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Risks Associated with Harvesting and Human Consumption of Two Turtle Species in New Jersey

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RISKS ASSOCIATED WITH HARVESTING AND HUMAN CONSUMPTION OF TWO TURTLE SPECIES IN NEW JERSEY

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by

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RISKS ASSOCIATED WITH HARVESTING AND HUMAN CONSUMPTION OF TWO TURTLE SPECIES IN NEW JERSEY

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ABSTRACT

RISKS ASSOCIATED WITH HUMAN CONSUMPTION AND HARVESTING OF TWO TURTLE SPECIES IN NEW JERSEY

by Natalie R. Sherwood

Snapping turtles and diamondback terrapins have unique life characteristics, making their populations' survivorship heavily dependent upon the turtles that reach sexual maturity, limiting the harvest potential of turtles and making them vulnerable to exploitation. Therefore, this research tests mercury concentrations in diamondback terrapins and snapping turtles to determine if turtle meat should require human consumption advisories, and examines transport of mercury through the snapping turtle food web by testing prey items for mercury burden and mapping food webs using stable isotope composition.

Consumption of New Jersey diamondback terrapins and snapping turtles pose a health risk. 25% of Cape May and 46% of Meadowlands terrapin muscle samples surpassed the U.S. Environmental Protection Agency mercury threshold for fish consumption. For snapping turtles, Lake Wapalanne had the highest percent of turtle samples surpassing the threshold (36%), followed by Kearny Freshwater Marsh (33%) and Lake Hopatcong (28%). Based on the results of this study it is crucial to implement human consumption advisories for consumed turtle species.

Neither the commercial or recreational harvest of snapping turtles in New Jersey is well understood. We therefore administered a survey to learn about current harvest

practices, willingness of commercial and recreational harvesters to pay increased license fees, and their willingness to comply with new regulations.

Respondents to the recreational harvest survey collected approximately 2,285 snapping turtles between 2012 and 2014. Respondents from the commercial harvesting survey reported collecting 1,506 turtles during the 2014 season. Commercial harvesters are willing to pay a higher permit price, up to $29.22, to keep their harvesting privileges.

The results of this study suggest diamondback terrapin and snapping turtles pose a human consumption health risk due to elevated mercury concentrations. We suggest consumption advisories be developed for snapping turtles starting with locations of heavy harvest while advising the sensitive population to avoid the consumption of turtles. Based on the results of the harvest surveys we can suggest both recreational and commercial harvesters are willing to follow regulations in order to ensure future harvest. Harvesters are also willing to pay a higher permit price to keep their current harvesting privileges.

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Table of Contents

List of Figures

List of Tables

Chapter 1. Turtle Life History, Threats, and Conservation

1.1 Introduction

Turtles are among the most endangered vertebrates with approximately half of their 328 species threatened with extinction (Turtle Conservation Coalition, 2011). Turtles have survived for 220 million years, but in recent decades their populations have been rapidly dwindling and many face extinction. Turtles experience many threats, such as pollution, habitat loss, harvesting for traditional medicine, as pets, and for food. Due to these pressures the world's turtle populations have experienced major declines. In 2000, the International Union for Conservation of Nature (IUCN) reported 3% of all turtles to be extinct, 9% to be critically endangered, 18% endangered, 21% vulnerable, 14% near threatened, 2% data deficient, and 33% of least concern (Turtle Conservation Fund, 2002). This equates to 65% of turtles worldwide considered at risk or threatened with extinction.

In the last three decades, there has been a growing concern that the decline of many turtle species has been driven mainly by human consumption demands (Klemens and Thourbjanarson, 1995; Mali et al., 2014). Turtles are consumed in the United States, India, and many countries in the Amazon region and in Asia (Krishnakumar et al., 2009; Schneider et al., 2011, Sung et al., 2013; Mali et al., 2014). The increase in turtle harvest and overall population decline is attributed to the export of turtles to Southeast Asia, where turtles are used in traditional medicine, kept as pets, and most importantly consumed by humans (Mali et al., 2014; van Djik et al., 2000). As a result, 68% of the turtle species from this region are imperiled and many are on the brink of extinction

(Turtle Conservation Fund, 2002). Turtle Conservation Fund (2002) reported 1% of the turtle species in Asia are already extinct in the wild, 20% are critically endangered, 31% are endangered, 25% are vulnerable, 7% are near threatened, while 7% remain data deficient and 9% are of least concern.

1.2 Snapping Turtles (*Chelydra serpentina*)

Chelydra serpentina is composed of four subspecies and can be found from Canada to Ecuador, with some gaps along this range. The two subspecies found in North America, *C. serpentina serpentina*, the common snapping turtle, and *C. serpentina osceola*, the Florida snapping turtle, vary in geographical ranges and several morphological aspects (Ernst et al., 1994). *C. serpentina serpentina* ranges from southern Canada to Texas and eastward to the Atlantic coast. *C. serpentina serpentina* exhibits juxtaposed plates covering the back of the head. The dorsal surface of the neck is covered by wart like tubercles (Figure 1.1b). *C. serpentina osceola* is only found in Florida. It has granular scales and scattered pointy tubercles on the back of the head and the neck (Ernst et al., 1994) (Figure 1.1a). *C. serpentine serpentina* will hereafter be referred to as simply "snapping turtle" in this study.

a. b.

Figure 1.1 Morphological differences between (a) the common snapping turtle and (b) the Florida snapping turtle (Photo credit: Chelydra.org).

Snapping turtles are the second largest freshwater turtles in North America and the largest in New Jersey. Snapping turtles can be identified by their large size and serrated carapace (Ernst et al., 1994). Their carapace varies in color from tan or brown to black. The hinged plastron is reduced and ranges from yellow to tan in color (Figure 1.2). Snapping turtles have long tails and long necks, which can reach pass half of their carapace. The head is large with a saw-toothed upper jaw. Female snapping turtles measure from 23 to 36 cm while males range from 25 to 39 cm (Ernst et al., 1994). Secondary sexual characteristic such as longer nails and longer and thinner tails are also exhibited (Ernst et al., 1994).

a. b.

Figure 1.2 The common snapping turtle carapace view (a) and plastron view (b).

1.2.1 Habitat and Distribution

Snapping turtles are the most abundant and have the widest distribution of turtle species in the United States. Outside of its native range, snapping turtles have been introduced to several states and can be found in some water bodies in California, Oregon, Washington, Idaho, Nevada, Utah, Arizona, New Mexico and Puerto Rico (Ernst et al., 1994; Phillips et al., 1996) (Figure 1.3). The introduction of this species to non-indigenous areas has been mainly attributed to pet release (Beebee and Griffiths, 2000).

Figure 1.3 Map of the distribution of the common snapping turtle (IUCN, 2012).

Snapping turtles live in freshwater habitats in water depths of 20 inches to 8 feet, with a preference for slow-moving water (Graves and Anderson, 1987). Snapping turtles are a bottom-walking species, preferring soft bottoms and abundant submerged vegetation, brush, tree trunks and water lilies (Ernst et al., 1994). They are most often found in shallow water at the edges of lakes and rivers, but require deep enough water to allow them to overwinter below the ice. Hatchlings and juveniles are poor swimmers, limiting them to small streams (Graves and Anderson, 1987). As they mature they migrate to ponds, rivers, marshes, and shallow areas of large lakes to establish their territories. Snapping turtles can also be found in brackish water, however, studies have shown their osmoregulating abilities are incompletely developed due to the absence of salt glands, limiting the extent of their exposure to brackish water (Ernst et al., 1994).

1.2.2 Life History Characteristics

Snapping turtles are long-lived (up to 60 years) and reach sexual maturity between ages 11 and 16 (Congdon et al., 1994; Golet and Haines, 2000). The mating season begins in March, followed by the nesting season starting from April through November, with most of the nesting occurring from May to June. Snapping turtles rarely leave the safety of the water, except during the nesting season, when females travel out of the water in search of nesting sites (Graves and Anderson, 1987). Both male and female snapping turtles exhibit high site fidelity. Large male snapping turtles have fixed home ranges, while nesting females return to the same nesting area each season, with site fidelity ranging from 75 to 92% (Graves and Anderson, 1987). Home ranges and site fidelity have been shown to increases with age (Graves and Anderson, 1987).

Snapping turtles lay 20 to 40 eggs, comparable in size to ping pong balls, in shallow dug-outs usually in well-drained and sunny location such as in banks, road embankments, and gardens, among others (Graves and Anderson, 1987). Snapping turtles have temperature-dependent sex determination. Nests incubated at 20˚C produce females, while nests incubated at 21-22˚C produce both female and males. Nests incubated at 23-24˚C produce males (Ernst et al., 1994). Hatching events are weather dependent and usually occur from August to October after an incubation period of 80 to 90 days.

Nest success and hatchling rates of young, sexually mature females are lower than the rates of older females. Females can delay fecundity, therefore not laying a nest every year (Galbraith et al., 1993). Overall, snapping turtles have low nesting success rate and high hatchling and juvenile mortality rates. Nests are often preyed upon, resulting in up to 94% of unsuccessful nesting (Graves and Anderson, 1987). As hatchlings and juveniles, snapping turtles are also vulnerable to many predators including hawks, herons, raccoons, fish, snakes and other turtles. For unpredated nests, approximately 20 to 45% of eggs hatch each year. However, a hatchling's chance of surviving to sexual maturity is only about 2% (Galbraith et al., 1989); it is estimated that approximately 1 out of every 133 hatchlings will make it into the breeding population (Galbraith et al., 1989). These characteristics support a bet-hedging life strategy with a high rate of adult survival and with 88 to 97% surviving beyond the age of 18 (Brooks et al., 1991, Congdon et al., 1994). In addition, long reproductive life compensates for the high mortality rates of eggs, hatchlings and juveniles (Congdon and Gibbons, 1990).

Snapping turtles are considered ecologically important scavengers, consuming carrion as an important food source. Alexander (1943) estimated that plants compose 36.5% of snapping turtle's gut content while animals composed 54.1%. More recent studies agree that turtles are generally omnivorous, but indicate that aquatic vegetation comprises approximately 60% of their diet (Graves and Anderson, 1987). Animal matter found in turtles includes fish, mollusks, crustaceans, frogs, and a variety of amphibian, reptiles and invertebrates (Alexander, 1943; Graves and Anderson, 1987).

1.2.3 Status of the Common Snapping Turtle

The IUCN classifies snapping turtle conservation status as of least concern. In the U.S. forty states currently allow the commercial or recreational harvest of snapping turtles. Snapping turtles are considered as in need of management in South Carolina, of special concern in Minnesota and Canada, yet a "nuisance" in Rhode Island (van Dijk, 2012). Many states have limited or have terminated the commercial harvest of this species due to dwindling populations. For example, states such as Alabama, Illinois, Maine, New Hampshire, Oklahoma, West Virginia, Nebraska, South Dakota, Mississippi, North Carolina, among others, have terminated or enforced stricter regulation on the commercial harvest of snapping turtles (Miller, 2009). Snapping turtle populations in New Jersey are considered stable, but the current unlimited commercial harvest and one turtle a day recreational harvest per angler cause a concern over the long-term stability of the populations.

1.2.4 Human Impact on Snapping Turtles

Snapping turtles face many anthropogenic threats including pollution, habitat loss, road mortality, and harvest. Snapping turtles have been observed in polluted and urban waters, suggesting the ability to tolerate and adapt to human actions and the changing environment. Snapping turtles' sedentary behavior makes them well suited to assess the health of an ecosystem (Bishop et al., 1995, 1996, 1998; de Solla et al., 2001; EPA, 2007). Pollution shows little to no effect on adult snapping turtles' health, but high mercury concentrations seem to affect their reproductive success (Bell et al., 2006;

Hopkins et al., 2013). Nests of mothers with high mercury concentrations have lower hatchling success rates and higher rates of deformities in hatchlings (Bell et al., 2006).

Mature female snapping turtles leave the safety of the water every spring to find nesting sites, which often takes them across roadways, especially in urban landscapes such as many urban area in New Jersey. Studies suggest that approximately 95% of the turtles hit by vehicles are adult females (Brooks et al., 1991; Haxton, 2000). Road mortality can detrimentally impact snapping turtle's population stability since eliminating a mature female from the population by extension eliminates the future hatchlings that could have entered the breeding population.

Another significant threat is the lost of nesting sites, forcing many turtles to nest on man-made sites such as dams, roads, gravel pits, and mulch beds, among others. Habitat loss also leads to turtles forming nests in a common area, which has also led to an increase in nest predation. Predators, such as raccoons, skunks, foxes, and mink, have been recorded to destroy up to 94% of nests, of which 90% are destroyed during the first 24 hours (Graves and Anderson, 1987). Additionally, the commercial and recreational harvests of snapping turtles are also a significant, if not the most significant threat to the species.

1.2.5 Snapping Turtle Harvest

As native turtle populations severely declined in Southeast Asia due to high demand for human consumption, the market for turtles became global. In response to the overseas demand, several states in the U.S., primarily Louisiana and Oklahoma, opened private turtle farms that generate millions of dollars per year (Mali et al., 2014). Most farms primarily focus on turtle species traded as pets, for example red-eared sliders, map turtles, and river cooters. However, turtle farms did not help with reducing the pressure of harvest of wild turtles. On the contrary, state laws allow turtle farms to capture an unlimited number of wild turtles for numerous years until a healthy broodstock is developed (Florida Fish & Wildlife Conservation Commission, 2012), which stimulates the harvest of wild turtles. Captive bred turtle popularity declined in the 1970's due to Salmonella outbreaks associated with farm-raised turtles since Salmonella is the cause of around 400 human deaths each year in the U.S. (Harris et al., 2010). This has led to the continued dependence on wild caught turtles to supply the global market.

Most states in the U.S. currently have loose turtle harvesting and export regulations on most turtles species, with nearly 10 million turtles exported annually. For example, in 2009, an estimate of 655,541 snapping turtles was exported to supply the global market (Table 1.1) (van Dijk, 2012). These numbers also make snapping turtles one of the most harvested and exported turtle species (Figure 1.4). Although some of the exported turtles originated from commercial turtle farms, an estimated 38.9% of the 229,443 snapping turtles exported in 2004 were wild-caught (Senneke, 2005).

Table 1.1. U.S. Export Numbers of the Common Snapping Turtles (van Dijk, 2012).

Year	1990	1995	2003	2005	2008	2009
Export numbers	3,122	17,495	129,499	320,940	497,107	655,541

The harvest of long-lived organisms is argued to be unsustainable and any commercial harvesting of wild turtles can severely cause local turtle populations to decline. The demand for turtles does not only come from Asian countries, but also from within the United States. Prior to sea turtles being listed as endangered, the demand for sea turtle meat was present throughout the U.S. After the listing of sea turtles, the demand fell upon the alligator snapping turtle, the largest freshwater turtle in North America. As a result, the alligator snapping turtle was hunted to the verge of extinction and today it is protected in every state, with the exception of Louisiana (Roman and Bowen, 2000). The concern for the common snapping turtle is that history might repeat itself; the current ban on the harvest of alligator snapping turtle might lead to the overharvesting of the common snapping turtle.

The turtle trade market is considered to be the main cause of wild turtle population declines in the U.S. (Dixon, 2000; Gibbons et al., 2000). Unfortunately, there is very little data available on the turtle trade and its' impact on turtle populations. Currently turtle trade is not regulated in the U.S., and the evaluation of the magnitude and impact of the trade is complex and difficult (Ceballos and Fitzgerald, 2004).

Table 1.2. Snapping turtle harvest regulations in the United States.

State	Regulation	Source
Alabama	Daily limit: 2 turtles	http://www.biologicaldiversity.org/news/press_releases/2012/freshwater-turtles-04-09-2012.html
Alaska	Not native	
Arizona	Daily limit: 20 turtles Harvest season: year round	http://www.azgfd.gov/w_c/nonnativeturtles.shtml
Arkansas	Daily limit: unlimited	http://www.agfc.com/enforcement/Documents/CommercialFishingRegs.pdf
California	Not native	
Colorado	Daily limit: unlimited Harvest season: April 1 to October 31	https://cpw.state.co.us/Documents/RulesRegs/Brochure/smallgame.pdf
Connecticut	Daily limit: 5 turtles Seasonal limit: 10 turtles Size restriction: 13” Harvest season: July 15 to September 30	http://www.ct.gov/deep/cwp/view.asp?a=2700&q=531694&deepNav_GID=1633
Delaware	Size restriction: 11” Harvest season: June 15 to May 15	http://regulations.delaware.gov/AdminCode/title7/3000/3900%20Wildlife/3904.shtml
Florida	Daily limit: 1 turtle Harvest season: year round Limited take for turtle farms.	http://myfwc.com/wildlifehabitats/managed/freshwater-turtles/
Georgia	Commercial harvest: unlimited Recreational daily limit: 10 turtles Harvest season: year round	http://www.georgiawildlife.com/turtling
Hawaii	Not native	
Idaho	Not native permit required	http://idfg.idaho.gov/public/docs/rules/amphibsReptiles.pdf
Illinois	Daily limit: 2 turtles Harvest season: June 15 to August 31	https://www.dnr.illinois.gov/fishing/Documents/IllinoisFishingInformation.pdf
Indiana	Daily limit: 4 turtles Size restriction: 12” Harvest season: June 1 to March 31	http://www.in.gov/dnr/fishwild/3328.htm
Iowa	Commercial harvest: 100 pounds of live turtles or 50 pounds of dressed turtles	http://www.iowadnr.gov/Fishing/Fishing-Licenses-Laws/Additional-Regulations/Frogs-Turtles

	Recreational daily limit: 4 turtles Harvest season: year round	
Kansas	Daily limit: 5 turtles Harvest season: year round	http://ksoutdoors.com/Hunting/Hunting-Regulations/General-Information/Reptiles-Other-Species
Kentucky	Recreational harvest: unlimited Harvest season: year round	http://fw.ky.gov/Hunt/Pages/Other-Hunting-Seasons.aspx
Louisiana	Commercial harvest: unlimited	http://fw.ky.gov/Hunt/Pages/Other-Hunting-Seasons.aspx
Maine	Recreational harvest: turtles and eggs.	http://www.maine.gov/ifw/warden_service/faq.html#snapping
Maryland	Commercial harvest: tidal waters only Recreational possession limit: 1 turtle Size limit: 11”	http://dnr.maryland.gov/fisheries/Pages/mgmt-committees/stwg-index.aspx
Massachusetts	Daily limit: 2 turtles Size limit: 12” Harvest season: July 17 to April 30th	http://www.mass.gov/eea/agencies/dfg/dfw/laws-regulations/cmr/321-cmr-300-hunting.html
Michigan	Daily limit: 1 turtle Size limit: 13” Harvest season: July 15 to September 15	http://www.michigan.gov/documents/dnr/2016-2017MIFishingGuide_515573_7.pdf
Minnesota	Commercial harvest: unlimited Capped commercial license: 35 permits issued Size limit: 12”	https://www.revisor.mn.gov/rules/?id=6256.0500
Mississippi	Daily limit: 1 turtle Season limit: 4 turtles Harvest season: July 1st to March 30th	https://www.mdwfp.com/fishing-boating/freshwater-commercial/turtle-information.aspx
Missouri	Daily limit: 5 turtles Harvest season: year round	https://huntfish.mdc.mo.gov/fishing/species/turtle/turtle-seasons-hours
Montana	Commercial harvest: none	https://training.fws.gov/resources/course-resources/pesticides/Aquatic%20Effects/2hp1.pdf
Nebraska	Daily limit: 5 turtles Harvest from private waters	http://digital.outdoornebraska.gov/i/769053-fishing-guide-2017-web
Nevada	Commercial harvest: none	

New Hampshire	Recreational possession limit: 2 turtles Size limit: smaller than 6” or 12 to 15” Harvest season: July 16 to May 14.	http://www.wildlife.state.nh.us/nongame/rules-amp-rept.html
New Jersey	Commercial harvest: unlimited Recreational daily limit: 1 turtle Size limit: 12” Harvest season: January 1 to April 1 and July 1 to October 31	http://www.state.nj.us/dep/fgw/pdf/2017/digfsh17.pdf
New Mexico	Commercial harvest: unlimited Recreational seasonal limit: 20 turtles	http://www.wildlife.state.nm.us/download/enforcement/special-permits/commercial-collecting/Amphibian-Reptile-Collection-Information-Limits.pdf
New York	Daily limit: 5 turtles Season limit: 30 turtles Size limit: 12” Harvest season: July 15 to September 30th	http://www.dec.ny.gov/outdoor/31339.html
North Carolina	Commercial daily limit: 10 turtles Commercial seasonal limit: 100 turtles Recreational season limit: 4 turtles	http://www.ncwildlife.org/Portals/0/WDCA/documents/herps.pdf
North Dakota	Recreational season limit: 1 turtle Harvest season: July 1 to November 15	https://gf.nd.gov/fishing/regulations-guide#turtles
Ohio	Daily limit: 4 turtles Size limit: 11” Harvest season: July 1 to December 31	http://codes.ohio.gov/oac/1501:31-25-04v1
Oklahoma	Commercial harvest: private waters Recreational daily limit: 6 turtles	https://www.wildlifedepartment.com/sites/default/files/fish1617.pdf
Oregon	Not native	
Pennsylvania	Commercial daily limit: 15 turtles Commercial season limit: 30 turtles Harvest season: July 1st to October 31st	http://www.fishandboat.com/Transact/Forms/NonGameForms/Documents/turtle_snapping.pdf

Rhode Island	Commercial harvest: special permit Size limit: 12”	http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/turtles.pdf; http://sos.ri.gov/documents/archives/regdocs/released/pdf/DEM/6560.pdf
South Carolina	Daily limit: 10 turtles Seasonal limit: 20 turtles	http://www.scstatehouse.gov/code/t50c015.php
South Dakota	Daily limit: 2 turtles Harvest season: year round	http://gfp.sd.gov/ePubs/wildlife/2017fishing-handbook/flipbook/
Tennessee	Daily limit: 5 turtles Size limit: 12” Commercial harvest for sale	http://pub.eregulations.com/doc/jfgriffin/14tnfw/2014012301/50.html#50
Texas	May possess, transport, sell, resell, import, or export. No person, while on or in public water, may possess or use a net or trap for catching a turtle.	http://tpwd.texas.gov/newsmedia/releases/?req=20070529a
Utah	A person may collect or possess any number of snapping turtles, turtles without a certificate of registration if the animal is either killed immediately upon removing them from the water.	https://wildlife.utah.gov/guidebooks/amphibians_reptiles/
Vermont	Commercial or recreational harvest: none	
Virginia	Size limit: 9” Harvest season: June 1st to September 31st	https://www.dgif.virginia.gov/forms-download/PERM/PERM-018.pdf;https://www.dgif.virginia.gov/forms-download/PERM/PERM-030.pdf
Washington	Not native	
West Virginia	Daily limit:10 turtles Possession limit: 20 turtles Harvest season: January 1 to May 15 and July 15 to December 31	http://www.wvdnr.gov/fishing/Regs16/2016_fishingRegs.pdf
Wisconsin	Daily limit: 5 turtles Size limit: 12 to 16” Harvest season: July 15 to November 30th	http://dnr.wi.gov/files/PDF/pubs/er/ER0102.pdf
Wyoming	Commercial harvest: none Recreational daily limit: unlimited	https://wgfd.wyo.gov/Regulations/Regulation-PDFs/WYFISHINGREGS_BROCHURE

1.2.6 Snapping Turtle Harvest in New Jersey

Snapping turtles are one of the 12 native turtle species found in New Jersey and the only species commercially harvested in the state. The impact of commercial and recreational harvesting pressure on the wild populations is poorly understood. The snapping turtle harvest is under the jurisdiction of the Bureau of Freshwater Fisheries within the New Jersey Department of Environmental Protection's (NJDEP) Division of Fish and Wildlife. The state currently allows both recreational and commercial harvesters to collect turtles throughout the year, with the exception of the nesting season from May 1 to July 15th. NJDEP regulations state "any person with a valid fishing license or those entitled to fish without a license" may take one snapping turtles per day, either by traps or with hands, either adults or juvenile, with no reporting requirement (New Jersey Fish and Wildlife Digest, 2011, 2016). This leaves the recreational harvesting of snapping turtle unregulated and without any data on how many turtles are collected annually by recreational harvesters. Commercial harvesting is only lightly regulated. The commercial harvester permit requires purchase of valid fishing license at $22.50 per person, and an additional $2 for commercially harvesting of snapping turtles. Commercial harvesters are required to submit a monthly report to the Bureau of Freshwater Fisheries with the number of snapping turtles caught and the name of the waterbody where they were harvested (New Jersey Fish and Wildlife Digest, 2011). Currently, commercial harvests have no limits on number of turtles harvested, no limits on weight or sex, and no restrictions on the locations where harvesting is permitted. Up to 2012, both the number of commercial harvesting permits issued and the number of reported turtles harvested have increased (Figures 1.5 and 1.6). This trend can have severe impacts on the sustainability of the snapping turtle harvest in New Jersey.

