNA Isolation

In September 2004, *M. terrapin* blood samples were collected by Russell Burke from terrapins that were confiscated from the Fulton Fish Market in New York City, New York. A total of 63 terrapins, all adult females, were sampled. The blood samples were stored at room-temperature on FTA cards (which are chemically treated filter paper that is designed for the collection and storage of blood samples for DNA analysis). The DNA was isolated using Puregene DNA extraction kits and resuspended in TE buffer.

Microsatellite DNA Analysis

Microsatellite DNA loci developed for bog turtles (*Glyptemys muhlenbergi*) by King and Julian (2004) were screened in all terrapin samples. The analysis used 12 polymorphic markers, which were used by Hart (2005) (Table 3). The 12 loci (*Gmu*A18, *Gmu*B08, *Gmu*B67, *Gmu*B91, *Gmu*D21, *Gmu*D55, *Gmu*D62, *Gmu*D87, *Gmu*D90, *Gmu*D93, *Gmu*D114, and *Gmu*D121) were amplified in multiplexed PCR reactions.

Polymerase Chain Reactions

Each Polymerase Chain Reaction (PCR) contained 100-200 ng of DNA, 0.875X PCR buffer, 3.75 mM $MgCl_2$, 0.31 mM dNTPs, 0.15-0.25 µM of forward and reverse primers, and 0.4 U AmpliTaq. The forward primer was 5' modified with FAM, NED, or HEX fluorescent labels. The amplification conditions were 94ºC for 2 minutes, 35 cycles of 94ºC denaturation for 45 seconds, 56ºC annealing for 45 seconds, 72ºC extension for 2 minutes, and final extension of 72ºC for 10 minutes. Thermal cycling was performed in an MJ DNA Engine PTC 200 that had a heated lid.

Fragment Analysis and Allelic Designations

The techniques used to perform fragment analysis and allelic designations were described by King et al. (2001). Before electrophoresis, one microliter of the PCR product was diluted with deionized water, mixed, and then added to 12µl of deionized formamide plus 0.2µl of GeneScan-500 ROX size standard. The mixture was denatured at 95°C for 2 minutes and then chilled on ice for 5 minutes. Capillary electrophoresis was then performed on an ABI Prism™ 3100 Genetic Analyzer. GeneScan software version 3.7 was used to generate fragment size data. Finally, Genotyper software version 3.6 was used to score, bin, and assign genotypes to each individual terrapin sample.

Statistical Analysis

GeneClass 1.0.02 software was used to assign individuals to populations via the Bayesian method (Piry & Cornuet 1998). GeneClass assigned individuals to the population where the likelihood of their genotype occurring was the highest. This was done by computing the posterior probability that an individual terrapin sample originates from one of the known subpopulations or metapopulations and then comparing that probability to a chosen threshold, which in this case was 0.001 (Pritchard et al. 2000). The program was used to determine which of eighteen subpopulations or six metapopulations studied by Hart (Hart 2005) were most similar to the unknown market terrapins.

Results

All of the 63 market terrapin samples were assigned to subpopulations and metapopulations along the east coast of the United States between New York and South Carolina. Each of the unknown market terrapin samples was compared to eighteen known subpopulations (Hart 2005). The sample was then given a population score that described how closely the unknown sample related to the known subpopulations (Table 4). The lowest population score for each sample represents the subpopulation where the terrapin was most likely to originate. Of the previously studied subpopulations, the market terrapins were assigned to eleven of the eighteen subpopulations ($p<0.001$) (Figure 3). The other seven subpopulations were all located along the New England, Florida, or Gulf coasts. Thirty-one of the market terrapins were assigned to one of the three previously sampled sites in Maryland. Eleven terrapins were assigned to New Jersey, one was assigned to New York, ten were assigned to Virginia, six were assigned to North Carolina, and four were assigned to South Carolina.

When the analysis was run using metapopulations instead of subpopulations, the samples were assigned to three of the six possible metapopulations ($p<0.001$). Thirty-four terrapins were assigned to the Chesapeake Bay (MD), nineteen were assigned to the Coastal Mid-Atlantic (NY, NJ, DE, and VA), and ten were assigned to Coastal Carolina (NC, SC, and GA) (Figure 4; Table 5).

All of the market terrapin samples were analyzed using nine or more loci out of the twelve possible loci (Figure 5). Only one of the 64 samples was analyzed with nine loci, whereas almost 70% of the samples were analyzed using all twelve loci. An additional 17.5% were analyzed with eleven loci.

Discussion

Over the past decade, genetics has emerged as a powerful conservation tool when attempting to identify the origin of animal products sold in markets. Several different genetic techniques (which include the analysis of mitochondrial DNA, ribosomal DNA, cytochrome b gene, or microsatellite DNA markers) have been utilized to identify animal products used for human consumption to the species or population level (Baker et al. 2000; Berry et al.

2004; Birstein et al. 1998; Clarke et al. 2006; King & Julian 2004; Malik et al. 1997; Roman & Bowen 2000).

In one study, researchers used mitochondrial DNA sequences and statistical comparisons of intraspecific haplotype frequencies to identify whale meat sold in Japanese and Korean markets to the species level (Baker et al. 2000). In this study, researchers identified 655 whale products from eight different species including baleen whales (*Balaenoptera*), sperm whales (*Physeter*), pygmy sperm whales (*Kogia breviceps*), two species of beaked whales (*Mesoplodon*), porpoises (*Phocoenidae*), killer whales (*Orcinus orca*), numerous species of dolphins, and non-whale species such as domestic sheep and horses. Interestingly, many of the baleen and sperm whale species that samples were assigned to are protected by international agreements and thus should not be hunted. This groundbreaking study demonstrated that genetics can be a powerful tool to monitor whale meat markets.

The trade of shark fins is largely unregulated and a serious threat to shark populations worldwide. One technique that has proven successful in identifying shark fins to the species level is ribosomal DNA analysis. The world's largest shark fin market is located in Hong Kong (Clarke et al. 2006). In this market, fins are labeled by traders into categories based on the market value, not by shark species. Researchers used a technique that relies on DNA sequence differences among shark species in the ribosomal DNA ITS2 locus to determine the shark species of 596 fins (Shivji et al. 2002). They found that the shark fins were dominated by fins from blue (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), silky (*Carcharhinus falciformis*), sandbar (*Carcharhinus plumbeus*), bull (*Carcharhinus leucas*), hammerhead (*Sphyrna*), and thresher sharks (*Alopiidae*) (Clarke et al. 2006).

Differences between the cytochrome b gene regions can also be used to determine the origin of a species. Pinniped penises are commonly sold in Chinese medicine shops in Asia and North America (Malik et al. 1997). Researchers looked at twenty-one samples from stores in Bangkok, Hong Kong, Shanghai, Toronto, Calgary, Vancouver, and San Francisco and sequenced a region of the cytochrome b gene that is 261 base pairs long for each sample. Twelve samples were identified as harp seals (*Pagophilus groenlandicus*), one as a hooded seal (*Cystophora cristata*), one as an Australian fur seal (*Arctocephalus forsteri*) (which cannot be legally hunted), and the remaining seven samples were determined not to be pinniped species. The samples that were not pinnipeds consisted of domestic cattle (N=4), African wild dog (N=2), and water buffalo (N=1). This study found that the pinniped penis trade can be used as a cover for illegal trade of penises from different animal species. In another study, 95 caviar samples were analyzed using the cytochrome b gene (Birstein et al. 1998). The samples were obtained from fifteen gourmet shops in New York City, or were mail-ordered from companies in New Jersey, Massachusetts, or Florida. The researchers found that 23% of the labels made by caviar suppliers were labeled with the wrong species name.