Although it is clearly stated on the permit application that a monthly harvest report is required, many commercial harvesters fail to submit reports or submit questionable data. Commercial harvesters who fail to submit their monthly reports by the end of the year are prohibited from renewing their license. According to NJDEP records, a total of 24,317 snapping turtles were commercially harvested in New Jersey between 2009-2014 (Figure 1.5 and 1.6). In 2012, 111 harvesting permits were issued, the last year in which the number of permits issued increased above the previous year. However, the number of reported harvests declined in 2012, a trend that continued through 2015. This trend could represent failure in reporting, a decreased interest by harvesters or possibly the decline of snapping turtle populations in the state.

Although it might seem simple to propose the discontinuation of commercial harvest of turtles in New Jersey, it is important to note that the harvest is a source of income for harvesters. The average turtle caught is estimated to weigh approximately eight pounds, with a sale price of approximately $2.00 per pound. With these numbers we can estimate the 2012 snapping turtle harvest in New Jersey yielded $84,320 in income for 111 harvesters. If all commercial harvesters had the same success rate, their yearly income from the harvest would be $760 per harvester. We know that the catch number is not equal among the harvesters; there were 29 permit holders who failed to submit reports, and 13 harvesters who reported catching no turtles. The top three harvesters reported 611, 520, and 484 turtles caught.

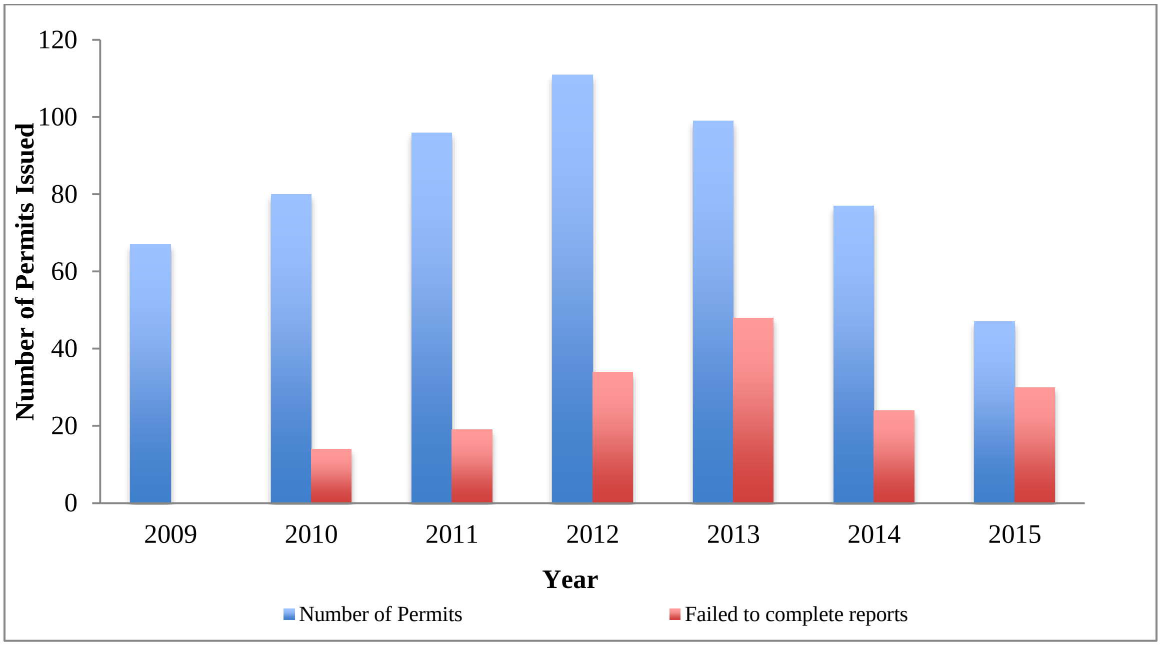

Figure 1.4 Number of commercial harvesting permits issued in New Jersey by year (blue) and the number of permit holders with missing harvest records (red).

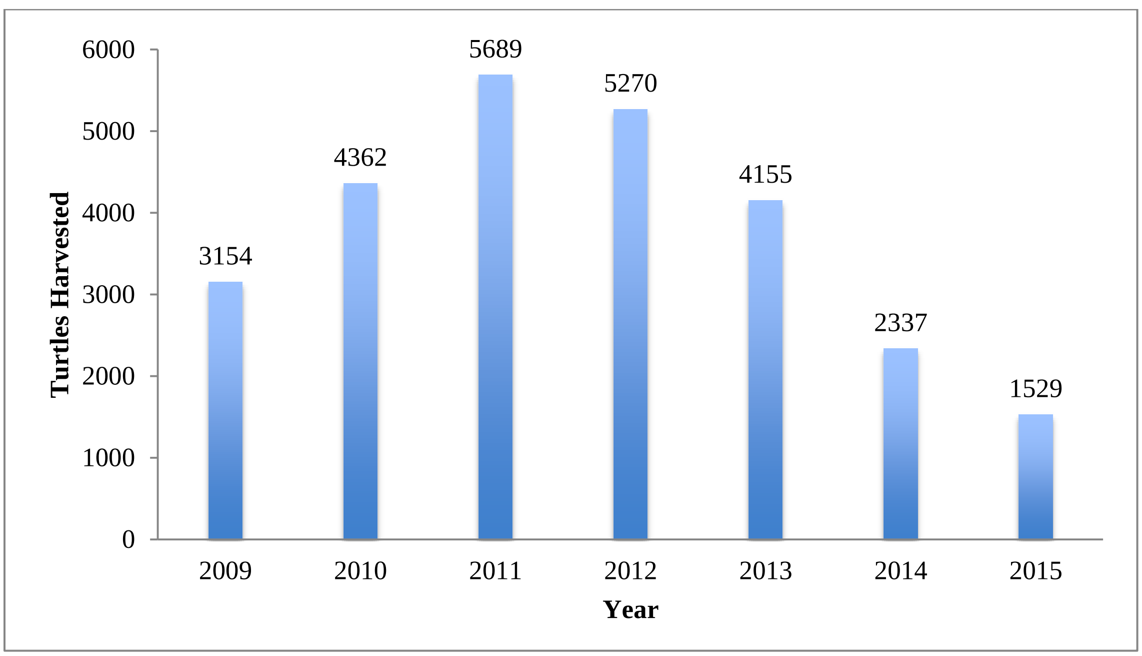

Figure 1.5 Numbers of reported turtles commercially harvested in New Jersey.

Congdon et al. (1994) studied a stable population of snapping turtles in Michigan for over 18 years and constructed a life table and population simulation. They concluded that it would take 2,000 years for a non-harvested population to double, and an increase in adult mortality by 10% annually would halve the population in 10 years (Congdon et al., 1994). Additional long-term studies in Canada by Brooks et al. (1991) also found that populations could not tolerate a harvest of more than 10% of the population. Gibbs and Amato (2000) found no report of a sustainable harvest for wild turtles, and Congdon et al. (1994) gave strong arguments against sustained harvests of long-lived organisms.

The current harvest of the snapping turtle in New Jersey may be unsustainable for some individual water bodies based on the most recently reported harvest data. For example, NJDEP reported that among 40 harvested waterways, the Cohannsey River, approximately 43 hectares in size, had the highest commercial snapping turtle harvest with 959 turtles reported taken in 2009. Based on reported maximum density of 75 snapping turtles per hectare, (Brooks et al., 1988; Galbraith et al., 1988) the Cohannsey River may support a population of up to 3,200 turtles. The reported harvest size from the Cohannsey River, 959 turtles, would represent a minimum of 30% loss of the population, well above the threshold necessary to keep the population stable and sustainable. The current snapping turtle harvesting program in New Jersey may fail to maintain sustainable wild snapping turtle populations.

1.3 Diamondback Terrapin *(Malaclemys terrapin)*

Diamondback Terrapin, *Malaclemys terrapin* is a medium-size turtle characterized by its spotted skin. The carapace color ranges from light brown to black while the plastron is yellow to green. This species exhibits sexual dimorphism with females being much larger than males. Adults' straight line carapace measures 10 to 23 cm (Ernst et al., 1994). Male diamondback terrapins reach sexual maturity at around 10 to 14 cm in carapace lengths, or about 3 years of age. Females reach sexual maturity between 13.2 to 18.4 cm or 6 years of age (Fitzsimmons and Greene, 2001; Lovich and Gibbons, 1990; Montevecchi and Burger, 1975). Diamondback terrapins are estimated to live between 20 to 40 years of age (Ernst et al., 1994; Seigel, 1984). This species also often exhibits a dark marking on the upper jaw and the feet are highly webbed.

1.3.1 Habitat and Distribution

Diamondback terrapins are composed of seven subspecies all found along the eastern and southern coast of North America from Cape Cod to Florida and west to Texas. The most northern subspecies of *Malaclemys terrapin*, the Northern diamondback terrapin, *M. terrapin terrapin*, is found along the Atlantic Coast from Cape Cod to North Carolina (Ernst et al., 1994). The other six subspecies, *M. terrapin centrata*, the Carolina diamondback terrapin, ranges from the Carolinas to Florida and has a breeding population in Bermuda (Bacon et al., 2006; Davenport et al., 2005). *M. terrapin tequesta*, the Florida east coast diamondback terrapin, occurs along the Atlantic coast of Florida. *M. terrapin rhizophorarum*, the mangrove diamondback terrapin, is found in the Florida

Keys. *M. terrapin macrospilota*, the ornate diamondback terrapin, is found along the Gulf Coast of Florida. *M. terrapin pileata*, the Mississippi diamondback terrapin, ranges from the Gulf Coast of Florida to Louisiana. Lastly, *M. terrapin littoralis,* the Texas diamondback terrapin, ranges from western Louisiana and along the coast of Texas (Ernst et al., 1994). These seven subspecies vary in carapace color and ornamentation, yet determining their geographical variation is challenging and requires genetic testing (Ernst et al., 1994).

Diamondback terrapins are often found in coastal swamps, estuaries, lagoons, tidal creeks, mangrove thickets, and salt marshes, making it the only brackish water turtle in the U.S. (USFWS, 2013). This species is able to tolerate salinities ranging between 0 to 35 ppt (Ernst et al., 1994). Diamondback terrapins absorb less water in areas of high salinity, and drink rainwater during weather events, as they require periodic access to freshwater for long-term health (Ernst and Lovich, 2009). Diamondback terrapins are omnivorous and consume a wide variety of food items including gastropods, crabs, bivalves, carrion fish, and plant matter (Ernst et al., 1994).

1.3.2 Life History Characteristics

Diamondback terrapins generally remain active from March to November, which varies by geographical region. Hibernation can occur in groups or on an individual basis from November to January, with the animals buried in mud or in undercut banks. Mating season begins in March and April when water temperatures are between 24.8 and 27°C (Ernst et al., 1994). Nesting then occurs from April to July, with most of New Jersey females nesting in June and July (Burger, 1977; Ernst et al., 1994). Females often nest near vegetated sand dunes where they lay 4 to 18 eggs. Nests hatch between August and October after an incubation period of 61 to 104 days (Ernst et al., 1994). Unfortunately, 73% of eggs and 71% of nests were reported to be destroyed by predators soon after nesting (Ernst et al., 1994, Burger, 1977). Iverson (1991) estimated hatchling survivorship to be 23% once they had left the safety of the nest. The major predators are raccoons and foxes; ghost crabs, crows, gulls, musk rats, skunks, and minks also represent a threat (Burger, 1977; Ernst and Barbour, 1972). Besides human, predation risks are greatly reduced for adults with the exception of the occasional nesting female that falls prey to a fox or raccoon.

1.3.3 Status of the Diamondback Terrapin

The population size of diamondback terrapins across its range is currently unknown. van Dijk (2011) estimated the diamondback population size to exceed 100,000 individuals. Although most populations are thought to be declining due to various anthropogenic threats (Avissar, 2006; Butler et al., 2006; Dorcas et al., 2007), diamondback terrapins are considered at low risk/near threatened by the International Union for Conservation of Nature's Red List, and their export is monitored by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as an Appendix 2 species. As an Appendix 2 species it must fulfill 1 of the 2 criteria, and terrapins comply with both criteria:

A. “It is known, or can be inferred or projected, that the regulation of trade in the species is necessary to avoid it becoming eligible for inclusion in Appendix I in the near future.” (CITES, 2011)

B. “It is known, or can be inferred or projected, that regulation of trade in the species is required to ensure that the harvest of specimens from the wild is not reducing the wild population to a level at which its survival might be threatened by continued harvesting or other influences.” (CITES, 2011)

1.3.4 Human Impact on Diamondback Terrapins

Diamondback terrapin populations are heavily impacted by urbanization and habitat loss. With a long history of coastal development and draining and filling of salt marshes, terrapins have lost much of their daily habitat as well as nesting habitat. Shoreline and beach replenishment and armoring prevent or segregate intertidal marshes restricting terrapins to smaller habitats (CITES, 2013). For example, in June 2011, a John F. Kennedy Airport runway was shut down due to hundreds of turtles searching for adequate nesting sites. Habitat loss also impacts populations indirectly, such as having concentrated nesting habitat, resulting in increase predation of nests and adult females.

The concentration of humans along the coast has attracted many terrapin predators. Raccoons, Norway rats, and foxes account for the majority of nest predation, preying on up to 92% of nests and 20% of hatchlings (Draud et al., 2004; Feinberg and Burke, 2003). In the coastal town of Jamaica Bay, New York between 1998-2010, researchers found significantly high (92-100%) and consistent raccoon predation of eggs

(Feinberg and Burke, 2003). Moreover, female terrapins are often struck by cars during the nesting season while attempting to cross roads in search of nesting habitats, resulting in their death (Szerlag and McRobert, 2006; Wood and Herlands, 1997). A study by Wood and Herlands (1997), documented 4,020 road kills during a 7-year study on one short stretch of road in Cape May, New Jersey. Additionally, crab traps have been reported to be death traps for diamondback terrapins, especially for males and juveniles. Terrapins attracted by the bait enter crab traps that do not have turtle excluders, becoming trapped and eventually drowned. Crab traps in use as well as those abandoned or lost, also referred to as ghost traps, are a major threat to terrapins.

1.3.5 Diamondback Terrapins Harvest

Diamondback terrapins have been harvested for food since before the European settlement in North America. However, with large waves of settlers, the harvest of the species became increasingly popular. Considered a delicacy, the species was heavily harvested for several decades throughout much of its range for both local consumption and export (Schaffer et al., 2008). By the early 1900s, diamondback terrapins were harvested nearly to the point of extinction, but harvesting slowed down during the Great Depression (Conant, 1955; 1964). Since then populations seem to be recovering, but unfortunately, human consumption of turtles has again gained in popularity. In 2006 alone, Maryland harvesters reported to have caught 10,500 terrapins (CITES, 2013). The 2014 CITES records showed a total of 14,346 diamondback terrapins exported from the U.S., with 14 exported to Japan, 40 to Thailand, 126 to China, 210 to Taiwan, and 13,956 exported to Hong Kong (CITES, 2015). Although some of the exported terrapins might originate from commercial turtle farms, it is estimated that in 2005, 37.03% of the terrapins exported were wild caught (Senneke, 2005). Although most U.S. states now have legislation that regulates or bans the collection of terrapins (Watters, 2004), this species is still taken from the wild in parts of its range.

1.3.6 Diamondback Terrapin Harvest in New Jersey

Prior to 2016, the open season for diamondback terrapin harvest in New Jersey extended from November 1 to March 31. In 2014 and 2015, the harvest entered a moratorium after a noticeable increase in the demand for diamondback terrapins over the last several years (NJDEP, 2016). In 2016, legislation was passed to remove terrapins from the game species list, and a status review recommended the Special Concern status for this species within the state, but no formal rule proposal has been filed to date.

1.4 Mercury

Due to their long life span, sedentary life style, and place in the food web, the snapping turtle and diamondback terrapin have been used as bioindicator species in aquatic habitats (Blanvillain et al., 2007; Turnquist et al., 2011). Both wild-caught snapping turtles and diamondback terrapins are consumed by humans, making it important to monitor contaminants (i.e. mercury) in their tissues in order to determine consumers risk.

Mercury (Hg) and its’ compounds are highly toxic to most forms of life and pose a significant threat to aquatic ecosystems and human health (Boening, 2000; Brasso and Cristol, 2008; Burgess and Meyer, 2008; Day et al., 2007; Godley et al., 1999; Hopkins et al., 2013; Jacobson et al., 2015). Hg has both anthropogenic and natural sources (Pirrone and Mason, 2009). Anthropogenic processes such as coal burning, municipal waste combustion, steel, and iron smelting are some of the main pathways through which Hg enters the atmosphere, accounting for approximately two thirds of the Hg released (Mason et al., 2005). Natural sources of Hg include volcanic activity, forest fires, weathering of Hg-bearing rocks, and geothermal activity (UNEP, 2013).

Hg can be found in the environment in both inorganic and organic forms. The most common organic forms of mercury are dimethylmercury (C_2H_6Hg) and monomethylmercury (CH_3Hg). Inorganic forms include inorganic compounds containing either mercuric (2+ valence state) or mercurous (1+ valence state) Hg and elemental mercury (Hg°), which account for 95% of atmospheric Hg (Fitzgerald, 1994). Elemental Hg is a liquid and slightly volatile at room temperature. The mercuric form of Hg (Hg^{++}) often exists as mercuric chloride and mercuric sulfide (NJDEP, 2002). Mercuric sulfide is the most abundant Hg-bearing compound in aquatic environments, and is non-volatile and virtually insoluble in water ($K_{sp} = 2 \times 10^{-53}$) (NCSU, 2016). In contrast, mercuric chloride is soluble in water and can be found in aquatic environments, the atmosphere, and aerobic soils (NJDEP, 2002). The mercurous form (Hg^{+}) is not often found under normal environmental conditions (NJDEP, 2002).

Depending on the form and solubility, Hg can be deposited close to its source or transported further, making it difficult to determine its origin. Hg released into the atmosphere can be transported across the globe, with the longest residence time reported to be up to one year (UNEP, 2013). Hg is then deposited on land or water through wet and dry deposition (Fitzgerald, 1995; Gochfeld, 2003). Atmospheric models suggest the highest rate of Hg deposition in the United States occurs in the northeast, the Great Lakes regions, and the Ohio Valley (UNEP, 2013). Hg can also leak directly into soil and water from non-point sources such as septic tanks, landfill leachate, and sludge application, but these sources are now better regulated (NJDEP, 2002).

1.4.1 Mercury Behavior and Pathways in the Physical Environment

Once in an aquatic environment, Hg adsorbs onto sediment particles and reacts with sulfate to form insoluble mercuric sulfide, which is then methylated by anaerobic methanogenic- or sulfate-dependent bacteria, producing methylmercury (MeHg) (Gochfeld, 2003). MeHg is highly associated with diatoms, which allows the assimilation, retention, bioaccumulation and biomagnification of Hg in algae and in the organisms that consume them (Morel et al., 1998). Therefore, MeHg is the form of Hg most readily available and persistent in organisms. Approximately 95% of Hg in fish and 94% of Hg in snapping turtle is MeHg (Bloom, 1992; Turnquist et al., 2011).

Organisms absorb organic Hg directly through passive transport since most biological membranes are permeable to water. This results in the absorption of large quantities of water-soluble substances (McGeer et al., 2004). Hg enters cells by transmembrane cation transport or via diffusion through the lipid membranes with other metals allowing cellular uptake, retention and accumulation in an organism, particularly diatoms (Morel et al., 1998). However, some forms of inorganic mercury behave differently, binding to the cell walls or membranes (Boening, 2000); this is especially important for phytoplankton, algae, and periphyton. Consumers of these organisms cannot breakdown phytoplankton cell walls where inorganic mercury is retained, and is excreted along with the cell wall (Morel et al., 1998). The absorption and transfer of organic Hg is twice as fast as that of inorganic Hg (Boening, 2000).

MeHg is hydrophilic and attracted to fatty and soft tissues, which can serve as sinks for Hg (Boening, 2000). Therefore, MeHg is retained for longer amounts of time, allowing the bioconcentration of the toxin in organisms (Boening, 2000). The intestinal walls of fish readily absorb MeHg, which leads to accumulation in the muscles (NJDEP, 2002). As a neurotoxin, MeHg has the ability to pass the blood-brain barrier, allowing it to interact with brain cellular and nuclear processes (Boening, 2000). For these reasons, MeHg has been the major focus for human consumption advisories and guidelines by government agencies. Elemental Hg as vapor has also been of concern for human health, but exposure is mainly work place.

1.4.2 Mercury in the Aquatic Food Web

Hg as a human health hazard mainly comes from self-caught fish consumption (Burger and Gochfeld, 2005). According to the U.S. Environmental Protection Agency (EPA), Hg analysis of commercial fish indicated concentrations ranging from 0.004 to

0.16 ppm (EPA, 2012). New Jersey's self-caught fish w reported to have higher Hg concentrations, ranging from 0.05 ppm to 0.6 ppm (Burger and Gochfeld, 2005). These reported results raise a concern for Hg contamination in New Jersey's aquatic food webs.

The transfer and accumulation of Hg throughout the food web is poorly understood (Kainz et al., 2006). Phytoplankton, algae, and periphyton concentrate MeHg from water (Chumchal et al., 2011). Trophic levels above the primary producers acquire their Hg loads mainly through their diets. At lower trophic levels, Hg loads are seasonal due to shifts in diets (Atwell et al., 1998; Chumchal et al., 2011). Most of the organic MeHg absorbed by organisms is redistributed to muscle tissue where it binds to sulfhydryl groups and accumulates in proteins (Atwell et al., 1998; Weiner et al., 2003). Inorganic forms of Hg bind to proteins in the liver (Atwell et al., 1998; Bridges and Zalups, 2005; Khan and Wang, 2009).

Bioconcentration, bioaccumulation, and biomagnification of contaminants such as mercury are threats to health of ecosystems, aquatic biota and to humans. Bioconcentration is the enrichment of a chemical in an organism through direct uptake or via physical contact such as through tissues or gills. Bioaccumulation is the enrichment of a chemical in an organism across time via uptake through contact as well as food. Biomagnification is the amplification of a chemical concentration as it travels from one trophic level to the next as predators consume prey. Hg has the ability to biomagnify because it is accumulated in proteins faster than it is excreted (Trudel and Ramussen, 2006). Hg transports and accumulations in an aquatic system are influenced by chemical, physical and ecological variables (Burger and Gochfeld, 2005; Chen et al., 2005; Watras et al., 1998). For example, the length of the food web, seasonality of food preference, presence of invasive species, age structure, water body size, watershed size, canopy cover, pH, and concentration of dissolved organic matter can all influence Hg concentrations and biomagnifications rates (Atwell et al., 1998; Chumchal and Hambright, 2009; Cremona et al., 2008; Hogan et al., 2007; Kelly et al., 1995; Zhang et al., 2012;). Some studies have shown a negative correlation between Hg concentration and water quality variables including alkalinity, pH, and conductivity (Chen et al., 2005). It has also been shown that highly productive lakes with higher dissolved organic carbon (DOC) and higher algae degradation may exhibit a decrease in the amount of Hg available for uptake in the system and lower mercury accumulations in organisms (Chen et al., 2005).

Hg trophic dynamics depend on community structure, composition and feeding relationships, which affect mercury biomagnification (Chasar et al., 2009). For example, Piscivourous, older, and slower growing fish have higher Hg concentration than fast growing insectivores (Wiener et al., 2003). Somatic dilution of Hg has also been observed in a food web (Ward et al., 2010). Large, faster growing organisms produce more cells, diluting the Hg concentration in the cells of organism (Ward et al., 2010). Snapping turtles, which are long-lived and slow-growing, are expected to bioaccumulate and biomagnify and have higher Hg concentrations in its body.

1.4.3 Mercury Concentration in a Snapping Turtle Food webs

Snapping turtles are at the top of aquatic food chains and can bioaccumulate contaminants, and are therefore known as good bio-indicators for pollutants. Many studies have reported detectable mercury concentrations in snapping turtles with several surpassing the EPA and/or the U.S. Food and Drug Administration (FDA) thresholds (Stone et al., 1980; Albers et al., 1986; Golet and Haines, 2000; Hudson River Natural Resource Trustees, 2005). The FDA limits mercury levels in market fish and other foods to be below 1 ppm for human consumption (FDA, 2013). Meanwhile, the EPA threshold is 0.3 ppm to require action such as consumption advisories (EPA, 2010).

A study by Stone et al. (1980) found snapping turtles in the Hudson River unsafe for human consumption under the FDA fish contaminant limits, while another study found mercury levels to be below the thresholds of contaminants approved by the FDA (Hudson River Natural Resource Trustees, 2005). A study conducted on Connecticut’s snapping turtles by Golet and Haines (2000) reported mercury levels in various body tissues to be below the FDA’s threshold. The study also found leg, shoulder and tail mercury tissue concentrations to correlate. A study conducted in Maryland and New Jersey by Albers et al. (1986) found mercury present in all 32 snapping turtles captured. This study also found mercury concentrations to be higher in New Jersey turtles but below the FDA mercury threshold in fish. In 1998 and 1999, the Patrick Center for Environmental Research conducted a study in various areas of concern in New Jersey including waterways in Camden, sections of the Delaware River and the Raritan Bay. They found all turtles tested for mercury to have detectable levels, but these levels were below the FDA threshold. A study conducted in Minnesota found mercury levels in snapping turtle meat to range from 0.3 to 0.5 ppm, again below the FDA threshold but above the EPA threshold (Helwig and Hora, 1983). Another study conducted on snapping turtles in Tennessee reported the mean level of mercury in the kidney at 1.30 ppm, surpassing the FDA limit. Lastly, a study examining New York snapping turtles found muscle mercury concentration between 0.041 to 1.50 ppm with 61% surpassing the EPA's threshold (Turnquist et al., 2011). These studies show the presence of detectable mercury levels in snapping turtles, which is alarming. Thus, mercury levels in these animals should be continuously monitored in order to detect any increases in mercury levels that can be potentially harmful to its human consumers.

1.4.4 Human Health Risks

Hg possesses many serious threats to humans. Humans risk ingesting high levels of Hg through the consumption of contaminated food, especially seafood. Our intestinal tract absorbs up to 100% of the Hg consumed (NJDEP, 2002). Once ingested, Hg acts as a neurotoxin, affecting the brain and the nervous system. Ingestion of Hg is most dangerous to sensitive populations, which includes women of childbearing age, pregnant and lactating women (who risk transferring Hg to the fetus in-utero and through breastfeeding), and young children, as well as the highly exposed population, which includes recreational anglers and subsistence fish consumers.

A fetus is at a significantly higher risk because Hg levels in cord blood are on average 70% higher than in the mother's blood (Megler et al., 2007). The Centers for

Disease Control and Prevention (CDC) reported in 2001 that 10% of U.S. women have Hg levels that could adversely affect the healthy development of a fetus (CDC, 2001). In New Jersey, it is estimated that 10% of women of childbearing age have elevated blood Hg levels with the potential of affecting fetus development (Stern et al., 2001). It is estimated that 300,000 to 600,000 newborns are exposed in-womb to Hg concentrations sufficient to impair their neurological health and development (Mahaffey et al., 2004; Transade et al., 2005). Fetal and infant exposure to Hg causes damage to the brain and nervous system, resulting in distal sensory disturbance, constriction of visual fields, blindness, ataxia, dysarthria, deafness and tremor (Clarkson, 1992; Megler et al., 2007). Studies have also reported infants and young children exposed to Hg while in the womb have poorer neurologic status and delayed development (Transade et al., 2005). In adults, Hg consumption can result in neurotoxicity, damaging motor, psychomotor, visual and cognitive functions (Clarkson, 1992; Megler et al., 2007). Studies have also shown adults to suffer from various cardiovascular diseases, such as coronary heart disease, ischemic heart, alteration in heart rate (Clarkson, 1992; Megler et al., 2007).

As of 2010, over 35% of freshwaters in the U.S. had consumption advisories due to elevated Hg concentrations (Ward et al., 2010). In 2011, 211 new mercury advisories were issued for 173 lakes and 37 rivers (EPA, 2011). In New Jersey, as of 2012, 54% of all assessed river and stream miles were impaired due to elevated Hg contaminations as well as approximately 87% lakes, reservoirs, and ponds (EPA, 2012). Among all consumption advisories currently in effect across the United States, over 81% are due to elevated Hg concentrations. Therefore, elevated Hg concentrations continue to be of major concern across the world, habitats, and species (Evers et al., 2011).

In 2001 the EPA derived a "safe dose" for MeHg, also called a reference dose (RfD), as a safety guide for fish consumers and other sensitive populations. An RfD is an estimated daily intake of a chemical that can be consumed without the expectation of health effects during a lifetime (EPA, 2000 and 2001; Rice, 2004). The MeHg RfD was constructed from child development studies in the Faroe Islands (Grandjean et al., 1997), Seychelles Islands (Davidson et al., 1998; Myers et al. 2000), and New Zealand (Kjellstrom et al., 1989), which examined impairment in children and associated Hg levels in the mother's hair or blood. Based on these studies, the RfD for MeHg is 0.1 µg/kg/day (EPA, 2000 and 2001; Rice, 2004), meaning a person can safely consume 0.1 ppm of Hg per kilogram of body weight per day. Therefore, a person weighing 150 lbs (68 kg) can consume 6.8 ppm per day or 47.6 ppm a week. This RfD can be used to educate consumers about which fish are safe to eat and how often a type of fish can be eaten. A typical fish serving is approximately 6 ounces or 170 grams, which can be used to calculate an approximate MeHg dose for safe consumption (https://www.fda.gov/Food/FoodborneIllnessContaminants/Metals/ucm115644.htm).

1.5. Stable Isotope Analysis

Understanding local predator–prey interactions and energy flow is increasingly important in environmental management. Stable isotope analysis (SIA) is an insightful tool for modeling food web structures and dietary preferences, allowing scientists to understand and correlate Hg concentrations in complex ecosystems. SIA provides a glance into the diets of organisms, replacing old methods such as feeding observation, fecal collection, stomach flushing and dissection, which only provide a few days of information on the diet of an organism (Pearson et al., 2013). SIA depends on the naturally occurring isotopic composition of organisms changing in a predictable manner, and assumes that tissues reflect the composition of the food consumed (Lara et al., 2012).

Stable isotope compositions of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) are defined as follows:

$$\partial^{13}C = \frac{[\frac{13C}{12C}]sample - [\frac{13C}{12C}]standard}{[\frac{13C}{12C}]standard} * 1000 \qquad \text{eqn. 1}$$

$$\partial^{15}N = \frac{[\frac{15N}{14N}]sample - [\frac{15N}{14N}]standard}{[\frac{15N}{14N}]standard} * 1000 \qquad \text{eqn. 2}$$

with delta (δ) values reported in units of per mil (‰). These parameters are essential in determining trophic position and therefore in the constructing a food webs.

Trophic position inferred from SIA allows researchers to quantify relationships if biomagnification is occurring (Atwell et al., 1998; Rognerud et al., 2002; Campbell et al., 2003; Tadiso et al., 2011; Bezerra et al., 2015). $\delta^{15}N$ often exhibits a constant enrichment between 2.5‰ to 3.4‰ between trophic levels (DeNiro and Epstein, 1978; Minigawa and Wada, 1984; Peterson and Fry, 1987). This pattern arises from the preferential excretion of the lighter isotope (Peterson and Fry, 1987). Organisms feeding at higher trophic levels will exhibit more highly positive $\delta^{15}N$ values (Godley et al., 1998). Likewise but to a lesser degree, $\delta^{13}C$ increases between 0‰ to 1‰ per trophic level (DeNiro and Epstein, 1978; Miniwaga and Wada, 1984; Peterson and Fry, 1987). Since $\delta^{13}C$ only shows a slight enrichment, it is not the best indicator of trophic position, and is more effectively used to describe carbon sources and pathways (DeNiro and Epstein, 1978; Peterson and Fry, 1987).

Stable isotopes have relative slow turnover rates (λ = ‰·day^{-1}, a measure of the time period integrated by the measurement), allowing researchers to infer diets from days to years depending on the tissue media studied (Dalerum and Agerbjorn, 2005; Tieszen et al., 1983). Turnover rates vary by tissue type due to varying metabolic rates (Colborne and Robinson, 2013). Muscle tissue incorporates diet information over 5 to 7 months, while more metabolically active tissues, such as liver and blood, process much quicker, providing diet information for a shorter time period (Aresco et al., 2015; Seminoff et al., 2007).

1.6 Research Objectives

Snapping turtles and diamondback terrapins are among the most commonly harvested turtle species sold for human consumption. If mercury levels in turtles are above the established thresholds, there should be an inclination to better regulate or completely ban turtle harvesting practices. This study also aims to investigate Hg concentration in turtles' aquatic food web to better understand contaminant transfer from one trophic level to the next. Throughout this research we collaborated with the New Jersey Department of Environmental Protection, Bureau of Freshwater Fisheries, which provided us with commercial snapping turtle harvest data and access to the Department's website to conduct the online survey for recreational harvesters. We also collaborated with the lead herpetologists of the New Jersey's Endangered and Nongame Species Program.

Chapter 2, "Human Health Implication of Mercury Concentrations Diamondback Terrapins" focuses on testing Hg concentrations in New Jersey's diamondback terrapins to determine the consumption risk of diamond back terrapins. This chapter has been submitted to the journal *Environmental Assessment and Monitoring* and is currently under review. Chapter 3, "Mercury in Snapping Turtles: A Concern for Human Consumption" tested Hg concentrations in New Jersey's harvested snapping turtles to estimate the risk of human consumption. This chapter is in preparation for submission to the journal *Ecotoxicology*. Chapter 4, "Mercury and Trophic Interactions In Snapping Turtle Food Webs" studies the transfer of Hg in aquatic food webs. This chapter is in preparation for submission to the journal *Freshwater Biology*. Chapter 5, "The Commercial Harvest of Snapping Turtles In New Jersey" presents the results of a mail-in survey to commercial harvesters to better understand harvesting practices, pressures, and to assess harvesters' willingness to collaborate with new regulations. This chapter is in preparation for submission to the journal *Northeastern Naturalist*. Chapter 6, "Assessing Recreational Harvest of Snapping Turtles In New Jersey" was an online survey open to all fishing license holders in order to gather information on the unrecorded recreational harvest, including the number of turtles caught, fate of the turtles caught (consumed, kept as pets, etc.), and willingness to pay a permit fee for this activity. This chapter has been submitted to the journal *Environmental Management* and is currently under review.

1.7 Literature Cited

Albers, P. H., Sileo, L., and Mulhern, B. M. (1986) Effects of environmental contaminants on snapping turtles of a tidal wetland. *Archives of Environmental Contamination and Toxicology*, 15(1), 39-49.

Alexander, M. M. (1943) Food habits of the snapping turtle in Connecticut. *The Journal of Wildlife Management*, 7(3), 278-282.

Aresco, M. J., Travis, J., and MacRae, P. S. (2015) Trophic interactions of turtles in a North Florida lake food web: prevalence of omnivory. *Copeia*, 103(2), 343-356.

Atwell, L., Hobson, K. A., and Welch, H. E. (1998) Biomagnification and bioaccumulation of mercury in an arctic marine food web: insights from stable nitrogen isotope analysis. *Canadian Journal of Fisheries and Aquatic Sciences*, 55(5), 1114-1121.

Avissar, N. G. (2006) Changes in population structure of diamondback terrapins (*Malaclemys terrapin terrapin*) in a previously surveyed creek in southern New Jersey. *Chelonian Conservation and Biology*, *5*(1), 154-159.

Bacon, J. P., Gray, J. A., and Kitson, L. (2006) Status and conservation of the reptiles and amphibians of the Bermuda islands. *Applied Herpetology*, 3(4), 323-344.

Beebee, T. J. C., and Griffiths, R. A. (2000) Amphibians and Reptiles. A Natural History of the British Herpetofauna. HarperCollins Publishers, London. 270 pp.

Bell, B., Spotila, J. R., and Congdon, J. (2006) High incidence of deformity in aquatic turtles in the John Heinz National Wildlife Refuge. *Environmental Pollution*, 142(3), 457-465.

Bezerra, M. F., Lacerda, L. D., Rezende, C. E., Franco, M. A. L., Almeida, M. G., Macêdo, G. R., Pires, T. T., Rostan, G., and Lopez, G. G. (2015) Food preferences and Hg distribution in *Chelonia mydas* assessed by stable isotopes. *Environmental Pollution*, 206, 236-246.

Bishop, C. A., Lean, D. R. S., Brooks, R. J., Carey, J. H., and Ng, P. (1995) Chlorinated hydrocarbons in early life stages of the common snapping turtle (*Chelydra serpentina serpentina*) from a coastal wetland on Lake Ontario, Canada. *Environmental Toxicology Chemistry*, 14, 421-426.

Bishop, C. A., Ng, P., Norstrom, R. J., Brooks, R. J., and Pettit, K. E. (1996) Temporal and geographic variation of organochlorine residues in the eggs of the common snapping turtle (*Chelydra serpentina serpentina*) (1981-1991) and comparisons to trends in the herring gull (*Larus argentatus*) in the Great Lakes Basin in Ontario, Canada. *Archives of Environmental Contamination and Toxicology*, 31, 512-524.

Bishop, C. A., Ng, P., Pettit, K. E., Kennedy, S. W., Stegeman, J. J., and Norstrom, R. J. (1998) Environmental contamination and developmental abnormalities in eggs and hatchlings of the common snapping turtle (*Chelydra serpentina serpentina*) from the Great Lakes-St Lawrence River basin (1989-91). *Environmental Pollution*, 101, 143-156.

Blanvillain, G., Schwenter, J. A., Day, R. D., Point, D., Christopher, S. J., Roumillat, W. A., and Owens, D. W. (2007) Diamondback terrapins, *Malaclemys terrapin*, as a sentinel species for monitoring mercury pollution of estuarine systems in South Carolina and Georgia, USA. *Environmental Toxicology and Chemistry*, 26(7), 1441-1450.

Bloom, N. S. (1992) On the chemical form of mercury in edible fish and marine invertebrate tissue. *Canadian Journal of Fisheries and Aquatic Sciences*, 49, 1010-1017.

Boening, D. W. (2000) Ecological effects, transport, and fate of mercury: a general review. *Chemosphere*, 40(12), 1335-1351.

Brasso, R. L., and Cristol, D. A. (2008) Effects of mercury exposure on the reproductive success of tree swallows (*Tachycineta bicolor*). *Ecotoxicology*, 17(2), 133-141.

Bridges, C. C., and Zalups, R. K. (2005) Molecular and ionic mimicry and the transport of toxic metals. *Toxicology and applied pharmacology*, 204(3), 274-308.

Brooks, R. J., Galbraith, D. A., Nancekivell, E. G., and Bishop, C. A. (1988) Developing Management Guidelines for Snapping Turtles. In: Szaro RC, Severson KE, Patton DR (eds.) Management of Amphibians, Reptiles, and Small Mammals in North America. Proceedings of the Symposium, July 19-21, 1988, Flagstaff, Arizona. USDA Forest Service General Technical Report RM-166, 174-179.

Brooks. R. J., Brown, G. P., and Galbraith, D. A. (1991) Effects of a sudden increase in the natural mortality of adults in a population of the Common Snapping Turtle (*Chelydra serpentina*). *Canadian Journal of Zoology*, 69, 1314-1320.

Bulter, J. A., Heinrich, G. L., and Seigel, R. A. (2006) Third workshop on the ecology, status, and conservation of diamondback terrapins (*Malaclemy terrapin*). Results and recommendations. *Chelonian Conservation and Biology*, 5(2), 331-334.

Burger, J. (1977) Determinants of hatching success in diamondback terrapin, *Malaclemys terrapin*. *American Midland Naturalist*, 444-464.

Burger, J., and Gochfeld, M. (2005) Heavy metals in commercial fish in New Jersey. *Environmental Research*, 99(3), 403-412.

Burgess, N. M., and Meyer, M. W. (2008) Methylmercury exposure associated with reduced productivity in common loons. *Ecotoxicology*, 17(2), 83-91.

Cabana, G., and Rasmussen, J. B. (1994) Modelling food chain structure and contaminant bioaccumulation using stable nitrogen isotopes. *Nature*, 372(6503), 255-257.

Campbell, L. M., Hecky, R. E., and Wandera, S. B. (2003) Stable isotope analyses of food web structure and fish diet in Napoleon and Winam Gulfs, Lake Victoria, East Africa. *Journal of Great Lakes Research*, 29, 243-257.

Ceballos, C. P. and Fitzgerald, L. A. (2004) The trade in native and exotic turtles in Texas. *Wildlife Society Bulletin*, 32(3), 881-891.

Centers for Disease Control and Prevention (2001) Blood and Hair Mercury Levels in Young Children and Women of Childbearing Age - United States, 1999. Source: https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5008a2.htm.

Chasar, L. C., Scudder, B. C., Stewart, A. R., Bell, A. H., and Aiken, G. R. (2009) Mercury cycling in stream ecosystems. 3. Trophic dynamics and methylmercury bioaccumulation. *Environmental Science and Technology*, 43(8), 2733-2739.

Chen, C. Y., Stemberger, R. S., Kamman, N. C., Mayes, B., and Folt, C. (2005) Patterns of mercury bioaccumulation and transfer in aquatic food webs across multi-lake studies in the northeast U.S. *Ecotoxicology*, 14, 135-147.

Chumchal, M. M. and Hambright, K. D. (2009) Ecological factors regulating mercury contamination of fish from Caddo Lake, Texas, USA. *Environmental Toxicology and Chemistry*, 28:962–972.

Chumchal, M. M., Rainwater, T. R., Osborn, S. C., Roberts, A. P., Abel, M. T., Cobb, G. P., Smith, P. N., and Bailey, F. C. (2011) Mercury speciation and biomagnification in the food web of Caddo Lake, Texas and Louisiana, USA, a subtropical freshwater ecosystem. *Environmental Toxicology and Chemistry*, 30(5), 1153-1162.

Clarkson, T. W. (1992) Mercury: Major issues in Environmental Health. *Environmental Health Perspective*, 100, 31-38.

Colborne, S. F., and Robinson, B. W. (2013) Effect of nutritional condition on variation in δ13C and δ15N stable isotope values in Pumpkinseed sunfish (*Lepomis gibbosus*) fed different diets. *Environmental Biology of Fishes*, 96(4), 543-554.

Conant, R. (1955) Correspondence. *British Journal of Herpetology*, 1(12), 252-253.

Conant, R. (1964) Turtle Soup. *America's First Zoo*, 16, 28-30.

Congdon, J. D., and Gibbons, J. W. (1990) Turtle eggs: Their ecology and evolution. In J. W. Gibbons (ed.), Life history and ecology of the slider turtle, 109-123. Smithsonian Institution Press, Washington, D.C.

Congdon, J. D., Dunham, A. E., and Van Loben Sels, R. C. (1994) Demographics of Common Snapping Turtles (*Chelydra serpentina*): Implications for conservation and management of long-lived organisms. *American Zoologist*, 34, 397-408.

Convention On International Trade In Endangered Species Of Wild Fauna And Flora (2011) Criteria for the inclusion of species in appendices I and II. Source: https://www.cites.org/eng/com/ac/25/E25-10.pdf.

Convention On International Trade In Endangered Species Of Wild Fauna And Flora (2013) Consideration of proposals for amendment of appendices I and II. Source: https://www.fws.gov/International/cites/cop16/cop16-proposal-appendix-ii-listing-of-diamondback-terrapin.pdf.

Convention On International Trade In Endangered Species Of Wild Fauna And Flora (2015) Trade Database. Source: https://trade.cites.org/en/cites_trade/#.

Cremona, F., Planas, D., and Lucotte, M. (2008) Assessing the importance of macroinvertebrate trophic dead ends in the lower transfer of methylmercury in littoral food webs. *Canadian Journal of Fisheries and Aquatic Sciences*, 65, 2043-2052.

Dalerum, F., and Angerbjörn, A. (2005) Resolving temporal variation in vertebrate diets using naturally occurring stable isotopes. *Oecologia*, 144(4), 647-658.

Davenport, J., Glasspool, A. F., and Kitson, L. (2005) Occurrence of diamondback terrapins, *Malaclemys terrapin*, on Bermuda: Native or introduced? *Chelonian Conservation and Biology*, 4(4), 956-959.