For the past four centuries, much of the turtle meat sold in North America and Europe has come from marine turtles, most commonly green sea turtles (*Chelonia mydas*) (Roman & Bowen 2000). When marine turtle stocks began to drastically decline, alligator snapping turtle (*Macrochelys temminckii*) (the largest freshwater turtle in the United States) was then the turtle of choice for meat sales. Today, alligator snapping turtles are protected in every state in the US except for Louisiana. In a novel study, scientists purchased thirty-six turtle meat products in Louisiana and Florida (Roman & Bowen 2000) and used cytochrome b and control region sequences of the mitochondrial genome to identify turtle meat to the species level. They found that nineteen of the samples were from common snapping turtle (*Chelydra serpentina*), three were Florida softshell (*Apalone ferox*), one was softshell turtle (*Apalone mutica*), one was alligator snapping turtle, and eight were not turtle meat but instead American alligator (*Alligator mississippiensis*). Although the researchers found that alligator snapping turtle was rarely used for turtle meat, they did find that alligators were being marketed as turtle meat – a phenomenon that they referred to as the Mock Turtle Syndrome.

In our analysis, we used twelve microsatellite DNA markers to determine the origin of 63 mature female terrapins collected in September 2004 from the Fulton Fish Market in New York City, NY. Several other studies have employed this same technique to assign species such as redfish (*Centroberyx*), Atlantic salmon (*Salmo salar*), and grand skinks (*Oligosoma grande*) to different taxa or location of origin with high rates of success (Berry et al. 2004; King et al. 2001; Roques et al. 1999). Researchers have used microsatellite DNA analysis (with eight alleles) to study the potential of individual assignment of the North Atlantic redfish (Roques et al. 1999). The scientists used four redfish taxa from the North Atlantic to evaluate the potential to assign individuals to two different levels of group divergence. They found that the microsatellites could be used to assign species to different taxa. Another study was done that used microsatellite DNA analysis to assign Atlantic salmon to the continent of origin (King et al. 2001). Scientists used twelve alleles and found that 100% of the salmon (n=1682) were assigned to the correct continent of origin. The salmon came from 27 anadromous river populations and two nonanadromous strains from south-central Maine to northern Spain. Eighty-three percent of the salmon, on average, were correctly assigned to the province or country of origin. A natal population of grand skinks was identified using thirteen microsatellite DNA markers (Berry et al. 2004). The researchers used 261 skink samples that were taken from an ongoing mark-release-recapture study. They found that the success level of assigning skinks to the correct natal population was 65 to 100%.

In this study, we found that the market terrapins were from the east coast of the United States, between New York and South Carolina. The terrapins were released in Maryland in 2005 and thus many were placed in different locations than where they originated. Currently, terrapin harvesting is allowed during specific time periods in New York, New Jersey, Delaware, and Maryland (Table 2). However, terrapin harvesting is prohibited in Virginia, North Carolina, and South Carolina. Of the seven states where terrapins were found to originate, the largest number of terrapins was from Maryland.

When the blood samples were collected in 2004, Maryland's harvesting regulations allowed for the harvest of terrapins between six and ten inches in length for a nine month season (Anon. 2006a). On June 19, 2006, Maryland's harvesting regulations changed to allow the harvest of smaller terrapins that are four to seven inches in length for a three month commercial season. Female terrapins are significantly larger than male terrapins; therefore, the new regulations in Maryland allow for the capture of both male and female terrapins whereas in 2004 the market terrapins were all reproductive females. In addition, commercial fishermen were required to obtain permits from the Department of Natural Resources (DNR) in order to harvest terrapins.

Lawmakers in Maryland are currently considering bills that would ban terrapin harvesting (Anon. 2007b). When the Department of Natural Resources changed the guidelines for catching terrapins in 2006, officials were hoping to protect large, reproductive female turtles. Instead, the overall harvest increased significantly. Watermen reported catching about 10,000 terrapins during the 2006 season (Anon. 2007a). Just one year earlier in 2005, watermen reported a terrapin catch of 724 pounds. An average female terrapin weighs one pound; therefore, the terrapin catch increased more than ten fold in one year. On March 12, 2007, scientists in the Maryland Department of Natural Resources proposed to ban the harvest of terrapins from the Chesapeake Bay (Hurdle 2007). In response to that proposal, the North Carolina General assembly issued a ban on the commercial trapping of terrapins on April 11, 2007 (Pelton 2007a).

The individual terrapins analyzed in this study were assigned to one of eighteen known subpopulations or one of six known metapopulations using assignment tests. Unfortunately, the assignment tests can only assign terrapins to known populations. Therefore, if the terrapins were actually from a population that has not been sampled before, their assignment score to sampled areas would be low. In the future, additional range-wide samples should be collected (especially in Rhode Island, Connecticut, Delaware, Georgia, Alabama, and Mississippi) in order to expand upon the known database of samples and strengthen the potential to definitively assign individuals to the appropriate location of origin.

Chapter 4: Synthesis

In order to protect terrapins, rules and regulations (and the enforcement of those rules and regulations) need to be revised so that they establish no take or at least reasonable take limits. The number of terrapins harvested in Maryland over the past year was ten times the number that was harvested in the previous year (Anon. 2007a). Unfortunately, the regulations imposed in 2006 in Maryland did not protect terrapins but rather exploited more age and size classes of this species. The state of Maryland recently banned the harvest of terrapins. Hopefully, other states that still allow harvesting of terrapins will follow Maryland's lead and develop rules and regulations that will decrease the number of terrapins taken each year. The terrapin population cannot handle direct harvest because terrapins are slow to reach sexual maturity and long-lived (Congdon et al. 1993; Heppell 1998). In many cases, the terrapins are being killed before they have the chance to reproduce.

Furthermore, the export of terrapins to other countries needs to be regulated. Terrapins are not only used for food and pets in the United States but also in parts of Asia (Pelton 2007b). A terrapin farmer in Maryland recently sent 2,500 terrapins to a turtle dealer in Louisiana who in turn sent many of the turtles to China to be made into terrapin stew (Pelton 2006). It is unknown how many terrapins are shipped to Asia each year but it may be a significant number.

Currently, terrapins are considered "lower risk, but near threatened" by the IUCN and "a species of special concern" by the Endangered Species Act. However, the IUCN last evaluated diamondback terrapins in 1996, over ten years ago. Terrapin subpopulations are small in size because of a combination of multiple threats such as direct harvest but also from drowning in crab traps (Davis 1942; Roosenburg et al. 1997; Wood 1997), nesting females becoming roadkill (Wood & Herlands 1997), predators eating terrapin eggs and hatchlings

(Draud et al. 2004; Feinberg & Burke 2003; Seigel 1980), and loss of habitat. If analyzed again, the IUCN and the Endangered Species Act would likely find that terrapins should be classified as endangered or at least threatened.