Davidson, P. W., Myers, G. J., Cox, C., Axtell, C., Shamlaye, C., Sloane-Reeves, J., Cernichiari, E., Needham, L., Choi, A., Wang, Y., Berlin, M., and Clarkson, T. (1998) Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment: outcomes at 66 months of age in the Seychelles Child Development Study. *JAMA*, 280(8), 701-707.

Day, R. D., Segars, A. L., Arendt, M. D., Lee, A. M., and Peden-Adams, M. M. (2007) Relationship of blood mercury levels to health parameters in the loggerhead sea turtle (*Caretta caretta*). *Environmental Health Perspectives*, 1421-1428.

DeNiro, M. J., and Epstein, S. (1978) Influence of diet on the distribution of carbon isotopes in animals. *Geochimica et cosmochimica acta*, 42(5), 495-506.

De Solla, S. R., Bishop, C. A., Lickers, H., and Jock, K. (2001) Organochlorine pesticides, PCBs, dibenzodioxin, and furan concentrations in common snapping turtle eggs (*Chelydra serpentina serpentina*) in Akwesasne, Mohawk Territory, Ontario, Canada. *Archives of Environmental Contamination and Toxicology*, 40, 410–417.

Dixon, J. R. (2000) Amphibians and reptiles of Texas. Second edition. Texas A and M University Press, College Station, USA.

Dorcas, M. E., Willson, J. D., and Gibbons, J. W. (2007) Crab trapping causes population decline and demographic changes in diamondback terrapins over two decades. *Biological Conservation*, 137(3), 334-340.

Draud, M., Bossert, M., and Zimnavoda, S. (2004) Predation on hatchling and juvenile diamondback terrapins (*Malaclemys terrapin*) by the Norway rat (*Rattus norvegicus*). *Journal of Herpetology*, 38(3), 467-470.

Environmental Protection Agency (2000) Source:https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=20873andCFID=83852278andCFTOKEN=37076866.

Environmental Protection Agency (2001) Methylmercury (CASRN 22967-92-6) Source:https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0073.htm.

Environmental Protection Agency (2007) Contaminants in Snapping Turtle Eggs. Source:https://archive.epa.gov/solec/web/pdf/4506_contaminants_snappingturtleeggs.pdf

Environmental Protection Agency (2010) National Recommended Water Quality Criteria. Source: https://www.epa.gov/wqc/national-recommended-water-quality-criteria.

Environmental Protection Agency (2012) New Jersey Quality Assessment Report. Source:https://iaspub.epa.gov/waters10/attains_index.control?p_area=NJ#causes.
Environmental Protection Agency (2013) Fish Tissue Analysis for Mercury and PCBs from New York City Commercial Fish/Seafood Market. Report: EPA/600/R-11/066F.

Ernst, C. H., and Barbour, R. W. (1972) Turtles of the United States. *University Press of Kentucky, Lex-ington*.

Ernst, C. H., Lovich, J. E., and Barbour, R. W. (1994) Turtles of the United States and Canada. Smithsonian Institution Press, Washington and London. 578.

Ernst, C. H., and Lovich, J. E. (2009) Turtles of the United States and Canada. JHU Press.

Evers, D. C., Wiener, J. G., Basu, N., Bodaly, R. A., Morrison, H. A., and Williams, K. A. (2011) Mercury in the Great Lakes region: bioaccumulation, spatiotemporal patterns, ecological risks, and policy. *Ecotoxicology*, 20(7), 1487-1499.

Federal Drug and Food Administration (2013) Volume IV. Lab Manual 6.1 Introduction. Source:https://www.fda.gov/scienceresearch/fieldscience/laboratorymanual/ucm172150.htm#6_1_3.

Feinberg, J. A., and Burke, R. L. (2003) Nesting ecology and predation of diamondback terrapins, *Malaclemys terrapin*, at Gateway National Recreation Area, New York. *Journal of Herpetology*, 37(3), 517-526.

Fitzgerald, W. F. (1995) Is mercury increasing in the atmosphere? The need for an atmospheric mercury network (AMNET). *Water Air Soil Pollution*, 80, 245–254.

Fitzsimmons, N. N., and Greene, J. L. (2001) Demographic and Ecological Factors Affecting Conservation and Management of the Diamondback Terrapin (*Malaclemys terrapin*) in South Carolina. *Chelonian Conservation and Biology*, 4(1).

Florida Fish and Wildlife Conservation Commission (2012) Three Turtle Farmers Charged and Two Arrested For Illegal Turtle Trafficking. Souce:https://www.justice.gov/archive/usao/fls/PressReleases/2012/120503-02.html.

Florida Fish and Wildlife Conservation Commission (2012) Freshwater Turtles. Source:http://myfwc.com/wildlifehabitats/managed/freshwater-turtles/.

Galbraith, D. A., Bishop, C. A., Brooks, R. J., Simser, W. L., and Lampman, K. P. (1988) Factors affecting the density of populations of common snapping turtles (*Chelydra serpentina serpentina*). *Canadian Journal of Zoology*, 66, 1233-1240.

Galbraith, D. A., Brooks, R. J., and Obbard, M. E. (1989) The influence of growth rate on age and body size at maturity in female snapping turtles (*Chelydra serpentina*). *Copeia*, 1989, 896-904.

Galbraith, D. A., White, B. N., Brooks, R. J., and Boad, P. T. (1993) Multiple paternity in clutches of snapping turtles (*Chelydra serpentina*) detected using DNA fingerprints. *Canadian Journal of Zoology*, 71, 318-324.

Gibbons, J. W., Scott, D. E., Ryan, T. J., Buhlmann, K. A., Tuberville, T. D., Metts, B. S., Greene, J. L., Mills, T., Leiden, Y., Poppy, S., and Winne, C. T. (2000) The global decline of reptiles, Déjà Vu amphibians. *Bioscience*, 50, 653–666.

Gibbs, J. P., and Amato, G. D. (2000) Genetics and demography in turtle conservation. In: Klemens, M.W. (Ed.), Turtle Conservation. Smithsonian Institution Press, Washington, pp. 207–217.

Gochfeld, M. (2003) Cases of mercury exposure bioavailability and absorption. *Ecotoxicology and Environmental Safety*, 56, 174-179.

Godley, B. J., Thompson, D. R., Waldron, S., and Furness, R. W. (1998) The trophic status of marine turtles as determined by stable isotope analysis. *Marine Ecology Progress Series*, 166, 277-284.

Godley, B. J., Thompson, D. R., and Furness, R. W. (1999) Do heavy metal concentrations pose a threat to marine turtles from the Mediterranean Sea? *Marine Pollution Bulletin*, 38(6), 497-502.

Golet, W. A., and Haines, T. A. (2000) Snapping turtles (*Chelydra serpentina*) as monitors for mercury contamination of aquatic environments. *Environmental Monitoring and Assessment*, 71(3), 211–220.

Grandjean, P., Weihe, P., White, R. F., Debes, F., Araki, S., Yokoyama, K., Murata, K., Sorensen, N., Dahl, R., and Jørgensen, P. J. (1997) Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. *Neurotoxicology and Teratology*, 19(6), 417-428.

Graves, B. M., and Anderson, S. H. (1987) Habitat suitability index models: snapping turtle. *U.S. Fish Wildlife Service Biology*, 82, 141.

Harris, J. R., Neil, K. P., Behravesh, C. B., Sotir, M. J., and Angulo, F. J. (2010) Recent Multistate Outbreak of Human Salmonella Infections Acquired from Turtles: A Continuing Public Health Challenge. *Clinical Infectious Disease*, 50, 554-559.

Haxton, T. (2000) Road mortality of snapping turtles, *Chelydra serpentine*, in central Ontario during their nesting period. *Canadian Field- Naturalist*, 114, 106-110.

Helwig, D., and Hora, M. (1983) Polychlorinated biphenyl, mercury, and cadmium concentrations in Minnesota snapping turtles. *Bulletin of Environmental Contamination and Toxicology*, 30, 186-190.

Hogan, L. S., Marschall, E., Folt, C., and Stein, R. A. (2007) How non-native species in Lake Erie influence trophic transfer of mercury and lead to top predators. *Journal of Great Lakes Research*, 33(1), 46-61.

Hopkins, W. A., Bodinof, C., Budischak, S., and Perkins, C. (2013) Nondestructive indices of mercury exposure in three species of turtles occupying different trophic niches downstream from a former chloralkali facility. *Ecotoxicology*, 22(1), 22-32.

Hudson River Natural Resource Trustees (2005) Data report for screening for organochlorine and metal contaminant levels in Hudson River, New York Bullfrogs (*Rana catesbeiana*) and snapping turtle (*Chelydra serpentina serpentina*). Hudson River Natural Resource Damage Assessment. U.S. Department of Commerce. Silver Spring, MD.

International Union for Conservation of Nature (2012) Snapping turtle distribution. Source: http://maps.iucnredlist.org/map.html?id=163424.

Iverson, J. B. (1991) Patterns of survivorship in turtles (order Testudines). *Canadian Journal of Zoology*, 69(2), 385-391.

Jacobson, J. L., Muckle, G., Ayotte, P., Dewailly, É., and Jacobson, S. W. (2015) Relation of prenatal methylmercury exposure from environmental sources to childhood IQ. *Environmental Health Perspectives,* 123(8), 827.

Kainz, M., Telmer, K., and Mazumder, A. (2006) Bioaccumulation patterns of methyl mercury and essential fatty acids in lacustrine planktonic food webs and fish. *Science of the Total Environment,* 368, 271–282.

Kelly, C. A., Rudd, J. W., St Vincent, L. L., and Heyes, A. (1995) Is total mercury concentration a good predictor of methyl mercury concentration in aquatic systems? In *Mercury as a Global Pollutant* (pp. 715-724). Springer Netherlands.

Khan, M. A., and Wang, F. (2009) Mercury-selenium compounds and their toxicological significance: toward a molecular understanding of the mercury-selenium antagonism. *Environmental Toxicology and Chemistry*, 28(8), 1567-77.

Kjellström, T., Kennedy, P., Wallis, S., Stewart, A., Friberg, L., Lind, B., Wutherspoon, T., and Mantell, C. (1989) Physical and mental development of children with prenatal exposure to mercury from fish. Stage 2. Interviews and psychological tests at age 6.

Klemens, M.W., and Thorbjarnarson, J. B. (1995) Reptiles as a food resource. *Biodiversity and Conservation*, 4, 281-298.

Krishnakumar, K., Raghavan, R., and Pereira, B. (2009) Protected on paper, hunted in wetlands: exploitation and trade of freshwater turtles (*Melanochelys trijuga coronata and Lissemys punctata punctata*) in Punnamada, Kerala, India. *Tropical Conservation Science*, *2*(3), 363-373.

Lara, N. R. F., Marques, T. S., Montelo, K. M., de Ataídes, Á. G., Verdade, L. M., Malvásio, A., and de Camargo, P. B. (2012) A trophic study of the sympatric Amazonian freshwater turtles *Podocnemis unifilis* and *Podocnemis expansa* (Testudines, Podocnemidae) using carbon and nitrogen stable isotope analyses. *Canadian Journal of Zoology*, 90(12), 1394-1401.

Lovich, J. E., and Gibbons, J. W. (1990) Age at maturity influences adult sex ratio in the turtle *Malaclemys terrapin*. *Oikos*, 126-134.

Mahaffey, K. R., Clickner, R. P., and Jeffries, R. A. (2009) Adult women's blood mercury concentrations vary regionally in the United States: association with patterns of fish consumption (NHANES 1999-2004). *Environmental health perspectives*, 117(1), 47.

Mali, I., Vandewege, M. W., Davis, S. K., and Forstner, M. R. (2014) Magnitude of the freshwater turtle exports from the US: long term trends and early effects of newly implemented harvest management regimes. *PloS one*, 9(1).

Mason, R. P., and Gill, G. A. (2005) Mercury in the marine environment. *Mercury: Sources, Measurements, Cycles and Effects*, 34.

McGeer, J., Henningsen, G., Lanno, R., Fisher, N., Sappington, K., and Drexler, J. (2004) Issue Paper On The Bioavailability And Bioaccumulation Of Metals. Source: https://www.epa.gov/sites/production/files/2014-11/documents/bio_final.pdf

Megler, D., Anderson, A. A., Chan, L. H. M., Mahaffey, .R., Murray, M., Sakamoto, M., and Stern, A. H. (2007) Methylmercury Exposure and Health Effects in Humans: A Worldwide Concern. *Royal Swedish Academy of Science*, 36, 1, 1-12.

Miller, J. (2009) Eight States Petitioned to End Unsustainable Turtle Harvest;
Turtles Contaminated With Mercury and Other Toxins Sold as Food. *Center for Biological Diversity*, 510, 499-9185.
Source:http://www.biologicaldiversity.org/news/press_releases/2009/freshwater-turtles-03-11-2009.html.

Minagawa, M., and Wada, E. (1984) Stepwise enrichment of 15 N along food chains: further evidence and the relation between δ 15 N and animal age. *Geochimica et cosmochimica acta*, 48(5), 1135-1140.

Montevecchi, W. A., and Burger, J. (1975) Aspects of the reproductive biology of the northern diamondback terrapin, *Malaclemys terrapin terrapin*. *American Midland Naturalist*, 166-178.

Morel, François M. M., Kraepiel Anne M. L., and Amyot, M. (1998) The Chemical Cycle and Bioaccumulation of Mercury. *Annual Review of Ecology and Systematics*, 29, 543-566.

Myers, G. J., Davidson, P. W., Cox, C., Shamlaye, C., Cernichiari, E., and Clarkson, T. W. (2000) Twenty-seven years studying the human neurotoxicity of methylmercury exposure. *Environmental Research*, 83(3), 275-285.

New Jersey Department of Environmental Protection (2002) Volume II Exposure and Impacts and Volume III Sources of Mercury to New Jersey's Environment. Source:http://www.nj.gov/dep/dsr/mercury_task_force.htm.

New Jersey Department of Environmental Protection (2016) Administrative Order No. 2016-02. Source:http://www.nj.gov/dep/docs/ao2016-02.pdf.

New Jersey Fish and Wildlife Digest (2011) A summary of rules and management information. New Jersey Department of Environmental Protection, Division of Fish, Game and Wildlife.

New Jersey Fish and Wildlife Digest (2011) Licenses information and regulations http://www.state.nj.us/dep/fgw/pdf/2011/digfsh11-regs.pdf.

New Jersey Fish and Wildlife Digest (2016) Licenses information and regulations http://www.eregulations.com/wp-content/uploads/2016/12/17NJFW-LR.pdf.

North Carolina State University (2016) Solubility Product Constants. Source: http://www4.ncsu.edu/~franzen/public_html/CH201/data/Solubility_Product_Constants.pdf.

Patrick Center for Environmental Research (2000) Assessment Of PCBs, Selected Organic Pesticides And Mercury In Fishes From New Jersey: 1998-1999 Monitoring Program. Source:http://www.nj.gov/dep/passaicdocs/docs/DSRTStudies/NJDEP00015443.pdf.

Pearson, S. H., Avery, H. W., Kilham, S. S., Velinsky, D. J., and Spotila, J. R. (2013) Stable isotopes of C and N reveal habitat dependent dietary overlap between native and introduced turtles *Pseudemys rubriventris* and *Trachemys scripta*. *PloS one*, 8(5).

Peterson, B. J., and Fry, B. (1987) Stable isotopes in ecosystem studies. *Annual review of ecology and systematics*, 18(1), 293-320.

Phillips, C. A., Dimmick, W. W. and Carr, J. L. (1996) Conservation Genetics of the Common Snapping Turtle (*Chelydra serpentina*). *Conservation Biology*, 10, 397-405.

Pirrone, N., and Mason, R. (2009) Mercury fate and transport in the global atmosphere. *Dordrecht, The Netherlands: Springer*, 10, 978-0.

Rice, D. C. (2004) The US EPA reference dose for methylmercury: sources of uncertainty. *Environmental Research*, 95(3), 406-413.

Rognerud, S., Grimalt, J. O., Rosseland, B. O., Fernandez, P., Hofer, R., Lackner, R., Lauritzen, B., Lien, L., Massabuau, J. C. and Ribes, A. (2002) Mercury and organochlorine contamination in brown trout (*Salmo trutta*) and arctic char (*Salvelinus alpinus*) from high mountain lakes in Europe and the Svalbard archipelago. *Water, Air and Soil Pollution: Focus*, 2(2), 209-232.

Roman, J., and Bowen, B. W. (2000) The mock turtle syndrome: genetic identification of turtle meat purchased in the south-eastern United State of America. *The Zoological Society of London*, 3, 61-65.

Schaffer, C., Wood, R.C., Norton, T.M., and Schaffer, R. (2008) Terrapins in the stew. *Iguana*, 15, 78-85.

Schneider, L., Ferrara, C. R., Vogt, R. C., and Burger, J. (2011) History of turtle exploitation and management techniques to conserve turtles in the Rio Negro Basin of the Brazilian Amazon. *Chelonian Conservation and Biology*, 10(1), 149-157.

Seigel, R. A. (1984) Parameters of two populations of diamondback terrapins (Malaclemys terrapin) on the Atlantic coast of Florida. *Vertebrate ecology and systematics: a tribute to Henry S. Fitch. Museum of Natural History of the University of Kansas special publication*, (10), 77-87.

Seminoff, J. A., Bjorndal, K. A., and Bolten, A. B. (2007) Stable carbon and nitrogen isotope discrimination and turnover in pond sliders *Trachemys scripta*: insights for trophic study of freshwater turtles. *Copeia*, (3), 534-542.

Senneke, D. (2005) Declared Turtle Trade From the United States. The World Chelonian Trust. Source: http://www.chelonia.org/articles/us/USmarket_8.htm.

Stern, A.H., Gochfeld, M. C. Weisel, and Burger, J. (2001) Mercury and methylmercury exposure in the New Jersey pregnant population. *Archives of Environmental Health: An International Journal*, 56(1), 4–10.

Stone, W. B., Kiviat, E., and Butkas, S. A. (1980) Toxicants in snapping turtles. *New York Fish and Game Journal*, 27, 39-50.

Sung, Y. H., Karraker, N. E., and Hau, B. C. (2013) Demographic evidence of illegal harvesting of an endangered Asian turtle. *Conservation Biology*, 27(6), 1421-1428.

Szerlag, S., and McRobert, S. P. (2006) Road occurrence and mortality of the northern diamondback terrapin. *Applied Herpetology*, 3(1), 27-37.

Tadiso, T. M., Borgstrøm, R., and Rosseland, B. O. (2011) Mercury concentrations are low in commercial fish species of Lake Ziway, Ethiopia, but stable isotope data indicated biomagnification. *Ecotoxicology and Environmental Safety*, 74(4), 953-959.

Tieszen, L. L., Boutton, T. W., Tesdahl, K. G., and Slade, N. A. (1983) Fractionation and turnover of stable carbon isotopes in animal tissues: implications for δ13C analysis of diet. *Oecologia*, 57(1-2), 32-37.

Trasande, L., Landrigan, P. J., and Schechter, C. (2005) Public health and economic consequences of methyl mercury toxicity to the developing brain. *Environmental Health Perspectives*, 590-596.

Trudel, M., and Rasmussen, J. B. (2006) Bioenergetics and mercury dynamics in fish: a modeling perspective. *Canadian Journal of Fisheries and Aquatic Sciences*, 63, 1890-1902.

Turnquist, M. A., Driscoll, C. T., Schulz, K. L., Schlaepfer, M. A. (2011) Mercury concentrations in snapping turtles (*Chelydra serpentina*) correlate with environmental and landscape characteristics. *Ecotoxicology*, 20(7), 1599-608.

Turtle Conservation Coalition (2011) Rhodin, A. G. J., Walde, A. D., Horne, B. D., van Dijk, P. P., Blanck, T., and Hudson, R. (Eds.)]. Turtles in Trouble: The World's 25+ Most Endangered Tortoises and Freshwater Turtles—2011. Lunenburg, MA: IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, Turtle Conservation Fund, Turtle

Turtle Conservation Fund (2002) A Global Action Plan for Conservation of Tortoises and Freshwater Turtles. Strategy and Funding Prospectus 2002–2007. Washington, DC: Conservation International and Chelonian Research Foundation, 30 pp.

United Nations Environment Programme (2013) Global Mercury Assessment, Sources, Emissions, Releases and Environmental Transport. Source:http://www.unep.org/chemicalsandwaste/Mercury/Informationmaterials/ReportsandPublications/tabid/3593/Default.aspx.

United States Fish and Wildlife Service (2013) Source:https://www.fws.gov/international/cites/cop16/diamondback-terrapin.html.

van Dijk, P. P., Stuart, B. L., and Rhodin, A. (2000) Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia. Lunenburg, Massachusetts, USA: *Chelonian Research Foundation.*

van Dijk, P. P. (2011). Malaclemys terrapin. IUCN 2011 Assessment. IUCN Red List of Threatened Species.

van Dijk, P. P. (2012) Chelydra serpentina. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>.

Ward, D. M., Nislow, K. H., and Folt, C. L. (2010) Bioaccumulation syndrome: identifying factors that make some stream food webs prone to elevated mercury bioaccumulation. *NY Academy of Science,* 1195, 62-83.

Watras, C. J., Back, R. C., Halvorsen, S., Hudson, R. J., Morrison, K. A., and Wente, S. P. (1998) Bioaccumulation of mercury in pelagic freshwater food webs. *The Science of the total environment*, 219, 183-208.

Watters, C. F. (2004) A Review of the range-wide regulations pertaining to diamondback terrapins (Malaclemys terrapin). *Wetlands Institute, Stone Harbor, NJ*, 1-12.

Wiener, J. G., Krabbenhoft, D. P., Heinz, G. H., and Scheuhammer, A. M. (2003) Ecotoxicology of mercury. Pages 409–463 in D. J. Hoffman, B. A. Rattner, G. A. Burton, Jr., and J. Cairns, Jr., editors. Handbook of ecotoxicology, 2nd edition. Lewis Publishers, Boca Raton, Florida.

Wood, R. C., and Herlands, R. (1997) Turtles and tires: the impact of roadkills on northern Diamondback Terrapin, *Malaclemys terrapin terrapin*, populations on the Cape May Peninsula, southern New Jersey, USA. In Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles-An International Conference. New York: New York Turtle and Tortoise Society, 1, 46-53.

Zhang, L., Campbell, L. M., and Johnson, T. B. (2012) Seasonal variation in mercury and food web biomagnification in Lake Ontario, Canada. *Environmental Pollution*, 161, 178-184.

Chapter 2. Human Health Implications of Mercury Concentrations in Diamondback Terrapins

2.1 Abstract

Mercury contamination in consumed foods poses a significant threat to human health globally. The consumption of mercury contaminated turtle meat is of special concern due to mercury's capability to bioaccumulate and biomagnify in organisms. Turtles are long-lived predators, allowing for a high degree of bioaccumulation and biomagnification of contaminants. In the U.S., diamondback terrapins (*Malaclemys terrapin*) are legally harvested in several states throughout their range. Harvested turtles are usually sold to both local and global markets mainly for human consumption, which results in a human consumption threat. The objective of this study was to analyze mercury concentrations to determine if the consumption of terrapins poses a threat to human health. Diamondback terrapins were collected from two study sites: Cape May and Hackensack Meadowlands, New Jersey, US. Turtle carapace, blood, and muscle samples were analyzed for total mercury concentrations. Results showed no significant difference between females' and males' mercury concentrations, although the highest mercury concentrations were in females. Similarly, results showed no significant difference when comparing terrapin mercury concentrations between the two study sites. Results also showed that 50% of Cape May muscle samples and 72.7% Meadowlands muscles samples surpassed the sensitive threshold. Furthermore, 27.3% of Cape May muscle samples and 45.5% of Meadowlands muscles samples surpassed the U.S.