Diamondback terrapin populations are facing an enormous amount of pressure from predators and anthropogenic causes. Raccoons, foxes, and rats are digging up terrapin eggs before they have the chance to hatch. Habitat is being destroyed at a disturbing rate to allow more room to build beach houses and condos. Roads are being built on top of nesting habitat, leaving the female terrapins no option but to cross busy roads during the tourist season to find suitable nesting habitat. Male (and likely juvenile female) terrapins are drowning in blue crab traps. The last additional problem that the terrapin population needs is to be attacked by direct harvest.

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TABLES

Table 1. Summary information for 12 bog turtle (*Glyptemys muhlenbergii*) microsatellite loci used in our *M. terrapin* study. See King and Julian (2004) for further details. Colors are G = green, B = blue, Y = yellow, and Group indicates multiplexed reaction grouping for PCR reactions.

Locus	**Color/ Label**	**Group**	**Genbank accession No.**	**Size range of alleles (in bp)**
*Gmu*A18	G/HEX	A	AF337648	101-139
*Gmu*B08	B/FAM	A	AF517229	193-264
*Gmu*B67	Y/NED	A	AF517233	140-162
*Gmu*B91	B/FAM	A	AF517234	115-150
*Gmu*D21	Y/NED	B	AF517236	145-159
*Gmu*D55	B/FAM	B	AF517240	153-220
*Gmu*D62	G/HEX	C	AF517241	125-185
*Gmu*D87	B/FAM	A	AF517244	212-292
*Gmu*D90	G/HEX	A	AF517247	106-165
*Gmu*D93	Y/NED	A	AF517248	113-196
*Gmu*D114	Y/NED	B	AF517251	85-122
*Gmu*D121	G/HEX	B	AF517252	120-190

Table 2. Terrapin Harvest Rules and Regulations.

STATE	STATUS	LEGAL MANDATES	AUTHORITATIVE PARTY
Massachusetts	Threatened	Illegal to disturb, harass, hunt, fish, trap, or take adults, eggs or young by any means.	Division of Marine Fisheries
Rhode Island	Endangered	Illegal to buy, sell, or in any way traffic any terrapin or part thereof, either living or dead.	Division of Fish and Wildlife
Connecticut	State-regulated species	Open season from August 1 to April 30, up to five terrapins 4 to 7 inches allowed, illegal to take eggs.	Department of Environmental Protection
New York	No listing	Open season from August 1 to April 30, license required for take, terrapins 4 to 7 inches allowed, sale allowed May 5 to July 31 or year-round if killed and processed for consumption before May 5.	Department of Environmental Conservation
New Jersey	Species of special concern	Permit required for possession, open season Nov. 1 to March 31.	Division of Fish and Wildlife
Delaware	Species of greatest conservation need	Open season Sept. 1 to Nov. 15; four terrapins per day limit; illegal to take eggs; legal to raise terrapins in private ponds.	Department of Natural Resources and Environmental Control
Maryland	S4 Species	No take.	Department of Natural Resources
Virginia	S4 Species	No take.	Department of Game and Inland Fisheries
North Carolina	Species of special concern and S3	Take, possession, collection, transportation, purchase, and/or sale of five or more prohibited.	North Carolina Wildlife Resources Commission
South Carolina	No listing	Commercial take or possession is prohibited; no more than two terrapins per person may be possessed for a noncommercial purpose.	Department of Natural Resources
Georgia	Special concern animal and S3	No harvest permitted; protected under non-game laws; illegal to keep as a pet.	Department of Natural Resources
Florida	No listing	No person shall buy, sell, or possess for sale any terrapin; no person shall possess more than two terrapins unless authorized by permit.	Fish and Wildlife Conservation Commission
Alabama	Species of special concern and protected species	Unlawful to take, capture, kill, or attempt to take, capture or kill, possess, sell, trade for anything of monetary value, or offer to sell or trade for anything of monetary value without a scientific collection permit.	Department of Conservation and Natural Resources
Mississippi	Species of special concern and S2	Commercial traffic illegal without a captive propagation permit (allows capture of 16 animals); legal to possess up to four with a small game hunting and fishing license.	Department of Marine Resources
Louisiana	Species of special concern	Closed season April 15 to June 15; illegal to take by trap; reptile and amphibian collector's or wholesale/retail dealer's license required for sale, barter, or trade; fishing license required for collection; illegal to take eggs.	Wildlife and Fisheries Department
Texas	No listing	Illegal to possess more than 10 without a nongame collection or dealer permit; permit also required for sale or trade; hunting license required for collection.	Parks and Wildlife

Table 3. General collection localities, abbreviations, and sample size for diamondback terrapins sampled from MA to TX (Hart, 2005).

Collection #	Abbreviation	General Collection Site	*Sample Size*
1	WMA-14	Wellfleet, MA	58
2	SNMA-5	Sandy Neck, Barnstable, MA	19
3	HRNY-3	Jamaica Bay, Hudson River, NY	31
4	SandHk	Sandy Hook, NJ	21
5	CMCoNJ	Cape May County, NJ	29
6	MD-25	Kent Island, MD	25
7	BIMDII	Buzzards Island, Patuxent River, MD	60
8	SandlC	Sandy Island Cove, Nanticoke River, MD	55
9	MobBVA	Mobjack Bay, VA	45
10	WachVA	Wachapreague, VA	38
11	CINC-5	Cedar Island, NC	44
12	NRNC-9	North River, NC	42
13	SC-50	Charleston Harbor, SC	46
14	NestKF	Nest Key, FL	12
15	EA-047	Big Sable Creek, Everglades, FL (Site A)	101
16	TAMPAB	Tampa/St. Petersburg, FL	9
17	LA-41	Houma, LA	32
18	NueBTX	Nueces Bay, TX	14
		TOTAL	**681**

Table 4. Each market terrapin sample was compared to eighteen known subpopulations. The lowest score (red) in each row represents the subpopulation that the market terrapin sample is most closely related to and thus the population to which the terrapin was assigned.