Environmental Protection Agency's mercury threshold of 0.3 ppm for seafood consumption for the general public. Overall, the harvest of terrapins could pose a threat to consumers, and terrapins should be monitored closely or possibly banned for human consumption, especially in areas with known contamination history.

2.2 Introduction

Contaminants in aquatic food webs pose a significant threat to aquatic ecosystems and human health. Humans risk ingesting high levels of mercury through the consumption of contaminated food, especially through the consumption of fish and turtles. Mercury is a heavy metal, toxic to most forms of life (Boening, 2000; Brasso and Cristol, 2008; Burgess and Meyer, 2008; Day et al., 2007; Godley et al., 1999; Hopkins et al., 2013; Jacobson et al., 2015; Marcillera et al., 2016). Mercury in the environment has anthropogenic and natural sources. As mercury is released into the atmosphere it can be transported across the globe, with the longest residence time reported to be up to one year (UNEP, 2013). Depending on the form of mercury being released and its solubility, mercury can be deposited close to its source or transported much further, making it difficult to determine its origin.

Once mercury reaches aquatic environments and is incorporated into the sediment it reacts with sulfate to form insoluble mercuric sulfide, which is then methylated by anaerobic methanogenic- or sulfate-dependent bacteria, producing methylmercury (MeHg) (Gochfeld, 2003). Unlike other forms of mercury, MeHg is highly associated with diatoms, which allows the assimilation, retention, bioaccumulation and biomagnification of mercury in algae and the organisms that consume it (Morel et al., 1998). MeHg is the form of mercury most readily available and persistent in organisms. It has been estimated that 90 to 95% of mercury in fish and turtles is methylated (Bloom, 1992; Turnquist et al., 2011).

2.2.1 Human Health Risk

MeHg is attracted to fatty and soft tissues; therefore, MeHg is retained for longer amounts of time, allowing the bioaccumulation of the toxicant (Boening, 2000). As a neurotoxin, MeHg is also a greater threat because of its ability to pass the blood-brain barrier, allowing it to participate in cellular and nuclear processes, making mercury a serious threat to humans, especially pregnant women and young children (Boening, 2000). The Centers for Disease Control and Prevention (CDC) reported in 2004 that 6% of U.S. women have mercury levels that could adversely affect the healthy development of a fetus (CDC, 2004). In New Jersey, it is estimated that 10% of women of childbearing age have elevated blood mercury levels with the potential of affecting fetus development (Stern et al., 2001).

Mercury has been a major focus for human consumption advisories and guidelines recommended by government agencies. Two government agencies have provided mercury thresholds to the public, the U.S. Environmental Protection Agency (EPA) and the U.S. Food and Drug Administration (FDA). The EPA regulates mercury based on the health of the ecosystem at a threshold of 0.3 ppm. The FDA regulates market products for human consumption and established a mercury threshold of 1 ppm.

State agencies can also implement thresholds; in New Jersey the New Jersey Department of Environmental Protection (NJDEP) has a sensitive population threshold of 0.18 ppm. In the U.S., over 35% of freshwaters have consumption advisories due to elevated mercury concentrations (Ward et al., 2010). A 2012 EPA report stated 54% of all assessed river and stream miles in New Jersey are impaired due to elevated mercury concentrations as well as about 87% of lakes, reservoirs, and ponds (EPA, 2012). The EPA's mercury analysis research of New York cities' seafood markets sampled 33 seafood species and resulted in mean concentrations ranging from 0.005 to 0.42 ppm, with the lowest concentrations observed in shrimp and highest mercury concentrations found in tuna (EPA, 2013). New Jersey self-caught fish of similar species had higher concentrations, ranging from 0.01 to 0.65 ppm (Burger and Gochfeld, 2005). Similar to the EPA's results, Burger and Gochfeld (2005) also found shrimp to have the lowest mean mercury concentrations while tuna had the highest concentrations. These results cause concerns for mercury contamination in aquatic ecosystems.

2.2.2 Harvesting of Diamondback Terrapin

The diamondback terrapin, *Malaclemys terrapin*, is a medium-size turtle often found in estuaries and salt marshes, making it the only brackish water turtle in the U.S. Diamondback terrapins are found from Cape Cod to Florida and westward to Texas. Adults' carapace measures from 10 to 23 cm, with females being larger than males (Ernst et al., 1994). Diamondback terrapins are omnivorous, eating gastropods, crabs, bivalves, carrion fish, and plant matter (Ernst et al., 1994). Over the last two decades there has been a growing concern over the decline of many turtle species, driven by human consumption demands (Klemens and Thourbjanarson, 1995).

Diamondback terrapins were once considered a delicacy and were heavily harvested for several decades throughout much of its range (Schaffer et al., 2008). By the early 1900s, diamondback terrapin was harvested nearly to the point of extinction, but harvesting lost momentum during the Great Depression (Conant, 1955; 1964). Since then, populations seemed to be recovering, but unfortunately human consumption of turtles has once again gained in popularity. Residents of Southeast Asian countries comprise a high proportion of the demand for turtle meat available through legal trade (Compton, 2000). The increasing demand for turtle meat has resulted in an increased turtle harvest in the United States, which includes diamondback terrapins. According to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) records, 14,220 diamondback terrapins were exported from the U.S. in 2014, with 14 exported to Japan, 40 exported to Thailand, 126 exported to China, 210 exported to Taiwan, and 13,956 exported to Hong Kong (CITES, 2015). Today, this species is considered at low risk/near threatened by the International Union for Conservation of Nature’s Red List, and their export is monitored by CITES as a category 2 species (Tortoise and Freshwater Turtle Specialist Group, 1996). Despite this, the species is still recuperating from its close encounter with extinction, and their harvest is allowed in some states throughout its range (Butler et al., 2006). In New Jersey, a moratorium was placed on the terrapin harvest in March of 2015 after a noticeable increase in the demand for diamondback terrapins over the last several years (NJDEP, 2016). In June 2016, New Jersey passed a bill that called for the complete and immediate close of the diamondback terrapin harvest.

Due to turtles' long life span, sedentary life style, and place on the food web, the diamondback terrapin and other turtles have been used as a bioindicator species in aquatic habitats (Meyer and Walton, 1994; Blanvillain et al., 2007; Turnquist et al., 2011). A prior study conducted in New Jersey found diamondback terrapins from Cape May have higher heavy metal concentrations than Hackensack Meadowland terrapins (McIntyre, 2000), which was unexpected since the Hackensack Meadowlands is historically a heavily industrialized area and has several Superfund sites. With the increase in demand for human consumption and given their life characteristics, it is important to continuously monitor mercury concentration in diamondback terrapins in New Jersey. The objectives of this study are to determine (1) if terrapins from a known contaminated area have higher mercury concentrations than a relatively more pristine area, (2) if there are relationships between mercury concentration and size and sex, and (3) if terrapins are safe for human consumption.

2.3 Methods

2.3.1 Study Site

The Hackensack Meadowlands (HM) is located in northern New Jersey in the NY/NJ Harbor Estuary, surrounded by a highly developed area with a long industrial history (Figure 2.1). The HM consists of various wetland habitats including tidal, brackish, freshwater, and forested wetlands, including the preferred habitats for diamondback terrapins (Tsipoura et al., 2008). However, the industrial history has resulted in several Superfund sites being designated, including one that is highly contaminated with mercury.

The second study site is located in Stone Harbor in Cape May (CM) County along the southern coast of New Jersey. Stone Harbor is composed of 30 acres of salt marsh. Unlike the Hackensack Meadowlands, this study site was spared from industrial pollution. The main source of pollution in these waters was the release of untreated sewage, which took place until the mid-1980s (Wood and Herlands, 1997).

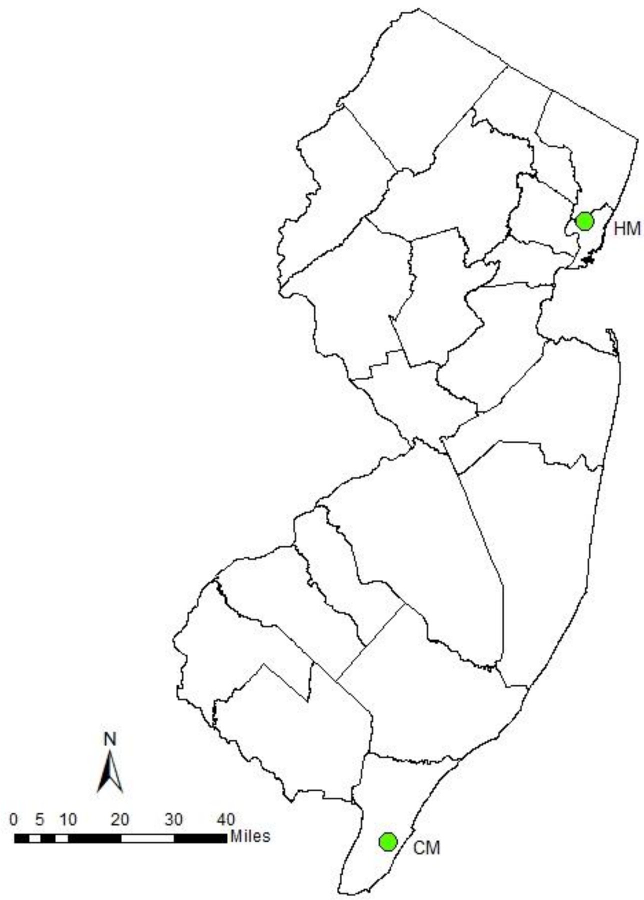

Figure 2.1 Location of diamondback terrapin study sites. The site in northern New Jersey is the Hackensack Meadowlands (HM) and the southern site is the Cape May (CM) located in Stone Harbor, New Jersey.

2.3.2 Sample Collection

Diamondback terrapins were collected by staff of the Meadowlands Environmental Research Institute in the HM, and by the Wetlands Institute in the CM. Terrapins collected from CM were mainly female casualties of vehicle collisions while HM terrapins were mainly males that had drowned in traps. Terrapin carcasses were kept in a -20°C freezer until analysis. The carapace lengths were measured using a dial caliper (Pittsburgh, 47257). Carapace, blood, and muscle samples were collected for each individual turtle when possible. A carapace shaving was taken using a sterile blade. Blood samples were taken from a tail vein, when possible, using a sterile 21 gauge syringe. A 0.25 g muscle tissue sample was collected from the rear leg using a sterile blade and curved scissors. All samples were stored in sterile 2 ml centrifuge tubes and kept in ice until they were transferred to the lab freezer.

2.3.3 Lab Analysis

Samples were transferred to acid-washed test tubes and weighed. The sample size was restricted to approximately 0.25 g wet weight. Carapace, blood and muscle mercury concentrations are reported as wet weight. One mL of a sulfuric acid and nitric acid mixture (in a 4:1 ratio) was added to every sample, then placed in a 58°C water bath until all tissues were dissolved. Samples were then transferred to an ice bath to cool, and 3 mL of 5% potassium permanganate was added to every sample while kept in an ice water bath to slow the rate of reaction. After the reaction ceased, samples were removed from the ice bath and the reaction was allowed to continue overnight at ambient temperature. Five mL of 3% hydroxylamine-hydrochloride were added to every sample as a reducing agent. One mL of stannous chloride (10%) was added to the sample and immediately analyzed by cold vapor atomic absorption spectrophotometry using a MAS-50D mercury analyzer by Bacharach, Inc. For quality assurance purposes, each sample batch included reagent blanks and certified reference material for mercury analysis (NRC-Canada

DOLT-2). Certified reference material recovery within 10% of the certified value was used as the batch validation criterion. Analytical blanks were also included in each sample batch to monitor contamination during digestion and sample preparation. A calibration equation was developed using 0, 0.03, 0.1 and 0.3 ppm Hg standards to determine Hg concentration per mass of sample from the absorbance value provided by the instrument. Method detection limits (MDL) were calculated as 3 times the standard deviation of procedural blanks, and all samples had Hg concentrations that exceeded the limit.

2.3.4 Statistical Analysis

Data was analyzed using JMP Pro 11.0 (SAS Institute, Cary, NC). The data was log transformed to satisfy the assumption of normal distribution. One-way analysis of variance (ANOVA) was used for the comparison between study sites, sex, size, and sample type. If a significant difference was observed, a Tukey-Kramer Honest Significant Difference (HSD) analysis was then conducted to determine which groups were different from each other. Linear Regression was used to determine the relationship between carapace length and tissue mercury concentrations.

2.4 Results

Twenty-two muscle samples (15 females and 7 males) were collected from CM. Eleven muscle samples (4 females and 7 males) were collected from HM. For carapace length, females at both study sites were larger than males, but only CM females were found to be significantly larger. CM female carapace length was 18.6 ± 1.6 cm and males were 12.3 ± 0.4 cm. ($p<0.0001$). We also found CM females to be significantly larger than HM females, with a mean of 18.6 ± 1.6 cm and 12.6 ± 1.5 cm, respectively ($p<0.0001$). Unlike females, male terrapins carapace length did not differ significantly between study sites ($p=0.7760$). CM males had a mean carapace length of 12.3 ± 0.4 cm while HM male terrapins had a mean of 12.2 ± 0.7 cm. Some variance between male and female terrapins could have been due to the low number of males collected, resulting in higher variance and lack of significance despite the large differences among means. The collection of mainly females at CM and males at HM was possibly due to the variation in the collection method of the specimens.

2.4.1 Mercury in Carapace

Carapace mercury concentrations for CM terrapins ranged from 0.185 to 13.048 ppm with a mean of 2.084 ± 2.717 ppm. Excluding the highest carapace mercury concentration of 13.048 ppm the mercury concentration ranged from 0.185 to 5.533 ppm with a mean of 1.607 ± 1.419 ppm. Mercury concentrations for HM terrapins ranged from 0.443 to 1.753 ppm with a mean of 0.957 ± 0.410 ppm (Table 1). Although mean concentrations were more than double for CM terrapins when compared to HM terrapins, ANOVA showed no significant difference in carapace mercury between the study sites ($p=0.2020$).

Comparing mercury contents between male and female turtles, mercury concentrations for female carapaces ranged from 0.185 to 13.048 ppm with a mean of

2.097 ± 2.906 ppm while concentrations for male terrapins ranged from 0.430 to 4.028 ppm in carapace with a mean of 1.206 ± 0.959 ppm (Table 2.1). Statistical analysis showed no statistical differences, although carapace mercury concentrations were twice as high in females ($p=0.3720$). Additionally, no statistically significant correlation was found between mercury in carapace and turtle carapace length ($p=0.430$).

2.4.2 Mercury in Blood

Blood mercury concentrations for CM terrapins ranged from 0.017 to 2.176 ppm with a mean of 0.347 ± 0.607 ppm. Mercury concentrations for HM terrapins ranged from 0.066 to 0.373 ppm with a mean of 0.165 ± 0.102 ppm (Table 2.1). Similar to mercury in carapace, mercury concentrations in blood were more than twice as high in CM terrapins, yet ANOVA showed no statistically significant difference ($p=0.854$).

Disregarding study sites, blood mercury concentrations ranged from 0.019 to 2.176 ppm with a mean of 0.404 ± 0.609 ppm in females, and from 0.017 to 0.244 ppm with a mean of 0.091 ± 0.071 ppm in males (Table 2.1). Female blood mercury concentrations were over four times higher than males; sex of a turtle significantly affects mercury concentrations in blood ($p=0.031$). Statistical analysis also found blood mercury concentrations to be significantly correlated with terrapin size within the 90% confidence limit ($p=0.075$).

<u>2.4.3 Mercury in Muscle</u>

Muscle mercury concentrations for CM terrapins ranged from 0.029 to 0.725 ppm with a mean of 0.250 ± 0.195 ppm, and mercury concentrations for HM terrapins ranged from 0.018 to 0.903 ppm with a mean of 0.284 ± 0.229 ppm (Table 2.1). There was no significant difference for muscle mercury concentrations between the two sites (p=0.768). Sex was not a significant influence on muscle mercury concentrations (p=0.438). In fact, muscle mercury concentrations showed the least variability among the study sites and sexes. Female muscle mercury ranged form 0.018 to 0.903 ppm with a mean of 0.264 ± 0.248 ppm, while males muscle mercury ranged from 0.057 to 0.583 ppm with a mean of 0.257 ± 0.135 ppm (Table 2.1). Carapace length did not correlate with muscle mercury concentrations in terrapins (p=0.961) of either sex (males p=0.209 and females p=0.481) or study site (CM p=0.787 and HM p=0.873). As carapace length did not influence mercury concentrations, the size of the turtles was not considered in further analysis.

Table 2.1. Mean ± standard deviations (SD) (line 1 in ppm), ranges of mercury concentrations (line 2 in ppm), and number (N) of samples (line 3) for carapace, blood, and muscle across both study sites with sexes individually and combined.

Site	**Carapace**	**Blood**	**Muscle**
	Mean ± SD Range Sample size	Mean ± SD Range Sample size	Mean ± SD Range Sample size
CM			
All samples	2.084 ± 2.717 0.185 - 13.048 N=24	0.347 ± 0.607 0.017 - 2.176 N=16	0.260 ± 0.196 0.032 - 0.739 N=22
Male	1.524 ± 1.304 0.43 - 4.028 N=8	0.044 ± 0.029 0.017 - 0.084 N=4	0.245 ± 0.190 0.078 - 0.596 N=7
Female	2.363 ± 3.204 0.185 - 13.048 N=16	0.449 ± 0.677 0.019 - 2.176 N=12	0.268 ± 0.205 0.032 - 0.739 N=15
HM			
All samples	0.957 ± 0.410 0.443 - 1.753 N=13	0.165 ± 0.102 0.066 - 0.373 N=8	0.284 ± 0.229 0.018 - 0.903 N=11
Male	0.923 ± 0.401 0.443 - 1.469 N=9	0.128 ± 0.074 0.066 - 0.244 N=5	0.287 ± 0.028 0.228 - 0.307 N=7
Female	1.032 ± 0.482 0.749 - 1.753 N=4	0.227 ± 0.126 0.227 - 0.373 N=3	0.282 ± 0.416 0.018 - 0.903 N=4
CM and HM			
All samples	1.690 ± 2.251 0.185 - 13.048 N=37	0.287 ± 0.501 0.017 - 2.176 N=24	0.268 ± 0.204 0.018 - 0.903 N=33
Male	1.206 ± 0.959 0.43 - 4.028 N=17	0.091 ± 0.071 0.017-0.244 N=9	0.258 ± 0.135 0.057 - 0.583 N=14
Female	2.097 ± 2.906 0.185 - 13.048 N=20	0.404 ± 0.609 0.019 - 2.176 N=15	0.264 ± 0.246 0.018 - 0.903 N=19

2.4.4 Human Consumption Safety

This study uses two mercury thresholds for data analysis: 0.18 and 0.3 ppm of mercury concentrations. A fish consumption mercury threshold of 0.3 ppm per week is recommended by the EPA for the general public (USGS, 2010). In New Jersey, a mercury threshold of 0.18 ppm per week is recommended for sensitive populations including women, children, and elderly. In this study, the two concentration thresholds will be referred to as sensitive (0.18 ppm) and EPA (0.3 ppm).

Muscle mercury concentrations in CM specimens ranged from 0.032 to 0.739 ppm with a mean of 0.260 ± 0.196 ppm (Figure 2.2). HM terrapin muscle mercury concentrations ranged from 0.018 to 0.903 ppm with a mean of 0.284 ± 0.229 ppm (Figure 2.3). At both locations, the mean muscle mercury concentration surpassed the sensitive threshold (Figure 2.2 and 2.3) and some individual muscle mercury concentrations also surpassed the EPA threshold (Figure 2.2 and 2.3).

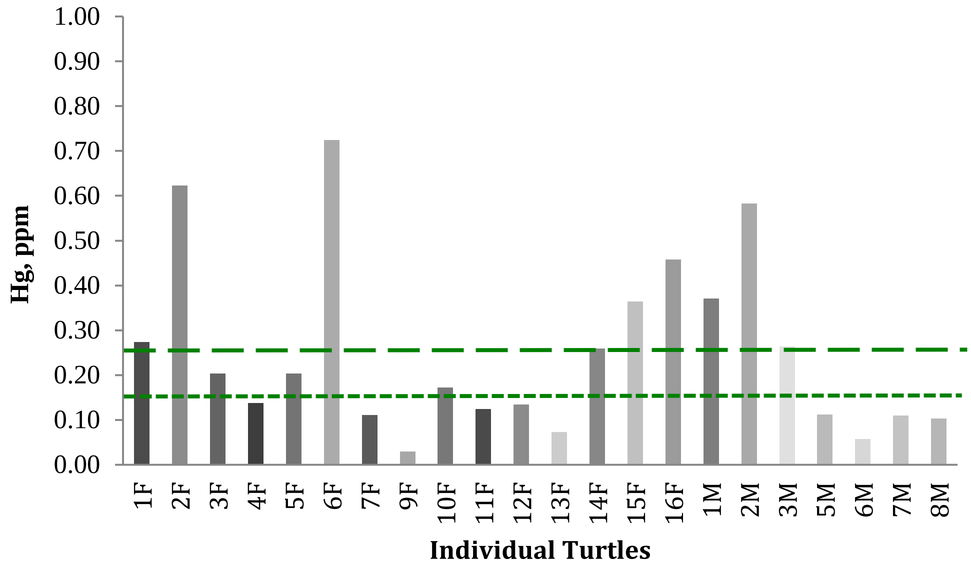

Figure 2.2. Mercury muscle concentrations for CM terrapins and per week thresholds for the sensitive population (short dashed) and EPA (long dashed) thresholds. Individual terrapins are represented by an ID number and letter corresponding to the sex.

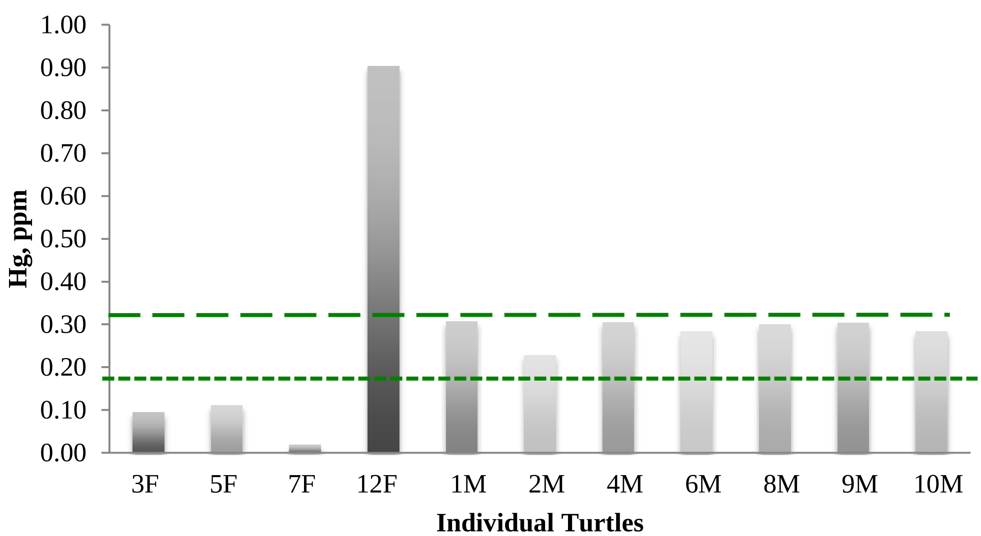

Figure 2.3. Mercury muscle concentrations for HM terrapins and per week thresholds for the sensitive population (short dashed) and EPA (long dashed) thresholds. Individual terrapins are represented by an ID number and letter corresponding to the sex.