name	loc.	WMA-14	SNMA-5	HRNY-3	SandHk	CMCoNJ	MD-25	BIMDII	SandIC	MobBVA	WachVA	CINC-5	NRNC-9	SC-50	NestKF	EA-047	TAMPAB	LA-41	NueBTX	classified in
CT-002	12	34.89	31.22	17.48	14.92	16.89	14.42	**14.15**	16.01	15.93	15.28	16.72	15.75	16.82	25.38	30.51	21.74	27.10	26.17	BIMDII-45
CT-003	12	34.52	28.01	16.37	15.96	17.60	14.95	14.64	14.71	16.39	14.91	16.47	14.02	**13.23**	33.36	41.26	29.43	32.46	32.45	SC-50
CT-004	12	28.06	25.14	15.97	15.39	**12.86**	14.64	14.71	14.24	15.76	15.25	16.76	15.42	17.24	32.48	37.41	26.76	25.08	28.38	CMCoNJ-30
CT-009	12	28.08	24.30	16.85	17.60	16.45	15.29	19.66	**14.50**	19.78	18.09	15.43	17.19	18.30	21.73	26.78	22.61	21.80	22.17	SandICMD-56
CT-010	12	23.80	16.70	13.87	13.44	13.10	**11.48**	12.43	12.32	12.26	13.22	13.73	14.21	14.51	32.43	42.62	26.27	26.07	28.80	MD-25
CT-013	12	22.71	20.26	12.67	14.45	13.34	11.60	11.84	**11.59**	11.66	11.99	14.36	13.33	13.76	25.84	32.60	21.84	23.37	24.13	SandICMD-56
CT-014	12	35.57	27.34	15.88	17.18	14.33	14.77	15.71	13.50	16.01	15.69	15.34	13.90	**13.16**	27.81	30.75	18.72	20.82	20.28	SC-50
CT-015	12	31.38	25.57	17.21	18.45	21.41	15.42	**14.82**	16.07	16.31	16.91	19.01	16.44	17.24	30.71	37.04	28.13	29.74	25.99	BIMDII-45
CT-017	10	24.29	16.39	12.88	12.55	14.13	12.07	**10.88**	11.67	11.34	13.81	11.27	13.32	12.48	30.03	40.17	24.06	28.40	31.31	BIMDII-45
CT-018	12	26.40	23.26	13.59	13.42	13.26	13.59	13.38	12.80	12.67	13.00	**12.26**	12.93	14.36	30.36	34.41	23.00	25.36	24.12	CINC-55
CT-019	12	31.40	27.98	17.77	18.08	17.86	14.60	**12.91**	13.41	15.25	15.72	15.70	13.64	16.95	29.96	38.17	26.91	30.73	32.73	BIMDII-45
CT-020	12	30.90	26.90	14.01	16.04	12.65	13.35	13.81	13.10	13.50	12.68	14.48	**12.36**	13.94	29.87	36.69	25.08	23.35	26.99	NRNC-91
CT-022	12	23.93	22.68	15.19	16.56	14.21	**12.56**	17.06	13.46	15.18	13.62	13.33	13.65	14.35	34.67	38.84	28.43	25.33	24.88	MD-25
CT-024	12	32.80	26.36	15.74	16.88	15.93	16.38	16.68	15.99	**15.46**	16.29	15.71	16.41	17.06	34.86	46.45	30.54	34.73	34.80	MobBVA-45
CT-025	11	31.37	28.68	17.67	19.17	15.89	15.20	14.20	15.13	17.12	15.83	14.33	**14.15**	15.33	31.55	38.33	27.55	29.46	30.62	NRNC-91
CT-026	12	30.55	26.85	18.49	17.38	17.49	16.38	**15.39**	15.59	17.05	17.91	17.06	17.77	16.14	32.84	39.70	24.00	31.40	29.32	BIMDII-45
CT-028	11	23.15	21.48	17.17	18.46	14.49	14.86	14.28	**13.27**	14.19	14.46	14.12	15.38	16.06	26.67	31.64	21.90	25.01	27.05	SandICMD-56
CT-029	12	27.30	22.76	14.97	16.72	15.98	14.94	**12.72**	13.00	13.21	14.76	13.71	15.34	14.50	31.87	38.43	26.26	24.96	27.57	BIMDII-45
CT-030	12	25.65	24.05	15.99	**13.88**	15.53	14.59	14.82	15.12	14.43	14.36	17.09	15.49	16.42	29.32	37.65	27.42	28.82	33.13	SandHkNJ-21
CT-032	11	26.26	23.63	12.07	13.05	12.48	12.12	11.67	**11.16**	11.37	13.07	11.47	11.96	12.86	28.35	35.63	25.78	24.85	25.93	SandICMD-56
CT-033	11	25.22	26.18	16.39	20.09	16.79	17.52	17.83	16.89	16.25	**14.73**	16.40	17.73	15.35	23.68	26.60	18.62	19.48	21.87	WachVA-38
CT-034	12	27.66	26.81	12.46	14.42	**11.39**	12.22	13.54	12.15	11.56	11.76	13.59	15.16	14.25	29.66	34.31	24.26	21.88	25.02	CMCoNJ-30
CT-035	12	33.34	29.55	19.93	19.77	**19.24**	19.92	21.95	20.35	19.91	19.25	20.99	20.90	20.08	29.32	37.80	27.44	26.84	28.27	CMCoNJ-30
CT-037	12	34.71	28.65	18.21	19.63	20.27	**16.71**	17.31	18.16	17.15	17.88	18.95	18.96	18.59	40.17	49.65	32.32	33.35	36.94	MD-25
CT-038	12	22.58	21.10	12.85	17.31	13.42	**12.53**	12.97	13.10	14.09	13.25	13.30	14.76	15.84	22.88	25.88	20.11	21.82	20.09	MD-25
CT-040	11	33.40	28.92	16.07	17.64	15.94	16.68	14.95	15.17	**14.83**	15.31	17.06	16.59	15.50	33.34	44.64	27.29	30.99	30.79	MobBVA-45
CT-041	12	32.22	28.17	19.13	24.37	17.82	17.34	16.75	**14.62**	18.61	17.18	18.88	19.08	16.66	31.73	36.85	28.97	26.71	28.23	SandICMD-56
CT-042	10	28.98	22.03	14.18	12.50	13.17	13.81	12.31	12.64	12.37	13.15	12.18	12.19	**11.86**	29.42	38.88	27.69	26.54	26.29	SC-50
CT-044	12	27.30	22.43	15.44	16.92	15.20	15.33	13.83	**12.87**	13.96	16.25	14.70	14.65	14.32	34.49	41.53	25.86	25.51	28.36	SandICMD-56
CT-045	12	29.00	26.92	13.72	16.59	14.11	14.03	14.11	14.11	14.54	**13.00**	13.32	14.50	16.53	34.55	40.60	28.18	26.39	30.35	WachVA-38
CT-046	12	31.04	26.55	16.44	17.39	16.04	16.36	16.25	17.43	17.51	**15.20**	16.23	16.90	17.77	26.94	34.24	23.10	30.68	27.70	WachVA-38
CT-047	11	22.62	19.03	14.47	13.43	16.15	15.60	13.15	14.51	**12.55**	16.11	13.16	13.37	13.65	29.79	33.64	21.05	27.73	25.22	MobBVA-45
CT-048	12	27.24	23.40	13.76	16.24	**12.61**	13.60	13.56	14.54	14.50	14.45	12.64	14.14	14.42	28.46	34.53	23.25	24.30	25.48	CMCoNJ-30
CT-049	11	25.43	23.13	20.56	19.94	20.05	18.74	17.72	**17.18**	18.71	20.43	17.50	17.88	18.06	33.08	36.22	27.97	24.93	23.93	SandICMD-56
CT-051	12	32.54	29.93	12.24	14.61	13.44	13.97	**11.98**	12.29	12.46	13.35	13.87	13.86	13.84	31.60	37.32	20.96	26.50	28.52	BIMDII-45
CT-052	10	17.89	16.91	9.26	11.46	9.63	9.85	10.13	9.00	10.84	**8.91**	9.57	10.24	10.62	21.97	28.10	15.16	19.93	21.66	WachVA-38
CT-053	11	29.93	24.34	15.99	19.50	15.89	17.24	18.25	16.28	16.92	**15.21**	16.13	16.92	18.37	29.57	39.05	25.32	30.72	28.33	WachVA-38
CT-055	12	31.04	27.49	17.77	18.75	16.84	16.69	17.95	**16.63**	18.29	17.78	17.61	17.65	16.86	29.49	33.55	24.81	20.93	21.19	SandICMD-56
CT-056	12	27.98	25.73	14.44	19.52	**12.47**	14.60	16.26	15.04	16.61	13.29	15.35	15.04	15.81	32.53	35.59	25.16	27.82	23.80	CMCoNJ-30
CT-057	11	31.53	29.72	12.91	17.63	13.74	14.92	13.36	13.31	13.49	14.27	13.74	14.06	**11.93**	30.63	36.93	22.92	25.25	28.91	SC-50
CT-060	12	28.42	26.57	15.75	18.97	15.45	16.18	17.25	**14.24**	14.71	16.16	17.83	19.32	16.30	33.81	40.45	25.23	27.18	26.78	SandICMD-56
CT-061	10	26.33	22.70	11.80	12.61	11.62	12.42	11.22	10.86	**10.10**	10.11	11.68	11.44	13.56	21.54	29.47	20.26	25.21	20.42	MobBVA-45
CT-062	12	30.46	25.25	19.80	17.13	17.88	18.39	17.39	16.28	17.49	19.54	**15.27**	16.48	19.07	35.70	40.68	31.08	28.40	26.10	CINC-55
CT-063	12	22.87	20.85	11.30	**10.34**	11.14	12.07	11.70	11.69	10.67	10.70	11.52	12.35	14.04	31.53	36.41	26.31	25.92	28.84	SandHkNJ-21
CT-064	12	25.30	20.83	11.69	13.97	14.34	13.86	13.19	**11.56**	13.58	13.42	13.56	13.04	14.66	33.55	43.43	21.42	25.65	25.87	SandICMD-56
CT-066	10	30.68	25.67	19.06	17.11	15.84	14.81	14.21	14.22	17.66	17.74	18.06	**13.18**	15.75	25.52	35.01	26.61	25.87	27.58	NRNC-91
CT-067	10	23.02	18.98	11.21	15.15	9.38	9.03	**8.89**	9.12	11.05	10.23	11.20	11.33	11.77	20.89	27.95	15.67	23.59	20.88	BIMDII-45
CT-068	12	29.92	23.76	14.14	**11.18**	13.10	13.21	13.73	12.94	16.82	17.09	14.15	14.71	15.33	32.40	38.20	24.16	26.69	21.94	SandHkNJ-21
CT-069	12	36.41	29.47	18.23	18.46	**16.37**	17.94	16.94	17.32	19.57	18.49	18.19	17.53	16.48	35.91	44.08	32.70	27.88	30.58	CMCoNJ-30
CT-070	12	28.87	24.43	14.72	16.21	13.63	**12.34**	13.34	12.63	13.53	14.57	14.55	13.39	15.26	29.29	36.66	25.32	26.76	28.12	MD-25
CT-071	11	31.89	29.49	16.17	15.78	13.29	**11.55**	12.67	12.29	14.04	12.44	12.50	12.56	13.51	27.98	32.82	24.63	23.31	26.56	MD-25
CT-072	12	27.43	27.27	13.79	19.39	16.12	**12.34**	12.65	12.39	12.58	13.31	14.95	14.53	13.01	29.19	34.09	26.77	25.50	26.46	MD-25
CT-073	11	23.66	19.69	13.89	18.60	16.63	14.70	13.58	**12.33**	13.27	12.93	14.29	13.34	14.57	30.61	37.37	26.90	31.02	25.88	SandICMD-56
CT-074	12	36.40	30.37	15.26	19.88	**15.06**	17.10	16.94	15.63	17.16	15.94	15.83	17.45	15.90	37.25	42.83	27.37	26.34	25.57	CMCoNJ-30
CT-076	12	30.93	26.52	14.30	15.67	13.77	15.10	15.75	**12.64**	13.85	15.07	14.79	16.30	14.88	29.76	35.47	22.75	25.71	27.14	SandICMD-56
CT-077	9	15.03	11.88	9.54	**8.74**	9.76	11.69	10.44	9.91	10.23	9.52	10.97	9.99	10.50	25.15	31.50	18.42	20.20	20.98	SandHkNJ-21
CT-078	12	24.23	18.77	12.69	13.54	11.65	11.68	**10.74**	11.40	11.11	11.10	12.35	13.33	14.61	25.26	33.85	21.10	29.90	28.62	BIMDII-45
CT-079	12	27.95	24.37	15.18	14.33	15.50	14.84	12.19	**12.04**	14.43	15.27	13.31	14.24	13.50	29.35	33.88	24.46	23.63	21.75	SandICMD-56
CT-080	10	27.12	22.10	16.16	15.54	15.56	17.27	14.07	**13.88**	15.51	16.17	15.75	15.15	14.87	22.27	26.54	22.83	22.52	19.55	SandICMD-56
CT-081	12	25.49	20.92	14.58	15.09	14.88	**12.82**	13.25	13.08	12.84	12.83	13.19	13.49	14.68	36.37	50.41	32.81	26.59	32.47	MD-25
CT-082	12	24.22	22.30	14.84	18.55	14.13	14.57	14.73	13.59	13.96	13.82	**13.47**	14.11	13.87	35.38	42.88	26.82	23.07	25.72	CINC-55
CT-083	12	29.32	25.37	12.98	14.52	12.60	13.38	13.17	12.21	**11.47**	12.36	11.78	12.48	14.08	35.46	42.95	28.19	28.83	30.49	MobBVA-45
CT-085	12	24.35	20.27	**14.62**	17.26	17.95	15.25	16.29	15.06	14.94	15.39	16.46	15.18	16.17	32.72	39.23	26.82	24.14	25.70	HRNY-32