Although not statistically significant, CM muscle mercury concentrations were lower than HM concentrations, with a means of 0.260 ± 0.196 ppm and 0.284 ± 0.229 ppm, respectively. HM terrapins exhibited a slightly higher muscle mercury concentration in both females and males (females 0.282 ± 0.416 ppm and males 0.287 ± 0.028 ppm) than CM females and males (females 0.268 ± 0.205 ppm and males 0.245 ± 0.190 ppm) (Table 2.1). Eleven of 22 (50%) of muscle samples collected from CM specimens surpassed the sensitive mercury threshold. Eight of 11 HM terrapin muscle samples (72.7%) surpassed the sensitive threshold (Table 2.2). Six of 22 (27.3%) CM and 5 of 11 (45.5%) HM mercury muscle samples surpassed the EPA threshold (Table 2.2).

Table 2.2. Percent of samples that surpassed the sensitive population threshold (0.18 ppm) and the EPA mercury threshold (0.3 ppm).

	% Exceeding Sensitive Threshold		% Exceeding EPA threshold	
	CM	HM	CM	HM
All Samples	50%	72.7%	27.3%	45.5%
Female Muscle	53%	25%	27%	25%
Male Muscle	43%	100%	29%	57.1%

2.5 Discussion

Mercury contamination in consumed foods requires special attention because of its high toxicity and its global distribution. Mercury content in organisms has been reported to vary by species, size, sex, tissue type, region, and habitat (Green et al., 2010; Godley et al., 1999). Published literature often suggests larger organisms, including turtles, contain higher contaminant concentrations (Stafford and Haines, 1997; Turnquist et al., 2011; Zapata et al., 2014). However, this study found a statistically significant relationship between size and mercury concentrations in blood samples tested, but found no relationship between size and mercury concentrations in carapace or muscle mercury concentrations. Golet and Haines (2001), Schneider et al. (2009) and Helwig and Hora (1983) also found no relationship between mercury concentration and body size of turtles.

In this study, females at both study sites were larger than males, but only CM females were significantly bigger than males. We also found CM females to be significantly larger than HM females. The results of this study also found female terrapins to have significantly higher blood mercury concentrations than male terrapins ($p = 0.031$) (Table 2.1). According to Lovich and Gibbons (1990) and Tucker et al. (1995), female terrapins have been observed to consume larger prey items than males due to their size difference, which can influence mercury burdens in female tissues. Female diamondback terrapins consume gastropods ranging in size from 4 to 21 mm, while males choose smaller prey, ranging from 2 to 15 mm (Lovich and Gibbons, 1990). The ability of larger females to consume bigger prey widens the range of food items available for consumption such as crabs, barnacles, and clams (Blanvillain et al., 2007). Female terrapins could also have a higher rate of consumption than males to support egg production (Blanvillain et al., 2007). The higher consumption rate coupled with larger size prey could lead to higher mercury burdens in female terrapins.

Sexually mature females are capable of relieving mercury burden through incorporation of Hg into eggs, resulting in lower mercury storage in female turtles (Basile et al., 2011; de Solla and Fernie, 2004; Kelly et al., 2008; Russell et al., 1999; Pagano et al., 1999). The transfer of mercury from mother to egg is suggested to occur from the contaminants stored in the maternal somatic lipids or by the diet recently consumed by female and the contaminants circulating in the female's plasma (Bishop et al., 1994; Pagano et al., 1999; Rauschenberger et al., 2004). In the case of terrapins, which show sexual dimorphism, the transfer of mercury from mother to egg can act as a significant excretion method to relieve the mercury burden of female terrapins, which might result in lower muscle mercury concentrations found in female terrapins larger in size. Although females reach sexual maturity within a carapace length range from 13.2 to 17.6 cm (Fitzsimmons and Greene, 2001; Lovich and Gibbons, 1990; Montevecchi and Burger, 1975), some studies suggest that terrapins from different populations can reach sexual maturity at different carapace length (Fitzsimmons and Greene, 2001; Lovich and Gibbons, 1990). HM female terrapins with an average carapace length of 12.6 cm could have been sexually mature, allowing them to transfer mercury to eggs during production, which could account for the lower muscle mercury concentrations found in HM female than in HM males.

Overall, HM terrapins had higher muscle mercury concentrations than CM terrapins. CM females had a higher mean muscle mercury concentration than CM males, yet HM male terrapins had slightly higher mean muscle mercury concentrations when compared to HM females. Lower muscle mercury concentrations in CM males is likely due to their smaller body size. With a smaller body size, CM males might be younger and limited to the consumption of smaller prey items. Due to this species' sexual dimorphism, the quantity of food consumed and the size of prey items might be a strong influencing factor.

Literature suggests larger turtles have higher mercury concentrations through bioaccumulation and biomagnification (Golet and Haines, 2001; Meyers-Schone et al., 1993). The results of this study correlate with previous findings. The larger CM terrapins contained significantly higher blood mercury concentrations. Although not significant, smaller size terrapins at HM were found to have higher muscle mercury concentrations. These results might be caused by the spatial variation and mercury distribution (Golet and Haines, 2001; Meyers-Schone et al., 1993). Blanvillan et al. (2007) found that terrapins from a site with a history of contaminations or closeness to coal burning plants to have higher blood and carapace mercury concentrations. Similarly, Green et al. (2010) found turtles inhabiting salt marshes that had been exposed to industrial discharge had higher carapace mercury concentrations than terrapins collected from relatively undeveloped areas. Given the HM long industrial, landfill and contaminant history, terrapins in this area were expected to have had overall higher mercury concentrations; the results of this study supported this hypothesis but only for muscle mercury concentrations. Similar to our results, Burger (2002) found southern New Jersey caught fish to have higher mercury levels than those caught at northern study sites. Burger et al.

(2011) suggests that although southern New Jersey has not had the industrialization of the northern part of the state, it has been exposed to contaminants carried by the Delaware River, which delivers contaminants to the southern parts of the state. This, along with the size difference of the terrapins, could have resulted in higher carapace and blood mercury concentrations found in CM terrapins.

Lastly, the current harvest size limit implemented in New Jersey of 12.70 cm plastron length is meant to protect the young terrapin population from being harvested, but this fails to protect the human populations. The size limit of 12.70 cm results in the harvest of larger terrapins, including more females and older individuals likely to contain higher mercury concentrations. This poses a risk for human consumption and demonstrated a dilemma for policy makers to balance wildlife conservation and human consumption safety.

The mean muscle mercury concentration for all terrapins collected in this study was 0.268 ppm. Based on the Natural Resource Defense Council (NRCD, 2016) calculations of mercury in seafood, the general population should be advised to consume no more than 6 oz of diamondback terrapin meat four times a month. Additionally, since mercury concentrations in terrapin muscle were found to be as high as 0.903 ppm in this study, the sensitive population should be advice to avoid consumption of diamondback terrapin meat.

2.5.1 Population Effects

Although toxicological effects of contaminants on turtles are not well understood, studies suggest metals can cause cytotoxic, mutagenic, and carcinogenic effects on animals (Wang, 2005). Wang (2005) suggested that higher contaminant concentrations in Kemp Ridley sea turtles could result in higher disease rates and lower reproductive outputs for this species. Eisenreich et al. (2009) found snapping turtle juvenile mortality rate to be associated with maternal exposure to PCBs and transfer of PCBs from mother to eggs. Meyers-Schone et al. (1993) reported a correlation between mercury and DNA strand breaks. Hopkins et al. (2013) found snapping turtles at mercury-contaminated sites to lay eggs with higher mercury concentrations than the reference sites. Higher muscle mercury concentration in mothers and therefore in eggs led to lower hatching success due to increased embryonic mortality and unfertilized eggs. Muscle mercury concentrations reported by Hopkins et al., (2013) were much higher than those observed in this study. However, a study by Bishop (1998) reported mercury concentrations in snapping turtles between 0.05 and 0.14 ppm with no abnormalities to the clutch.

Due to the lack of data on metal concentrations and their physiological and reproductive effects on turtles, studies often look into the more informed thresholds for avian species. Yu et al. (2011) planned to implement the 5 ppm threshold for detrimental effects in waterfowl for prediction of possible impacts on red-eared slider and found none of the samples surpassed the avian threshold. Avian data shows 1 ppm mercury concentration could result in behavioral effect while a mercury content of 5 to 6 ppm results in mortality (Zillioux et al., 1993). The results for muscle mercury for terrapins in this study are nowhere near the avian thresholds, yet there is an association between mercury concentration and potential health and reproductive effects which could be detrimental with the combination of human impact such as crab traps, road mortality, and habitat loss and alteration which alone already heavily impact terrapin population numbers.

2.6 Conclusions

The results of this study show a higher percentage of HM terrapins surpassing the Hg consumption thresholds than CM terrapins. Over a quarter of the CM samples surpassed the EPA threshold. It is important to make consumers aware of the potential human consumption risks that terrapins pose. This study also found mercury concentrations in diamondback terrapins to be highly variable among size, sex and location of populations. Other studies also documented length of the food web and several additional factors can also influence the contaminant concentrations within the same species (Becker et al., 2002; McIntyre and Beauchamp, 2007). Therefore, if implemented, human consumption advisories for terrapins should address those variables with a special focus on spatial variation.

2.7 Literature Cited

Basile, E. R., Avery, H. W., Bien, W. F., and Keller, J. M. (2011) Diamondback terrapins as indicator species of persistent organic pollutants: Using Barnegat Bay, New Jersey as a case study. *Chemosphere*, 82(1), 137-144.

Becker, P. H., González-Solís, J., Behrends, B., and Croxall, J. (2002) Feather mercury levels in seabirds at South Georgia: influence of trophic position, sex and age. *Marine Ecology Progress Series*, 243, 261-269.

Bishop, C. A., Brown, G. P., Brooks, R. J., Lean, D. R. S., and Carey, J. H. (1994) Organochlorine contaminant concentrations in eggs and their relationship to body size, and clutch characteristics of the female common snapping turtle (*Chelydra serpentina serpentina*) in Lake Ontario, Canada. *Archives of Environmental Contamination and Toxicology*, 27(1), 82-87.

Bishop, C. A., Ng, P., Pettit, K. E., Kennedy, S. W., Stegeman, J. J., Norstrom, R. J., and Brooks, R. J. (1998) Environmental contamination and developmental abnormalities in eggs and hatchlings of the common snapping turtle (*Chelydra serpentina serpentina*) from the Great Lakes-St Lawrence River basin (1989–1991). *Environmental Pollution*, 101(1), 143-156.

Blanvillain, G., Schwenter, J. A., Day, R. D., Point, D., Christopher, S. J., Roumillat, W. A., and Owens, D. W. (2007) Diamondback terrapins, *Malaclemys terrapin*, as a sentinel species for monitoring mercury pollution of estuarine systems in South Carolina and Georgia, USA. *Environmental Toxicology and Chemistry*, 26(7), 1441-1450.

Bloom, N. S. (1992) On the chemical form of mercury in edible fish and marine invertebrate tissue. *Canadian Journal of Fisheries and Aquatic Sciences*, 49, 1010–1017.

Boening, D. W. (2000) Ecological effects, transport, and fate of mercury: a general review. *Chemosphere*, 40(12), 1335-1351.

Brasso, R. L., and Cristol, D. A. (2008) Effects of mercury exposure on the reproductive success of tree swallows (*Tachycineta bicolor*). *Ecotoxicology*, 17(2), 133-141.

Burger, J. (2002) Metals in tissues of diamondback terrapin from New Jersey. *Environmental Monitoring and Assessment*, 77(3), 255-263.

Burger, J., and Gochfeld, M. (2005) Heavy metals in commercial fish in New Jersey. *Environmental Research*, 99(3), 403-412.

Burger, J., Jeitner, C., and Gochfeld, M. (2011) Locational differences in mercury and selenium levels in 19 species of saltwater fish from New Jersey. *Journal of Toxicology and Environmental Health, Part A*, 74(13), 863-874.

Burgess, N. M., and Meyer, M. W. (2008) Methylmercury exposure associated with reduced productivity in common loons. *Ecotoxicology*, 17(2), 83-91.

Butler, J. A., Heinrich, G. L., and Seigel, R. A. (2006) Third workshop on the ecology, status, and conservation of diamondback terrapins (*Malaclemy terrapin*). Results and recommendations. *Chelonian Conservation and Biology*, 5(2), 331-334.

Centers for Disease Control and Prevention (2004) Blood Mercury Levels in Young Children and Childbearing-Aged Women --- United States, 1999-2002 Source:https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5343a5.htm.

Compton, J. (2000) An overview of Asian turtle trade. *Chelonian Research Monographs*, (2), 24-29.

Conant, R. (1955) Correspondence. *British Journal of Herpetology*, 1(12), 252-253.

Conant, R. (1964) Turtle Soup. *America's First Zoo*, 16, 28-30.

Convention On International Trade In Endangered Species Of Wild Fauna And Flora (2015) Trade Database. Source: https://trade.cites.org/en/cites_trade/#.

Day, R. D., Segars, A. L., Arendt, M. D., Lee, A. M., and Peden-Adams, M. M. (2007) Relationship of blood mercury levels to health parameters in the loggerhead sea turtle (*Caretta caretta*). *Environmental Health Perspectives*, 1421-1428.

de Solla, S. R., and Fernie, K. J. (2004) Characterization of contaminants in snapping turtles (*Chelydra serpentina*) from Canadian Lake Erie Areas of Concern: St. Clair River, Detroit River, and Wheatley Harbour. *Environmental Pollution*, 132(1), 101-112.

Eisenreich, K. M., Kelly, S. M., and Rowe, C. L. (2009) Latent mortality of juvenile snapping turtles from the upper Hudson River, New York, exposed maternally and via the diet to polychlorinated biphenyls (PCBs). *Environmental Science and Technology*, 43(15), 6052-6057.

Environmental Protection Agency (2012) New Jersey Water Quality Assessment Report. Source:https://iaspub.epa.gov/waters10/attains_index.control?p_area=NJ#causes.

Environmental Protection Agency (2013) Fish Tissue Analysis For Mercury and PCBs from a New York City Commercial Fish/Seafood Market. Source:http://nepis.epa.gov/Exe/ZyPDF.cgi/P100HCKB.PDF?Dockey=P100HCKB.PDF.

Environmental Protection Agency (2015) Lower Hackensack River Bergen and Hudson Counties New Jersey. Source https://www.epa.gov/sites/production/files/2015-11/documents/r_hackensack_river_pa_09292015.pdf.

Ernst, C. H., Lovich, J. E., and Barbour, R. W. (1994) Turtles of the United States and Canada. Smithsonian Institution Press, Washington and London. 578 pp.

Fitzsimmons, N. N., and Greene, J. L. (2001) Demographic and Ecological Factors Affecting Conservation and Management of the Diamondback Terrapin (*Malaclemys terrapin*) in South Carolina. *Chelonian Conservation and Biology*, 4(1).

Gochfeld, M. (2003) Cases of mercury exposure bioavailability and absorption. *Ecotoxicology and Environmental Safety*, 56, 174–179.

Godley, B. J., Thompson D. R., and Furness, R. W. (1999) Do heavy metal concentrations pose a threat to marine turtles from the Mediterranean Sea? *Marine Pollution Bulletin*, 38, 6, 497-502.

Golet, W. J., and Haines, T. A. (2001) Snapping turtles (*Chelydra serpentina*) as monitors for mercury contamination of aquatic environments. *Environmental Monitoring and Assessment*, 71(3), 211-220.

Green, A. D., Buhlmann, K. A., Hagen, C., Romanek, C., and Gibbons, J. W. (2010) Tissue Distribution and Maternal Transfer of Mercury in Diamondback Terrapins with Implications for Human Health. Source:http://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=1172&context=scwrc.

Helwig, D. D., and Hora, M. E. (1983) Polychlorinated biphenyl, mercury, and cadmium concentrations in Minnesota snapping turtles. *Bulletin of Environmental Contamination and Toxicology*, 30(1), 186-190.

Hopkins, B. C., Willson, J. D., and Hopkins, W. A. (2013) Mercury exposure is associated with negative effects on turtle reproduction. *Environmental Science and Technology*, 47(5), 2416-2422.

Jacobson, J. L., Muckle, G., Ayotte, P., Dewailly, É., and Jacobson, S. W. (2015) Relation of prenatal methylmercury exposure from environmental sources to childhood IQ. *Environmental Health Perspectives*, 123(8), 827.

Kelly, S. M., Eisenreich, K. M., Baker, J. E., and Rowe, C. L. (2008) Accumulation and Maternal Transfer of Polychlorinated Biphenyls in Snapping Turtles of the Upper Hudson River, New York, USA. *Environmental Toxicology and Chemistry*, 27, 2565-2574.

Klemens, M. W., and Thorbjarnarson, J. B. (1995) Reptiles as a food resource. *Biodiversity and Conservation*, 4, 281-298.

Lovich, J. E., and Gibbons, J. W. (1990) Age at maturity influences adult sex ratio in the turtle *Malaclemys terrapin*. *Oikos*, 126-134.

Macirella, R., Guardia, A., Pellegrino, D., Bernabò, I., Tronci, V., Ebbesson, L. O., Sesti, S., Tripepi, S., and Brunelli, E. (2016) Effects of Two Sublethal Concentrations of Mercury Chloride on the Morphology and Metallothionein Activity in the Liver of Zebrafish (*Danio rerio*). *International Journal of Molecular Sciences*, 17(3), 361.

McIntyre, C. (2000) Heavy Metal Concentrations in Sediment and Diamondback Terrapin Tissues from Two Sites in New Jersey. Hampshire College. (Thesis) Source:http://passaic.sharepointspace.com/Public%20Documents/Heavy%20Metal%20Concentrations%20in%20Sediment%20and%20Diamondback%20Terrapin%20Tissues%20from%20Two%20Sites%20in%20New%20Jersey.pdf.

McIntyre, J. K., and Beauchamp, D. A. (2007) Age and trophic position dominate bioaccumulation of mercury and organochlorines in the food web of Lake Washington. *Science of the Total Environment*, 372(2), 571-584.

Meyers- Schöne, L., Shugart, L. R., Walton, B. T., and Beauchamp, J. J. (1993) Comparison of two freshwater turtle species as monitors of radionuclide and chemical contamination: DNA damage and residue analysis. Environmental. *Toxicology and Chemistry*, 12(8), 1487-1496.

Meyers-Schöne, L., and Walton, B. T. (1994) Turtles as monitors of chemical contaminants in the environment. In Reviews of environmental contamination and toxicology (pp. 93-153). Springer New York.

Montevecchi, W. A., and Burger, J. (1975) Aspects of the reproductive biology of the northern diamondback terrapin, *Malaclemys terrapin terrapin*. *American Midland Naturalist*, 166-178.

Morel, François M. M., Kraepiel Anne M. L., and Amyot, M. (1998) The Chemical Cycle and Bioaccumulation of Mercury. *Annual Review of Ecology and Systematics*, 29, 543-566.

Natural Resources Defense Council (2016) Calculations for Mercury in Seafood. Source:https://www.nrdc.org/sites/default/files/mercury-in-tuna-calculation-summary.pdf

New Jersey Department of Environmental Protection (2002) Volume II Exposure and Impacts and Volume III Sources of Mercury to New Jersey's Environment. Source: http://www.nj.gov/dep/dsr/mercury_task_force.htm.

New Jersey Department of Environmental Protection (2016) Administrative Order No. 2016-02 Source: http://www.nj.gov/dep/docs/ao2016-02.pdf.

Pagano, J. J., Rosenbaum, P. A., Roberts, R. N., Sumner, G. M., and Williamson, L. V. (1999) Assessment of maternal contaminant burden by analysis of snapping turtle eggs. *Journal of Great Lakes Research*, 25, 950-961.

Rauschenberger, R. H., Sepúlveda, M. S., Wiebe, J. J., Szabo, N. J., and Gross, T. S. (2004) Predicting maternal body burdens of organochlorine pesticides from eggs and evidence of maternal transfer in Alligator mississippiensis. *Environmental Toxicology and Chemistry*, 23(12), 2906-2915.

Russell, R. W., Gobas, F. A., and Haffner, G. D. (1999) Maternal transfer and in ovo exposure of organochlorines in oviparous organisms: a model and field verification. *Environmental Science and Technology*, 33(3), 416-420.

Schaffer, C., Wood, R. C., Norton, T. M., and Schaffer, R. (2008) Terrapins in the stew. Iguana, 15, 78-85.

Schneider, L., Belger, L., Burger, J., Vogt, R. C., and Ferrara, C. R. (2010) Mercury Levels in Muscle of Six Species of Turtles Eaten by People Along the Rio Negro of the Amazon Basin. *Archives Of Environmental Contamination and Toxicology*, 58(2), 444-450.

Stafford, C. P., and Haines, T. A. (1997) Mercury concentrations in Maine sport fishes. *Transactions of the American Fisheries Society*, 126(1), 144-152.

Stern, A. H., Gochfeld, M. C., Weisel, C., and Burger, J. (2001) Mercury and methylmercury exposure in the New Jersey pregnant population. *Archives of Environmental Health: An International Journal*, 56(1), 4-10.

Tortoise and Freshwater Turtle Specialist Group (1996) *Malaclemys terrapin*. The IUCN Red List of Threatened Species. Version 2014.3. Source:DiamondbackTerrapin.iucnredlist.org.

Tsipoura, N., Burger, J., Feltes, R., Yacabucci, J., Mizrahi, D., Jeitner, C., and Gochfeld, M. (2008) Metal concentrations in three species of passerine birds breeding in the Hackensack Meadowlands of New Jersey. *Environmental Research*, 107(2), 218-228.

Tucker, A. D., FitzSimmons, N. N., and Gibbons, J. W. (1995) Resource partitioning by the estuarine turtle Malaclemys terrapin: trophic, spatial, and temporal foraging constraints. *Herpetologica*, 167-181.

Turnquist, M., Driscoll, C., Schulz, K., and Schlaepfer, M. (2011) Mercury concentrations in snapping turtles (*Chelydra serpentina*) correlate with environmental and landscape characteristics. *Ecotoxicology*, 20(7), 1599-1608.

United Nations Environment Programme (2013) Global Mercury Assessment, Sources, Emissions, Releases and Environmental Transport. Source:http://www.unep.org/chemicalsandwaste/Mercury/Informationmaterials/ReportsandPublications/tabid/3593/Default.aspx.