Table 5. Each market terrapin sample was compared to the six known metapopulations and assigned to the metapopulation that it was most closely related. The samples were assigned to the metapopulation that had the lowest population score (red).

name	loc.	NE Atlantic	Coastal Mid-Atlantic	Chesapeake Bay	Coastal Carolina	South Florida	Gulf	classified in
CT-002	12	35.11	15.32	**14.65**	16.17	28.68	27.75	Chespeake Bay
CT-003	12	31.44	14.73	14.2	**13.64**	34.66	33.83	Coastal Carolina
CT-004	12	27.86	**14.53**	14.69	16.03	34.64	26.33	Coastal Mid-Atlantic
CT-009	12	26.18	15.68	**15.52**	16.42	25.14	22.22	Chespeake Bay
CT-010	12	21.2	12.5	**12.1**	13.95	37.58	27.12	Chespeake Bay
CT-013	12	21.46	11.65	**11.44**	13.02	29.45	24.19	Chespeake Bay
CT-014	12	33.67	14.71	14.29	**13.87**	26.34	21.1	Coastal Carolina
CT-015	12	30.25	17.37	**14.78**	17.15	34.75	30.33	Chespeake Bay
CT-017	10	21.02	11.75	**11.14**	11.98	35.03	29.68	Chespeake Bay
CT-018	12	27.08	**12.8**	12.93	12.86	31.24	25.7	Coastal Mid-Atlantic
CT-019	12	31.79	15	**13.1**	14.38	35.51	30.76	Chespeake Bay
CT-020	12	30.96	**12.78**	13.19	13.16	33.27	24.2	Coastal Mid-Atlantic
CT-022	12	23.16	13.42	13.84	**13.33**	35.3	25.2	Coastal Carolina
CT-024	12	31.74	**15.99**	16.52	16.48	42.48	36.1	Coastal Mid-Atlantic
CT-025	11	31.23	17.19	**13.93**	14.12	36.89	31.13	Chespeake Bay
CT-026	12	29.86	17.05	**15.69**	16.81	36.63	30.77	Chespeake Bay
CT-028	11	22.54	15.32	**13.22**	15.2	29.73	24.99	Chespeake Bay
CT-029	12	25.8	13.76	**12.92**	14.02	34.31	26	Chespeake Bay
CT-030	12	25.62	**14.75**	15.16	15.99	34.29	30.48	Coastal Mid-Atlantic
CT-032	11	25.99	11.94	**11.25**	11.68	34.99	24.13	Chespeake Bay
CT-033	11	26.31	16.22	18.08	**15.49**	24.49	20.41	Coastal Carolina
CT-034	12	26.39	**11.52**	12.51	13.73	33.44	22.47	Coastal Mid-Atlantic
CT-035	12	32.79	**19.43**	22.63	21.09	35.64	27.91	Coastal Mid-Atlantic
CT-037	12	33.46	18.6	**18.16**	19.25	43.96	35.17	Chespeake Bay
CT-038	12	23.26	13.62	**12.73**	14.12	24.8	20.04	Chespeake Bay
CT-040	11	32.84	15.5	**15.25**	16.06	41.37	30.95	Chespeake Bay
CT-041	12	31.66	17.18	**15.33**	17.29	35.31	27.88	Chespeake Bay
CT-042	10	26.04	13.07	12.79	**12.31**	36.97	27.52	Coastal Carolina
CT-044	12	26.52	14.27	**13.35**	14.2	36.06	26.31	Chespeake Bay
CT-045	12	29.28	**13.36**	13.81	14.03	38.96	27.65	Coastal Mid-Atlantic
CT-046	12	30.99	**17.09**	17.34	17.46	29.98	31.74	Coastal Mid-Atlantic
CT-047	11	22.68	13.54	13.66	**12.95**	27.8	27.07	Coastal Carolina
CT-048	12	25.88	**13.07**	14.15	13.26	29.79	24.78	Coastal Mid-Atlantic
CT-049	11	25.78	19.45	**18.13**	18.25	35.5	25.03	Chespeake Bay
CT-051	12	33.4	12.31	**12.19**	13.4	32.25	26.07	Chespeake Bay
CT-052	10	18.34	9.24	**9.19**	9.78	23.5	20.49	Chespeake Bay
CT-053	11	28.93	**16.81**	17.62	17.67	35.82	29.86	Coastal Mid-Atlantic
CT-055	12	30.5	18.38	17.91	**17.79**	32.24	21.01	Coastal Carolina
CT-056	12	28.47	**13.58**	14.88	14.83	30.63	28.02	Coastal Mid-Atlantic
CT-057	11	32.57	13.27	13.14	**12.64**	33.37	25	Coastal Carolina
CT-060	12	27.18	15.72	**15.41**	17.59	37.2	26.96	Chespeake Bay
CT-061	10	26.08	**10.47**	10.97	11.94	28.57	23.91	Coastal Mid-Atlantic
CT-062	12	29.45	18.03	16.63	**16.15**	37.98	27.98	Coastal Carolina
CT-063	12	22.86	**10.33**	11.59	12.28	32.81	27.06	Coastal Mid-Atlantic
CT-064	12	23.82	12.47	**12.39**	13.38	36.88	24.97	Chespeake Bay
CT-066	10	29.56	16.44	**14.34**	14.77	33.78	26.99	Chespeake Bay
CT-067	10	22.37	10.41	**8.86**	11.24	22.68	23.79	Chespeake Bay
CT-068	12	28.6	13.52	**12.3**	14.08	33.3	25.59	Chespeake Bay
CT-069	12	34.96	17.89	**17.25**	17.38	40.91	28.73	Chespeake Bay
CT-070	12	28	13.14	**12.69**	13.55	34.58	27.45	Chespeake Bay
CT-071	11	32.02	12.7	**11.71**	12.52	30.93	24.37	Chespeake Bay
CT-072	12	27.93	13.46	**12.19**	13.01	32.05	26.28	Chespeake Bay
CT-073	11	22.89	13.24	**12.76**	13.26	35.05	29.48	Chespeake Bay
CT-074	12	35.32	**15.57**	15.91	15.81	39.47	26.09	Coastal Mid-Atlantic
CT-076	12	29.67	13.87	**13.6**	14.97	32.85	26.34	Chespeake Bay
CT-077	9	13.68	**9.3**	10.34	10.2	27.2	21.11	Coastal Mid-Atlantic
CT-078	12	21.5	11.1	**10.86**	13.02	28.92	29.52	Chespeake Bay
CT-079	12	26.84	13.65	**12.14**	12.85	30.85	22.77	Chespeake Bay
CT-080	10	25.48	15.47	**14.32**	14.9	25.97	21.72	Chespeake Bay
CT-081	12	24.11	**12.83**	12.86	13.32	47.88	28.32	Coastal Mid-Atlantic
CT-082	12	23.13	13.74	14.05	**13.43**	36.15	23.98	Coastal Carolina
CT-083	12	28.81	**11.88**	12.6	12.2	39.1	28.91	Coastal Mid-Atlantic
CT-085	12	22.52	**15.48**	15.8	15.52	35.28	24.84	Coastal Mid-Atlantic