United States Geological Survey (2010) Mercury in Stream Ecosystem. Source:http://water.usgs.gov/nawqa/mercury/MercuryFAQ.html.

Wang, H. C. (2005) Trace metal uptake and accumulation pathways in Kemp's Ridley sea turtles *(Lepidochelys kempii)* (Doctoral dissertation, Texas A&M University).

Ward, D. M., Nislow, K. H., and Folt, C. L. (2010) Bioaccumulation syndrome: identifying factors that make some stream food webs prone to elevated mercury bioaccumulation. *NY Academy of Science*, 1195, 62-83.

Wood, R. C., and Herlands, R. (1997) Turtles and tires: the impact of roadkills on northern Diamondback Terrapin, Malaclemys terrapin terrapin, populations on the Cape May Peninsula, southern New Jersey, USA. In Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles-An International Conference. New York: New York Turtle and Tortoise Society, 1, 46-53.

Yu, S., Halbrook, R. S., Sparling, D. W., and Colombo, R. (2011) Metal accumulation and evaluation of effects in a freshwater turtle. *Ecotoxicology*, 20(8), 1801-1812.

Zapata, L., Bock, B., and Palacio, J. (2014) Mercury Concentrations in Tissues of Colombian Slider Turtles, Trachemys callirostris, from Northern Colombia. *Bulletin Of Environmental Contamination and Toxicology*, 92(5), 562-566.

Zillioux, E. J., Porcella, D. B., and Benoit, J. M. (1993) Mercury cycling and effects in freshwater wetland ecosystems. *Environmental Toxicology and Chemistry*, 12(12), 2245-2264.

Chapter 3. Mercury in Snapping Turtles: A Concern for Human Consumption

3.1 Abstract

Over the last several decades, there has been a growing awareness over the decline of many turtle species around the globe, mainly driven by human consumption demands. New Jersey currently allows the recreational and commercial harvesting of the common snapping turtles, *Chelydra serpentina serpentina*. Harvested animals are sold to processing factories as well as restaurants and diners mainly in southern New Jersey where turtles are served as snapper soup or stew. The growing demand for snapping turtles in worldwide markets has lead to the recognition of the potential dangers of consuming contaminated turtle meat. Turtles life history characteristics, such as being long-lived and omnivorous, could result in snapping turtles containing high levels of contaminants in their tissues through bioaccumulation, bioconcentration and biomagnification. The high mercury deposition and the increasing demand for snapping turtles has resulted in concerns over turtle meat consumption including in the State of New Jersey. Therefore, this study aims to determine mercury concentrations in snapping turtles among 3 study sites across varying site contamination histories. Mercury was found in all sample tissues tested, but no variation in concentrations among study sites was found for carapace and muscle. Carapace had the highest mercury concentrations followed by muscle and then blood. Results showed no correlation between mercury concentration and turtle carapace length or weight. All study sites had muscle mercury

concentrations that surpassed the U.S. Department of Food and Drug Administration consumption threshold, making this population a potential risk for consumers.

3.2 Introduction

All around the globe turtles face many threats, from habitat loss to contamination and predation, including being harvested by humans. Turtles have been exploited for medicine, turtle farms, pet trade, expositions, zoos, and for human consumption. Turtles are exploited in many parts of the world including South America, the United States, India, and China, among others. Turtles in Southeast Asia are the most imperiled due to the high demand for consumption. As a result, 68% of the turtle species found in this region are considered threatened and many are on the brink of extinction. This decline is referred to as the Asian Turtle Crisis (Wildlife Conservation Society, 2011). As native turtle populations began to severely decline in Southeast Asia, the market turned to global sources including the United States. In response to the overseas demand, private turtle farms have been operating in Louisiana, Florida, and Oklahoma, but their success has been limited due to their dependence on wild caught turtles for brooding stocks and the occurrences of Salmonella outbreaks within captive turtles (Florida Fish and Wildlife Conservation Commission, 2012). These limitations have led to the continued dependence and specific demand for wild caught turtles to supply the global market.

The demand for turtles does not only come from Asian countries, but also from within the United States. The United States had been harvesting turtles for human consumption since prior to the Asian Turtle Crisis. In the early 1900s, prior to the listing of sea turtles on the Endangered Species Act, the meat of sea turtle, alligator snapping turtle, and diamondback terrapin was consumed throughout the continental U.S. Among them the common snapping turtle (*Chelydra serpentina serpentina*) is the second largest freshwater turtle in North America, which has made it a target game species. In 2009 alone, an estimated 655,541 common snapping turtles were exported (van Dijk, 2012). Although many of the exported turtles might have originated from commercial turtle farms, it is estimated that approximately 39% of the exported turtles were wild caught (Senneke, 2005), making snapping turtles one of the most commonly exported turtle species in the United States.

Today, 40 states in the U.S. allow the harvest of snapping turtles either commercial, recreational or both. The International Union for Conservation of Nature (IUCN) classifies snapping turtle's conservation status as of least concern. In both Canada and Minnesota, snapping turtles are considered a special concern species. As the demand for turtle meat increased and the species' population sizes declined, several states have limited or terminated the commercial harvesting program of the snapping turtles. Alabama, Illinois, Maine, New Hampshire, Oklahoma, West Virginia, Nebraska, South Dakota, Mississippi, and North Carolina are among the states to have terminated or implemented stricter regulations on the commercial harvest of snapping turtles.

3.2.1 Snapping Turtle Harvest in New Jersey

Snapping turtles are one of 12 native turtle species in New Jersey and the only turtle species harvested in the state. The state currently allows both recreational and commercial harvesters to collect turtles throughout the year, with the exception of the nesting season from May 1 to July 15th. For recreational harvesting, "any person with a valid fishing license or those entitled to fish without a license" may take one snapping turtle per day either by traps or with hands, either adults or juvenile, with no reporting requirement (NJDEP, 2016).

The commercial harvester permit for snapping turtles costs $2 in addition to holding a valid fishing license. Currently, there are no limits on number of turtles that a commercial harvester can collect, and no limits on turtle weight, sex, or harvest locations. Commercial harvesters are required to submit a monthly report with the number of turtles caught and the body of water where they were harvested (NJDEP, 2016). In 2016, the first size limit regulation was implemented in the state, yet harvesters already had a size limit of 12 inches requirement imposed by most buyers. Up to 2011-2012, both the number commercial harvesting permits issued and the reported number of harvested turtles are exhibiting an increasing trend (Figure 3.1 and 3.2). A declining trend in the number of turtles caught began in 2012, which raised concerns on the sustainability of the snapping turtle populations in New Jersey given the current harvesting pressure, as well as pressures from other anthropogenic environmental impacts.

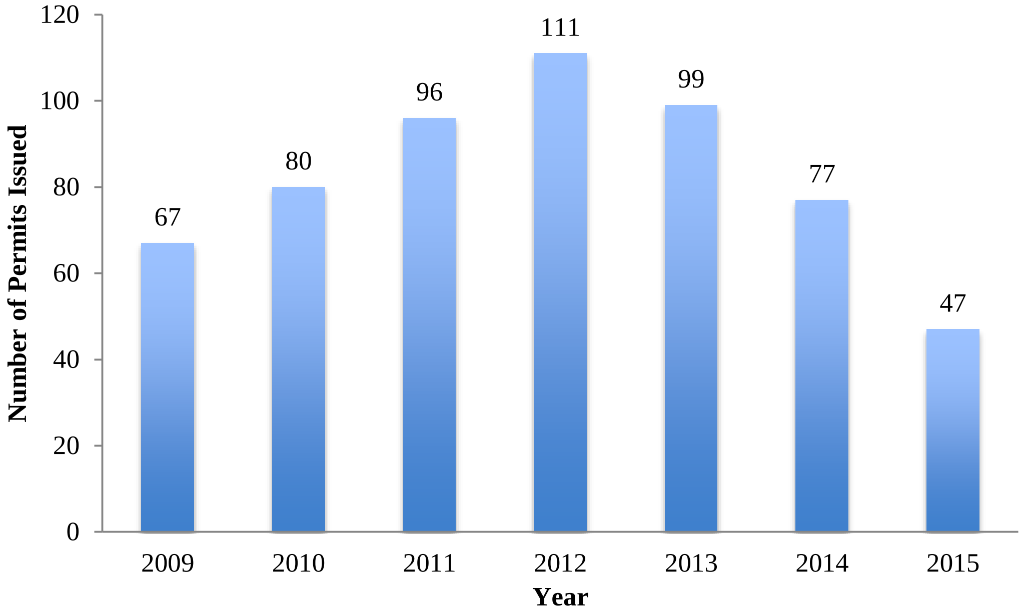

Figure 3.1. Numbers of commercial harvesting permits issued in New Jersey.

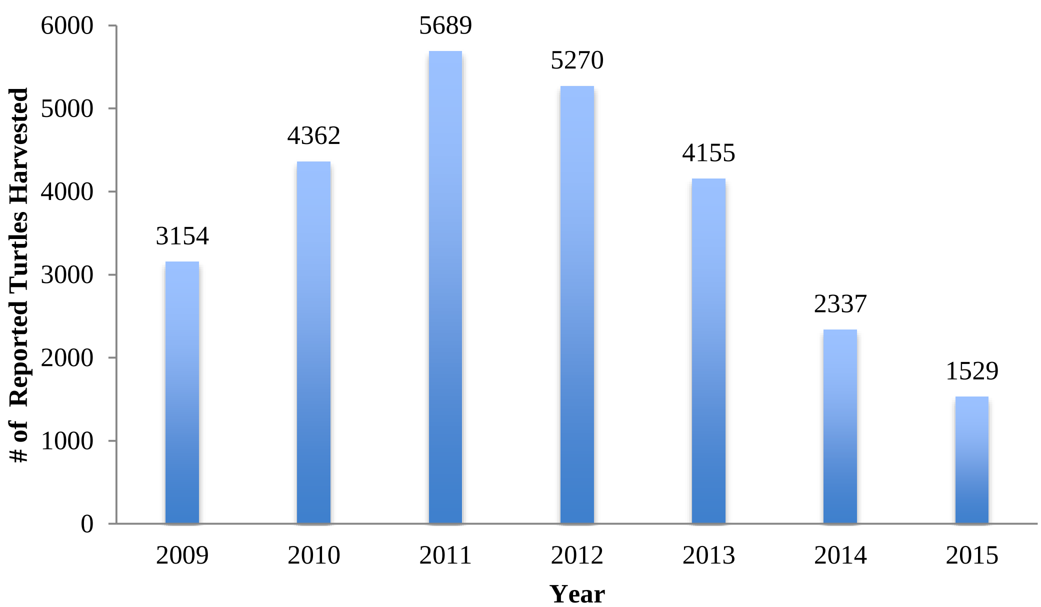

Figure 3.2. Number of turtles reported caught by commercial harvesters in New Jersey.

<u>3.2.2 Mercury</u>

Contaminants in aquatic food webs pose a significant threat to aquatic ecosystems and human health. Humans risk ingesting high levels of mercury through the consumption of contaminated food, especially through the consumption of fish and other aquatic animals such as turtles. Several studies have reported the presence of mercury and other contaminants in snapping turtles (Albers et al., 1986; Golet and Haines, 2000; Hudson River Natural Resource Trustees, 2005; Stone et al., 1980). Snapping turtles are at the top of their food chain and can bioaccumulate contaminants; therefore they are often used as bioindicators for pollutants (Golet and Haines, 2000).

Mercury is a heavy metal that is most often released into the atmosphere by coal burning plants (NJDEP, 2002). Depending on the form of mercury released, it can remain in the atmosphere for up to a year and get transported around the globe, making its' source unidentifiable (UNEP, 2013). Mercury is eventually deposited on land or water through wet and/or dry deposition (Fitzgerald, 1995; Gochfeld, 2003). Atmospheric models suggest the highest rate of mercury deposition in the United States occurs in the northeast, in the Great Lakes region and the Ohio Valley (UNEP, 2013). Mercury can also leak directly into soil and water from non-point sources such as septic tanks, landfill leachate, and sludge application, but these sources are now better regulated, especially since the launch of the Clean Water Act 1972 (NJDEP, 2002).

When mercury reaches aquatic environments it can be methylated by anaerobic methanogenic- or sulfate-dependent bacteria, producing methylmercury (MeHg) (Gochfeld, 2003). MeHg is able to cross into cells and be retained, bioaccumulated and biomagnificated in algae and the organisms that consume algae (Morel et al., 1998). MeHg is the form of mercury most readily available and persistent in organisms. Approximately 90 to 95% of mercury in fish and turtles was estimated to be methylated (Bloom, 1992; Turnquist et al., 2011).

MeHg is a neurotoxin that has the ability to pass the blood-brain barrier, allowing it to participate in cellular and nuclear processes, making mercury a serious threat to humans, especially pregnant women and young children (Boening, 2000). In 2004 the Centers for Disease Control and Prevention reported 6% of women to have mercury levels that could adversely affect the healthy development of a fetus (CDC, 2004). In New Jersey alone, it is estimated that 10% of women of childbearing age have elevated blood mercury levels with the potential of affecting fetus development (Stern et al., 2001).

Mercury has been a major focus for human consumption advisories and guidelines established by government agencies. Two government agencies have set mercury thresholds for the public, the U.S. Environmental Protection Agency (EPA) and the U.S. Food and Drug Administration (FDA). The EPA regulates mercury based on the drinking water quality and the health of ecosystems at a threshold of 0.3 ppm (EPA, 2010). The FDA regulates market products, for which it imposes a mercury threshold of 1 ppm (FDA, 2013). In addition, state governments can also impose their own regulations. For example, New Jersey's Department of Environmental Protection (NJDEP) implemented a threshold of 0.18 ppm for "sensitive populations" who have a higher risk of adverse health effects including women of childbearing age, women who are pregnant, and children (NJDEP, 2009).

Fifty-four percent of all assessed river and stream miles and about 87% of lakes, reservoirs, and ponds in New Jersey are impaired due to mercury contamination (EPA, 2012). Additionally, the EPA conducted a mercury analysis on market purchased fish and found concentrations of mercury ranging from 0.005 to 0.42 ppm (EPA, 2013). New Jersey self-caught fish, such as shrimp and tuna, were reported to contain higher concentrations of mercury ranging from 0.01 to 0.65 ppm (Burger and Gochfeld, 2005). These results alert the public of the risk of consuming mercury-contaminated seafood. With over 35% of U.S. freshwaters under mercury consumption advisories and the state of New Jersey under a statewide consumption advisory, it is crucial to monitor mercury levels in foods that could contain high concentrations of mercury (Ward et al., 2010).

This study aimed to assess mercury concentrations in snapping turtles across 3 northern New Jersey sites to determine if turtles are safe for human consumption based upon the available consumption thresholds. This study also examined any correlation between sex and size to determine if these characteristics can assist in monitoring mercury content in turtles.

3.3 Methods

3.3.1 Study Sites

Three study sites were selected across a gradient along northern New Jersey representing various levels of human disturbance and contamination sources (Figure 3.3).

Sites were also selected based on their accessibility and presence of snapping turtle habitats reachable by foot.

The first study site, Lake Wapalanne, is a 12 acre artificial lake created in 1933 (hereafter denoted WAP). WAP is located within the 16,025 acre Stokes Forest in the Kittatinny Mountains, Sussex County, New Jersey. The lake is part of Montclair State University's New Jersey School of Conservation, which serves as an environmental education facility. The lake does not experience much recreational activity except for canoeing by school children. The dominant fish in WAP are sunfish (*Lepomis gobbosus and Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*). WAP is fed by the Big Flat Brook, which was found not to pose any mercury risk (EPA, 2009).

The second study site, Lake Hopatcong, is the largest freshwater body in New Jersey encompassing 2,500 acres within Morris and Sussex Counties (hereafter denoted HOP). In the mid 1800s the lake fed the Morris Canal, a 90 mile waterway that ran from Newark to Philipsburg, for the purpose of transporting coal, iron ore, and zinc ore. Today the lake is heavily used for recreational activities such as fishing, boating, kayaking, jets skiing, and other water sports. The lake has been stocked with rainbow (*Oncorhynchus mykiss*), brook (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*). Natural inhabitants include largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), rock bass (*Ambloplites rupestris*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gobbosus*), chain pickerel (*Esox niger*), channel catfish (*Ictalurus punctatus*), bullhead (*Ameiurus melas*), carp (*Cyprinus carpio*), yellow (*Perca Flavescens*) and white perch (*Morone americana*). The entire lake is considered impaired due to findings of elevated mercury levels in fish (EPA, 2009). Elevated mercury concentrations are attributed to atmospheric deposition (EPA, 2009).

The third study site is the Kearny freshwater marsh, a 344 acre impoundment owned by the New Jersey Meadowlands Commission (NJMC) (herafter denoted KFM) with a long history of pollution. Prior to human alteration the marsh was dominated by white cedar swamp. As the swamp dried, the area became dominated by common reed and later filled by rainwater, leachate, and runoff from the surrounding urban areas. KFM has been affected by contaminants from combined sewer overflows, municipal stormwater discharge, regional atmospheric deposition, and improperly closed landfills, most notably the Keegan Landfill (Tsipoura et al., 2008).

Since its establishment in the 1940s to 2008, the 110 acre Keegan Landfill was a major source of contamination to the Kearny freshwater marsh (Tsipoura et al., 2008). Even through its inactive years from 1972 to 2008, the Keegan landfill leached approximately 246,000 liters (65,000 gallons) of contaminated liquids per day into Kearny Marsh (Quinn, 1997). It wasn't until 2008 when NJMC's containment project was completed that the leaching of mercury, lead, chromium and polychlorinated biphenyls (PCBs) was stopped. Several studies have shown high mercury concentrations in sediment, reptile, and birds at this site (Albers et al., 1986; Tsipoura et al., 2008, 2011; Obropta et al., 2008).

KFM stretches from the New Jersey Turnpike along the Belleville Turnpike to the Keegan Landfill on the western edge, and is bordered on the north and south by rail lines. The freshwater marsh has salinity between 1 to 2 ppt (Kiviat and MacDonald, 2002).

Water depth across much of the marsh ranges between 2 and 3 feet with reported inhabitants of carp, eel, and sunfish (Kiviat and MacDonald, 2002). The dominant plant species is common reed (*Phragmites australis*). Mulberry (*Morus*), hibiscus (*Hibiscus*), purple loosestrife (*Lythrum salicaria*), jewelweed (*Impatiens capensis*) and cattail (*Typha*) are also present (Kiviat and MacDonald 2004). Carp (*Cyprinus carpio*), eel (*Anguilla rostrata*), and sunsfish (*Lepomis macrochirus*) have been reported to inhabit KFM (Kiviat and MacDonald, 2004).

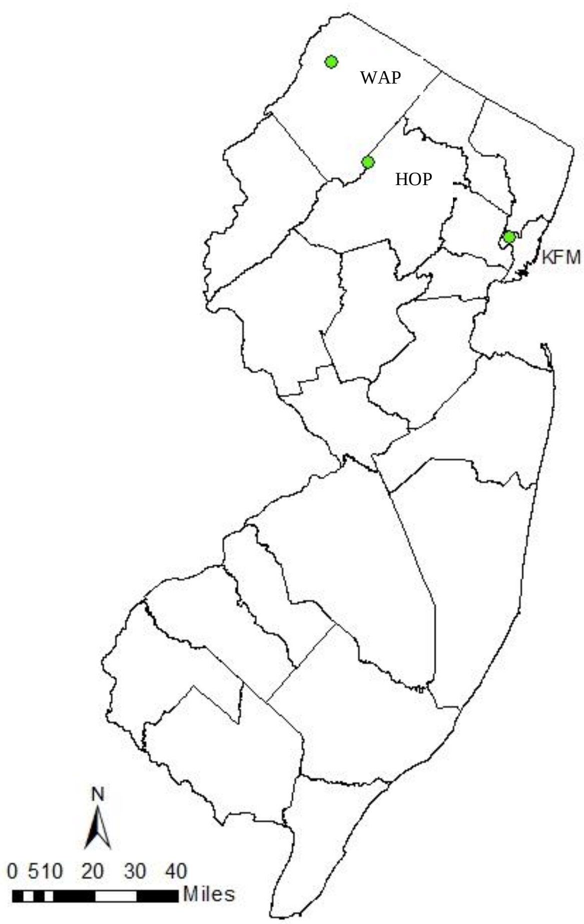

Figure 3.3. Lake Wapalanne (WAP), Lake Hopatcong (HOP) and Kearny Freshwater Marsh (KFM) (Left to right) are located in Northern New Jersey.

3.3.2 Sample Collection

Hoop and box traps were placed in previously identified snapping turtle microhabitats at each study site (Boundy and Kennedy, 2006; Eskew et al., 2010; Koper and Brooks, 2000). Traps were placed in water no deeper than 2 ft, baited with canned sardines, and checked every 24 hours (Hammer, 1969). Turtles found in traps were measured using a dial caliper (Pittsburgh Model 47257), weighed, tagged using pit tags implanted into the turtles left hind leg, and sexed. A 0.25 g tissue sample was collected from the tail using a sterile blade and biopsy needle. A carapace shaving was taken using a sterile blade. Blood samples were taken when possible from the tail using a sterile 21-gauge syringe. All samples were stored in sterile 2 ml centrifuge tubes and kept in ice until transferred to a laboratory freezer for mercury analysis. This study was conducted under a New Jersey Scientific Collection Permit following sampling protocols approved by the Montclair State University's Institutional Animal Care and Use Committee.

3.3.3 Lab Analysis

Samples were transferred to acid-washed test tubes and weighed. The sample size was restricted to approximately 0.25 g wet weight. Carapace, blood and muscle mercury concentrations are reported as wet weight. One mL of a sulfuric acid and nitric acid mixture (in a 4:1 ratio) was added to every sample, then placed in a 58°C water bath until all tissues were dissolved. Samples were then transferred to an ice bath to cool. 3 mL of 5% potassium permanganate was added to every sample while kept in an ice water bath to slow the rate of reaction. After the reaction ceased, samples were removed from the ice bath and the reaction was allowed to continue overnight at ambient temperature. Five mL of 3% hydroxylamine-hydrochloride were added to every sample as a reducing agent. One mL of stannous chloride (10%) was added to the sample and immediately analyzed by cold vapor atomic absorption spectrophotometry using a MAS-50D mercury analyzer by Bacharach, Inc. For quality assurance purposes, each sample batch included reagent blanks and certified reference material for mercury analysis (NRC-Canada DOLT-2). Certified reference material recovery within 10% of the certified value was used as the batch validation criterion. Analytical blanks were also included in each sample batch to monitor contamination during digestion and sample preparation. A calibration equation was developed using 0, 0.03, 0.1 and 0.3 ppm Hg standards to determine Hg concentration per mass of sample from the absorbance value provided by the instrument. Method detection limit (MDL) was calculated as 3 times the standard deviation of procedural blanks and all samples had Hg concentrations that exceeded the limit.

3.3.4 Statistical Analysis

Data was analyzed using JMP Pro 11.0 (SAS Institute, Cary, NC). The data was log transformed to satisfy the assumption of normal distribution. One-way analysis of variance (ANOVA) was used for the comparison between study sites, sex, size, and sample type. If significant difference was indicated, a Tukey-Kramer Honest Significant Difference (HSD) analysis was used to determine which groups were different from each other. Linear regression was used to determine relationships between mercury concentration and carapace length and weight.