FIGURES

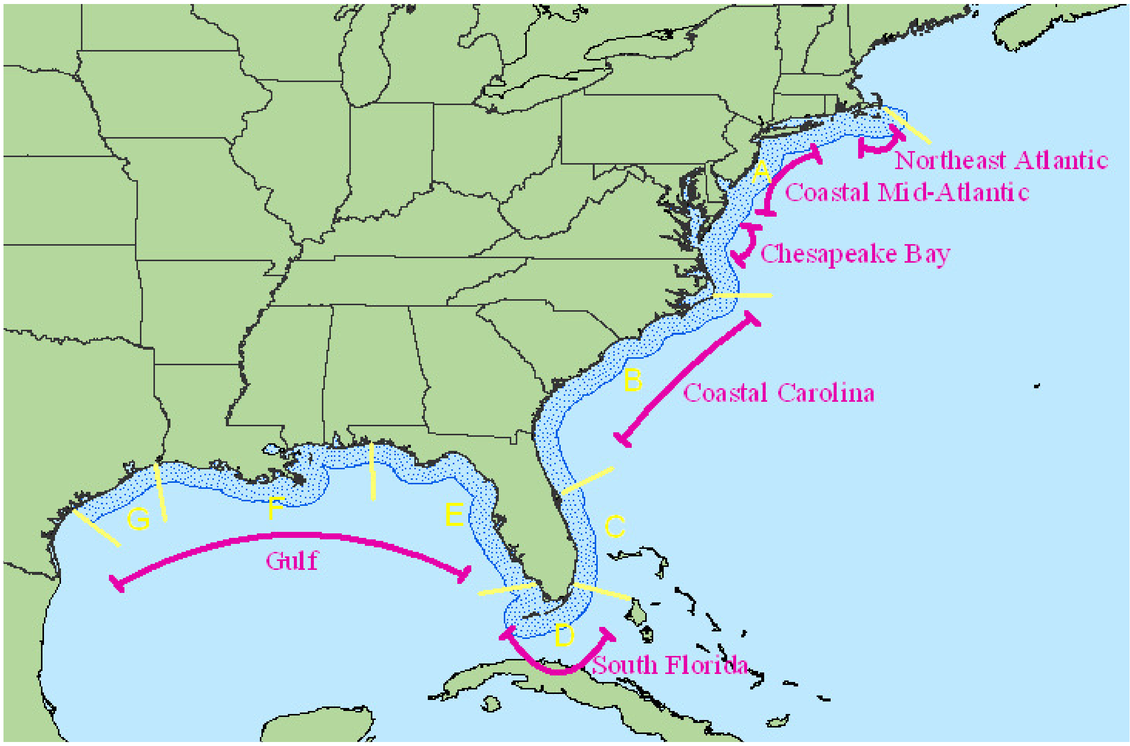

Figure 1. Terrapin Range, Subspecies, and Metapopulations Map (Hart, 2005). The blue dotted sections of the map represent the terrapin range from Cape Cod, Massachusetts to Corpus Christi, Texas. The yellow, lettered sections are the morphological subspecies and the pink, labeled sections are the six metapopulations.

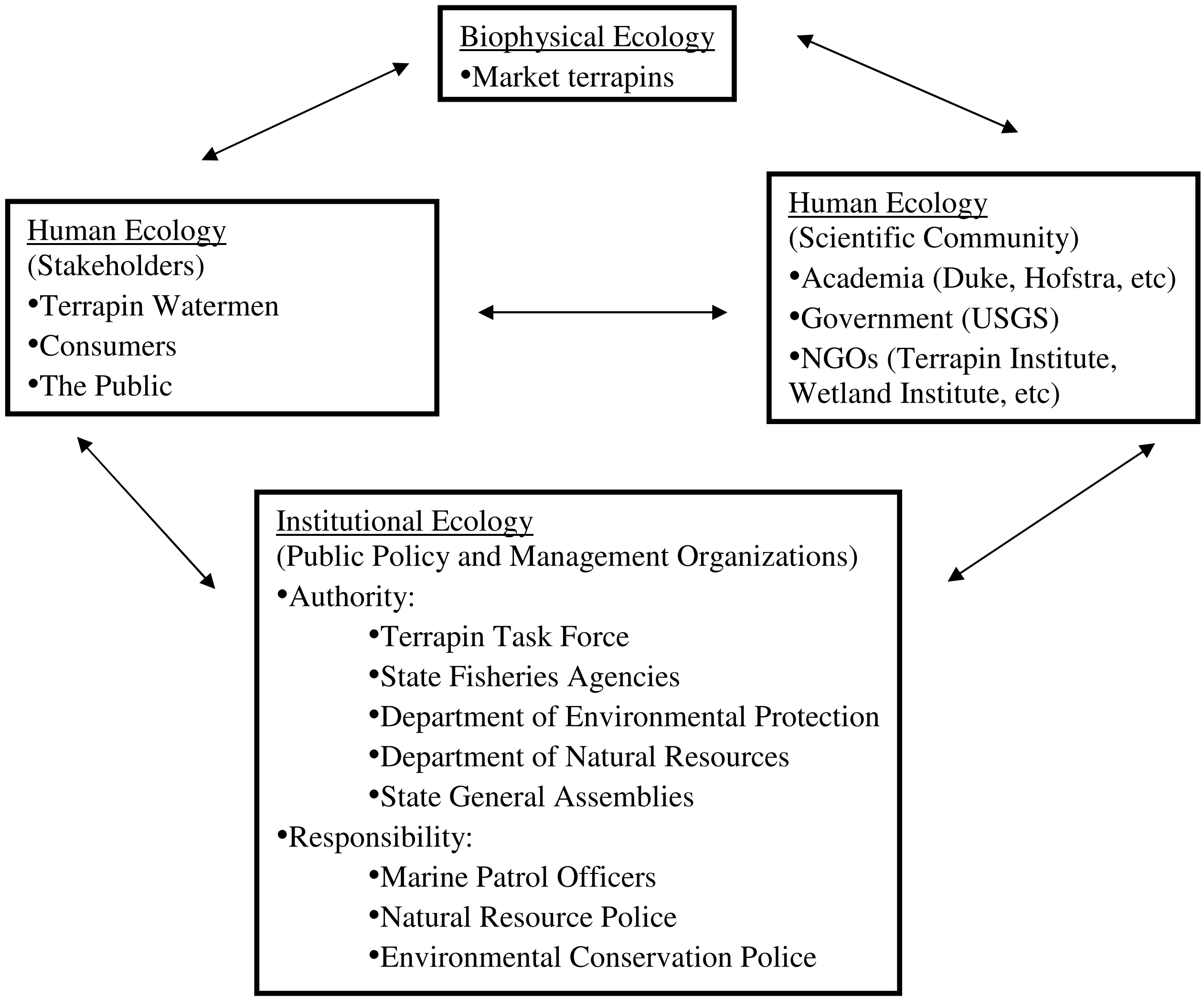

Figure 2. Human Ecology Diagram for Market Terrapins. This diagram represents the human ecology for the market terrapin issue. The institutional ecology is the most complicated. Authority is shared by the terrapin task force (who suggests management plans), the state fisheries agency, DEP, or DNR, and the state general assemblies (who officially declare rules and regulations). Marine patrol officers or police have the responsibility to enforce rules.

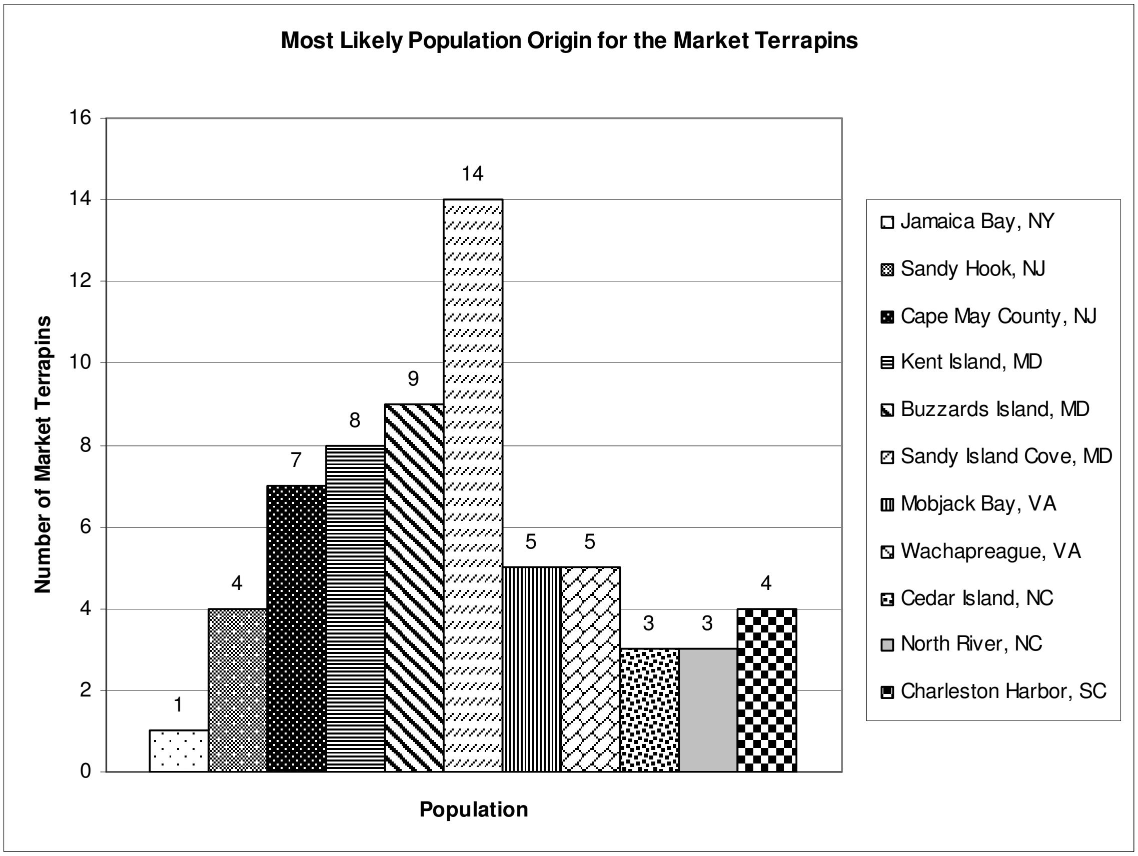

Figure 3. Most Likely Origin of the Market Terrapins at the Subpopulation Level. All of the samples were assigned to subpopulations between New York and South Carolina. The largest number of terrapins was assigned to the three subpopulations that are located in Maryland ($p<0.001$).

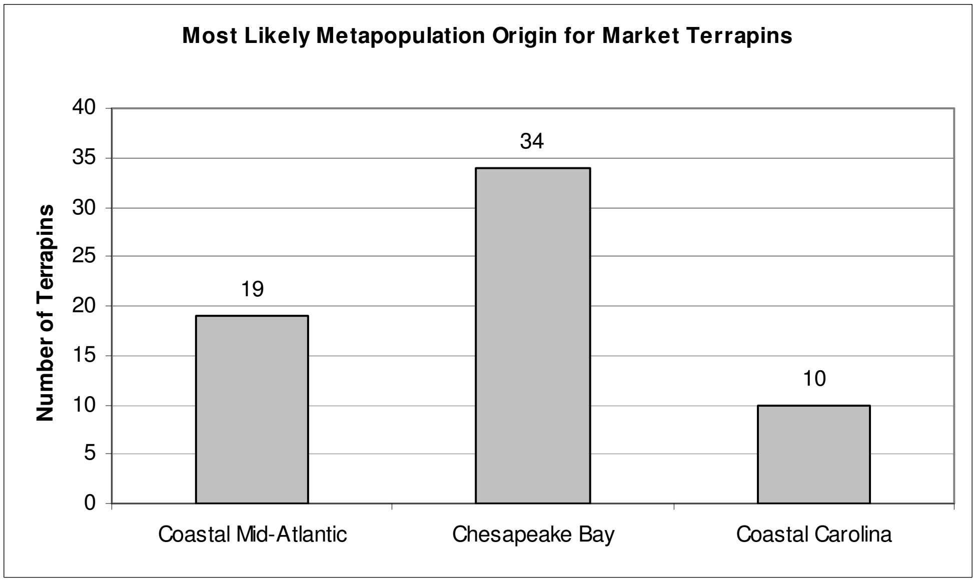

Figure 4. Most Likely Origin of the Market Terrapins at the Metapopulation Level. All 63 market terrapin samples were assigned to the Atlantic coast, between New York and South Carolina ($p<0.001$). The largest number of market terrapins was assigned to the Chesapeake Bay metapopulation, which consists of Maryland and Virginia.

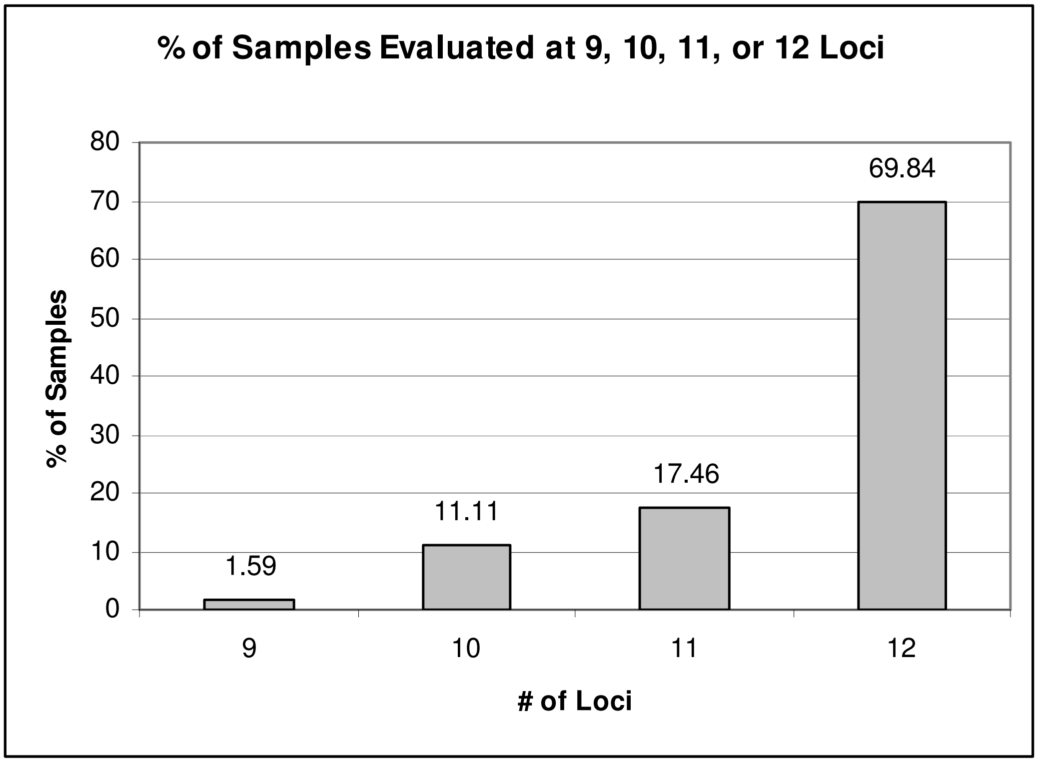

Figure 5. Percent of Samples Evaluated at 9, 10, 11, or 12 Loci. All of the market terrapin samples were evaluated using 9 or more of the 12 possible loci. More than 87% of the samples were evaluated with 11 or 12 loci which suggest that sample integrity was high. Sample integrity is an issue when the samples cannot be run at all loci. In this case, we had a large quantity of isolated DNA and our blood samples were good quality.