3.4 Results

Fifty-eight snapping turtles were trapped at WAP. Nineteen snapping turtles were collected from HOP and 19 turtles from KFM (Table 3.1). A total of two juveniles were caught, 1 each from HOP and WAP. Juveniles whose sex could not be defined were not included in the data analysis.

Table 3.1. Number of turtles caught at each site by sex.

Site	Male	Female	Juvenile	Total
HOP	8	10	1	19
WAP	22	35	1	58
KFM	3	16	0	19

Carapace lengths did not show significant differences between male and female turtles ($p=0.4031$). Females had a mean carapace length of 27.67 cm, ranging from 11 to 41.43 cm. Males' mean carapace length was 26.99 cm, ranging from 9.7 to 39.57 cm. Carapace length did not vary among the study sites ($p=0.9527$). Mean carapace length for WAP turtles was 27.34 cm, with a site range of 9.7 to 41.43 cm. The HOP mean carapace length was 26.79 cm, with a site range of 11 to 40.9 cm. The KFM mean carapace was 27.63 cm, with a site range of 11 to 41.43 cm.

Total weight of turtles did not vary by sex, but did vary by study site ($p<0.0020$). The heaviest turtle was caught at WAP, weighing in at 17.7 kg. HOP had the highest site mean weight of 9.79 kg, and weights ranged from 2.7 to 15.3 kg. KFM and WAP had mean weights of 7.12 kg (site range of 3.6 to 14 kg) and 5.27 kg (site range of 0.42 to 17.7 kg), respectively. HOP and WAP mean weights differed by 4.52 kg with a p-value of 0.0013. KFM turtle weights were not statistically different from either WAP or HOP (p=0.7027 and 0.5304, respectively).

3.4.1 Carapace length and weight

Turtle carapace length did not have a relationship with mercury concentrations in the carapace, blood, or muscle tissue (carapace p=0.4528, blood p=0.9221, and muscle p=0.6371). Turtle weight did not correlate with mercury concentration for the carapace (p=0.9930), blood (p=0.6911), or muscle (p=0.6326).

3.4.2 Sex Variation

Neither carapace, blood, or muscle mercury concentrations varied between sexes (carapace p=0.7666, blood p=0.5753, and muscle p=0.6515). The mean mercury concentration in male carapace samples was 1.516 ± 1.016 ppm, compared to 1.546 ± 1.183 ppm in females (Table 3.2). Mean mercury concentration in juvenile carapace samples was 1.365 ppm. Mean mercury concentration in male blood samples was 0.168 ± 0.262 ppm, compared to 0.110 ± 0.184 ppm in females. Juvenile mean blood mercury concentration was 0.0313 ppm. Mean mercury concentration in male muscle samples was 0.399 ± 0.600 ppm, compared to 0.357 ± 0.590 ppm in females (Table 3.2). Mean mercury concentration in juvenile carapace samples was 0.1030 ppm.

<u>3.4.3 Site Variation</u>

Of the 3 tested sample types, blood mercury concentrations were the only sample type to show significant variation among study sites (p=0.0086), while carapace and muscle mercury concentrations showed no site variation. KFM has the highest mean blood mercury concentration of 0.314 ± 0.372 ppm, followed by WAP at 0.107 ± 0.177 ppm and HOP at 0.070 ± 0.054 ppm (Table 3.2). KFM and HOP mean concentrations differed by 0.243 ppm and have a p value of 0.0069. KFM and WAP mean concentration differed by 0.208 ppm and have a p value of 0.0329.

Carapace mean mercury concentrations were not significantly different between sites (p=0.2391). The carapace mean mercury concentration for HOP was 1.885 ppm (site range of 0.378 to 5.066 ppm), followed by WAP carapace mean concentration of 1.451 ppm (site range of 0.131 to 3.843 ppm) and KFM carapace mean mercury concentration of 1.405 ppm (site range 0.241 to 6.535 ppm) (Table 3.2).

Muscle mercury concentrations also showed no site variation (p=0.2223). KFM mean muscle mercury concentration was 0.530 ppm. WAP and HOP mean muscle concentrations were 0.344 ppm and 0.273 ppm, respectively (Table 3.2).

Table 3.2. Means ± standard deviations (SD) (line 1 in ppm), ranges of mercury concentrations (line 2 in ppm), and number (N) of samples (line 3) for carapace, blood, and muscle across all three study sites, with sexes individually and combined.

Site	**Carapace**	**Blood**	**Muscle**
	Mean ± SD Range Sample size	Mean ± SD Range Sample size	Mean ± SD Range Sample size
WAP			
All Samples	1.451 ± 0.840 0.131 - 3.843 N=58	0.107 ± 0.177 0.004 - 1.040 N=49	0.344 ± 0.587 0.009 - 2.882 N=33
Female	1.574 ± 0.9223 0.131 - 3.724 N=35	0.078 ± 0.091 0.004 - 0.341 N=30	0.254 ± 0.458 0.009 - 2.072 N=20
Male	1.266 ± 0.686 0.287 - 3.848 N=22	0.152 ± 0.259 0.005 - 1.040 N=19	0.483 ± 0.744 0.027 - 2.882 N=13
Juvenile	1.219 N=1	NA	NA
HOP			
All Samples	1.885 ± 1.385 0.378 - 5.066 N=20	0.070 ± 0.054 0.021 - 0.719 N=19	0.273 ± 0.318 0.016 - 1.002 N=18
Female	1.693 ± 1.388 0.378 - 4.633 N=9	0.081 ± 0.067 0.005 - 0.193 N=9	0.290 ± 0.377 0.0340 - 1.002 N=8
Male	2.094 ± 1.496 0.496 - 5.066 N=10	0.063 ± 0.040 0.014 - 0.149 N=9	0.278 ± 0.295 0.016 - 0.790 N=9
Juvenile	1.511 N=1	0.031 N=1	0.103 N=1
KFM			
All Samples	1.405 ± 1.454 0.241 - 6.535 N=19	0.314 ± 0.372 0.016 - 1.216 N=13	0.530 ± 0.799 0.043 - 2.902 N=15
Female	1.401 ± 1.586 0.241 - 6.535 N=16	0.232 ± 0.360 0.016 - 1.216 N=10	0.530 ± 0.799 0.043- 2.902 N=15
Male	1.425 ± 0.414 1.051 - 1.869 N=3	0.588 ± 0.317 0.239 - 0.856 N=3	N=0

3.4.4 Human Consumption Safety

All study sites have samples whose mercury concentrations exceed established consumption thresholds (Table 3.3). KFM and WAP snapping turtles had the highest percent of samples surpassing the sensitive threshold, with 73% and 49%, respectively. WAP had the highest percent of samples surpassing the EPA threshold with 36%. KFM turtles surpassed the FDA threshold most often at 13% of all samples. WAP males surpass all thresholds more often than female snapping turtles, while HOP females surpass all thresholds more often than males. Since all 3 populations have individual turtles that surpass the FDA threshold, it is possible that consuming turtles from any of these sites could pose a risk to human health.

Table 3.3. Percent of samples per site and by sex that surpass the Sensitive, EPA and FDA mercury thresholds.

	Sensitive (0.18ppm)			**EPA (0.3ppm)**			**FDA (1ppm)**		
	WAP	**HOP**	**KFM**	**WAP**	**HOP**	**KFM**	**WAP**	**HOP**	**KFM**
ALL	49%	41%	73%	36%	35%	33%	6%	12%	13%
Female	35%	43%	73%	25%	43%	33%	5%	14%	13%
Male	70%	40%	0%	54%	30%	0%	8%	10%	0%

3.5 Discussion

The study results found that neither carapace length nor weight varied between the sexes. Since this species does not experience sexual dimorphism, variation was not expected (Bergeron et al., 2007; Hopkins et al., 2013). Carapace length and weight were found to have a significant positive relationship ($p<0.0001$). Weight varied significantly between the study sites while carapace length did not. HOP turtles have the heaviest mean weight (9.79 kg) but not the highest mean mercury concentration in either blood or muscle samples. Overall, neither weight or carapace length correlated with either carapace, blood, or muscle mercury concentrations. Therefore, snapping turtle measurements does not serve as good indicators or predictors of mercury concentrations within the turtle or its environment.

Previous studies that have shown larger organisms to contain higher mercury concentrations (Bergeron et al., 2007; Smith et al., 2016), particularly in fish (Stafford and Haines, 1997). Many turtle studies have non-correlating data. For example, Turnquist et al. (2011) reported the effect of size on muscle and carapace mercury concentrations to be minimal across 10 study sites in New York State. Turnquist et al. (2011) also saw no correlation between size and mercury concentrations across sites, but within a site, larger individuals had higher mercury concentrations. A study in Colombia found inconsistent relationships between size and mercury concentration (Zapata et al., 2014). Golet and Haines (2001), Schneider et al. (2010) and Helwig and Hora (1983) found no relationship between muscle mercury concentration and body size, including carapace length and weight.

Other studies have found mercury concentrations and size to have an inverse relationship, where larger turtles have lower mercury concentrations in their tissues. Turnquist et al. (2011) recorded decreasing mercury concentrations with increasing size at two study sites in New York. Similarly, Schneider et al. (2010) found juvenile turtles to have similar mercury concentrations as adults. Inverse relationships between size and mercury concentrations were often most expected in females, as they are known to excrete mercury through egg production (Bishop et al., 1998). Turnquist et al. (2011) attributes negative correlations between size and mercury concentrations to a switch in the turtles' diet that signify that larger turtles might be less likely to actively ambush prey than younger ones.

The results of this study showed site variations in mercury concentrations in blood samples. This phenomenon has been reported by many studies and has been attributed to variations in water chemistry, landscape characteristics, food chain length, and prey preference (Chen et al., 2005; Driscoll et al., 2007; Evers, 2005; Meyers-Schone et al., 1993; Miller et al., 2005; Turnquist et al., 2011; Zapata et al., 2014). Surprisingly, carapace and muscle samples did not vary significantly between sites. Blood and muscle mercury concentrations were highest in KFM>WAP>HOP. Carapace mercury concentrations were highest in HOP>WAP>KFM.

All study sites followed the same mercury concentration pattern, with mercury content in carapace to be greater than in muscle or in blood. Carapace is often reported as the main storage site for mercury (Golet and Haines, 2001). Muscle also serves as a main storage site, but muscle bound mercury is often excreted (Bishop et al., 1998). Blood is usually a short-term storage site and mercury is only in the blood stream until it is sequestered in other parts of the body. It is believed that this happens to reduce the risk of health impacts (Burgess et al., 2008). Differences might also be due to physiological processes, with accumulation in the carapace due to long-term exposure, while muscle represents more recent accumulation or availability of mercury in the environment (Turnquist et al., 2011).

The KFM site has a long history of mercury exposure, and turtles at this site were found to have the highest blood and muscle mercury concentrations. Multiple studies at KFM have shown high mercury concentrations in sediment, reptiles, and birds at this site (Albers et al., 1986; Obropta et al., 2008; Tsipoura et al., 2008, 2011). Tsipoura et al. (2011) found detecteable levels of mercury in all tissues tested including eggs and feathers of mallard duck, red-winged blackbird, marsh wren, and geese. Obrapta et al. (2008) reported mercury concentrations of groundwater to be above New Jersey standards.

WAP blood and muscle mercury concentrations, although lower than KFM, were higher than that of HOP. WAP is located within lightly urbanized Stokes Forest in a region where waterways are not classified as impaired due to elevated mercury. A 2012 EPA report stated the main source of New Jersey's mercury to be atmospheric deposition, unless another obvious source has been identified (EPA, 2012). With no previous history of contamination, the source of mercury for WAP is most likely from dry deposition due to its relatively higher elevation and forest dominated habitat. Studies have shown waterways within heavily arboreal areas to have high mercury concentration due to foliar uptake (Evers et al., 2005; Miller et al., 2005; Cogbill and White, 1991). Leaves of tall trees trap mercury from the atmosphere, and eventually mercury is deposited to the nearby waterbodies.

KFM had the highest mercury concentrations, but only blood concentrations were significantly distinct from the other study sites. With its long exposure to pollution, much higher mercury concentrations were expected across all samples. The lack of distinction in carapace and muscle mercury concentrations between study sites could be due to the poor or short food web at KFM compared to the other two study sites. Pumpkinseeds, freshwater shrimp, and phragmites dominated KFM, showing little variation in the fish, macroinvertebrate, and plant communities. Therefore, although the food web at KFM might be less variable, turtles might be exposed to food items with higher mercury levels, although less often, limiting biomagnification.

Many of the KFM turtles were nesting females, therefore, seasonality might also play a role in the blood mercury discrepancy. Females often consume large size and large quantities of prey before leaving the safety of the water in search of a nesting spot. Kenyon et al. (2001) found that blood mercury concentrations in females increased much more rapidly than in males. This finding further suggests that the two sexes might target different prey items or that foraging behavior might differ (Meyers-Schöne and Walton, 1994; Wiener and Spry, 1996).

All 3 study sites had mercury concentrations in turtle muscles that surpassed the EPA and FDA thresholds. Multiple turtle studies have recorded mercury concentrations in tissue, but only a few have surpassed the FDA regulations, which warrants a human consumption advisory on turtles (Albers et al., 1986; Golet and Haines, 2000; Helwig and Hora, 1983; Hudson River Natural Resource Trustees, 2005; Stone et al., 1980; Turnquist et al., 2011). A study by Stone et al. (1980) found snapping turtles in the Hudson River to surpass the FDA threshold, and were deemed unsafe for human consumption. In contrast, a 2005 study by the Hudson River Natural Resource Trustees found mercury levels to be below the FDA mercury threshold. A study conducted in Connecticut by Golet and Haines (2000) found leg, shoulder and tail tissues to contain correlated mercury levels, which were below the FDA's regulations. A study conducted in Maryland and New Jersey by Albers et al. (1986) found mercury in all 32 of the snapping turtles captured. This study also found mercury concentrations to be higher in New Jersey turtles but below the allowed FDA mercury concentration in fish. In 1998 and 1999 the Patrick Center for Environmental Research conducted a study in various areas of concern in New Jersey. They found all turtles tested for mercury to have detectable levels but these levels were below the FDA threshold. A study conducted in Minnesota found mercury levels in snapping turtle meat to range from 0.30 to 0.50 ppm, which are below the allowed FDA limit (Helwig and Hora, 1983). Another study examining New York snapping turtles found muscle mercury concentration between 0.041 to 1.50 ppm, with 61% surpassing the EPA's threshold (Turnquist et al., 2011).

The results of our study suggest consumption advisories are needed for all study sites, and especially in KFM. The presence of detectable mercury levels in snapping turtles is a real threat. Thus, mercury levels in these animals should be continuously studied in order to detect any increases that can be potentially harmful to human consumers. The mean muscle mercury concentration of all turtles collected in this study was 0.371 ppm. Based on the Natural Resource Defense Council (NRCD, 2016) calculations of mercury in seafood, the general population should be advised to consume no more than two 6 oz servings of snapping turtle per month. Meanwhile, due to muscle samples surpassing the sensitive population threshold, the sensitive population should be advised to avoid the consumption of snapping turtle meat.

3.6 Conclusions

The results of this study suggest that mercury concentrations, even within the same species, can be highly variable among sites. Many studies have suggested spatial variation, sex, size, and length of the food web to influence contaminant concentrations within the same species (Becker et al., 2002; McIntyre and Beauchamp, 2007). However, mercury concentrations in this study were not heavily impacted by turtle sex, size or location, eliminating snapping turtles as possible field mercury indicators. When the data is combined, patterns emerge that suggest more than one variable is at play.

This study suggests the need for human consumption advisories based upon harvest location, but not necessarily guided by a site's historical contamination. The site we assumed to be the least contaminated displayed high mercury concentrations in turtle tissues. Muscle mercury concentrations were elevated at all three sites, with many surpassing the sensitive populations, EPA and FDA thresholds. Particularly, snapping turtles should not be consumed by women who are pregnant, of childbearing age, or by children. The general population should be warned to consume snapping turtles no more than twice a month.

3.7 Literature Cited

Albers, P. H., Sileo, L., and Mulhern, B. M. (1986) Effects of environmental contaminants on snapping turtles of a tidal wetland. *Archives of Environmental Contamination and Toxicology*, 15(1), 39-49.

Becker, P. H., González-Solís, J., Behrends, B., and Croxall, J. (2002) Feather mercury levels in seabirds at South Georgia: influence of trophic position, sex and age. *Marine Ecology Progress Series*, 243, 261-269.

Bergeron, C. M., Husak, J. F., Unrine, J. M., Romanek, C. S., and Hopkins, W. A. (2007) Influence of feeding ecology on blood mercury concentrations in four species of turtles. *Environmental Toxicology Chemistry*, 26, 1733-1741.

Bishop, C. A., Brown, G. P., Brooks, R. J., Lean, D. R. S., and Carey, J. H. (1994) Organochlorine contaminant concentrations in eggs and their relationship to body size, and clutch characteristics of the female common snapping turtle (*Chelydra serpentina serpentina*) in Lake Ontario, Canada. *Archives of Environmental Contamination and Toxicology*, 27(1), 82-87.

Bloom, N. S. (1992) On the chemical form of mercury in edible fish and marine invertebrate tissue. *Canadian Journal of Fisheries and Aquatic Sciences*, 49, 1010-1017.

Boening, D. W. (2000) Ecological effects, transport, and fate of mercury: a general review. *Chemosphere*, 40(12), 1335-1351.

Boundy, J., and Kennedy, C. (2006) Trapping Survey Results for the Alligator Snapping Turtle (*Macrochelys temmickii*) in Southeastern Louisiana, with comments on Exploitation. *Chelonian Conservation and Biology*, 5, 3-9.

Burger, J., and Gochfeld, M. (2005) Heavy metals in commercial fish in New Jersey. *Environmental Research*, 99(3), 403-412.

Burgess, N. M., and Meyer, M. W. (2008) Methylmercury exposure associated with reduced productivity in common loons. *Ecotoxicology*, 17(2), 83-91.

Centers for Disease Control and Prevention (2004) Blood Mercury Levels in Young Children and Childbearing-Aged Women --- United States, 1999-2002 Source:https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5343a5.htm.

Chen, C. Y., Stemberger, R. S., Kamman, N. C., Mayes, B., and Folt, C. (2005) Patterns of mercury bioaccumulation and transfer in aquatic food webs across multi-lake studies in the northeast U.S. *Ecotoxicology*, 14, 135-147.

Cogbill, C. V., and White, P. S. (1991) The latitude-elevation relationship for spruce-fir forest and treeline along the Appalachian mountain chain. *Plant Ecology*, 94(2), 153-175.

Driscoll, C. T., Han, Y. J., Chen, C. Y., Evers, D. C., Lambert, K. F., Holsen, T. M., and Munson, R. K. (2007) Mercury contamination in forest and freshwater ecosystems in the northeastern United States. *Biological Science*, 57(1), 17-28.

Environmental Protection Agency (2009) TMDL Report. Source:https://iaspubepagov/waters10/attains_impaired_waterstmdl_report?p_tmdl_id=37909&p_report_type=.

Environmental Protection Agency (2010) National Recommended Water Quality Criteria. Source: https://wwwepagov/wqc/national-recommended-water-quality-criteria-human-health-criteria-table.

Environmental Protection Agency (2012) New Jersey Water Quality Assessment Report. Source:https://iaspub.epa.gov/waters10/attains_index.control?p_area=NJ#causes.

Environmental Protection Agency (2013) Fish Tissue Analysis For Mercury and PCBs from a New York City Commercial Fish/Seafood Market. Source:http://nepis.epa.gov/Exe/ZyPDF.cgi/P100HCKB.PDF?Dockey=P100HCKB.PDF.

Eskew, E. A., Price, S. J. and Dorcas, M. E. (2010) Survival and recruitment of semi-aquatic turtles in an urbanized region. *Urban Ecosystems*, 13, 365-373.

Evers, D. C., Burgess, N. M., Champoux, L., Hoskins, B., Major, A., Goodale, W. M., and Daigle, T. (2005) Patterns and interpretation of mercury exposure in freshwater avian communities in northeastern North America. *Ecotoxicology*, 14(1-2), 193-221.

Federal Drug and Food Administration (2013) Volume IV. Lab Manual 6.1 Introduction. Source:https://www.fda.gov/scienceresearch/fieldscience/laboratorymanual/ucm172150.htm#6_1_3.

Fitzgerald, W. F. (1995) Is mercury increasing in the atmosphere? The need for an atmospheric mercury network (AMNET). *Water Air Soil Pollution*, 80, 245-254.

Florida Fish and Wildlife Conservation Commission (2012) Three turtle farmers charged and two arrested for illegal turtle trafficking. Source:http://wwwjusticegov/usao/fls/PressReleases/120503-02html.

Gochfeld, M. (2003) Cases of mercury exposure bioavailability and absorption. *Ecotoxicology and Environmental Safety*, 56, 174-179.

Golet, W. J., and Haines T. A. (2001) Snapping turtles (*Chelydra serpen*tina) as monitors for mercury contamination of aquatic environments. *Environmental Monitoring and Assessment*, 71(3), 211-220.

Hammer, D. A. (1969) Parameters of a marsh snapping turtle population, Lacreek Refuge, South Dakota. *Journal Wildlife Management*, 33(4), 995-1005.

Helwig, D. D., and Hora, M. E. (1983) Polychlorinated biphenyl, mercury, and cadmium concentrations in Minnesota snapping turtles. *Bulletin of Environmental Contamination and Toxicology*, 30(1), 186-190.

Hopkins, W. A., Bodinof, C., Budischak, S., and Perkins, C. (2013) Nondestructive indices of mercury exposure in three species of turtles occupying different trophic niches downstream from a former chloralkali facility. *Ecotoxicology*, 22(1), 22-32.

Hudson River Natural Resource Trustees (2005) Data report for screening for organochlorine and metal contaminant levels in Hudson River New York Bullfrogs (Rana catesbeiana) and snapping turtle (*Chelydra serpentina serpentina*) Hudson River Natural Resource Damage Assessment US Department of Commerce Silver Spring MD.

Kenyon, L. O., Landry, A. M., and Gill, G. A. (2001) Trace Metal Concentrations in Blood of the Kemp's Ridley Sea Turtle (*Lepidochelys kempii*). *Chelonian Conservation Biology,* 4(1), 128-135.

Kiviat, E., and MacDonald, K. (2002) Hackensack Meadowlands, New Jersey, biodiversity: A review and synthesis. New York: Hudsonia, Ltd.

Kiviat, E., and MacDonald, K. (2004) Biodiversity patterns and conservation in the Hackensack Meadowlands, New Jersey. *Urban Habitats*, 2(1), 28-61.

Koper, N., and Brooks, R. J. (2000) Environmental constraints on growth painted turtles (*Chrysemys picta*). *Herpetologica,* 56, 421-432.

McIntyre, J. K., and Beauchamp, D. A. (2007) Age and trophic position dominate bioaccumulation of mercury and organochlorines in the food web of Lake Washington. *Science of the Total Environment*, 372(2), 571-584.

Meyers- Schöne, L., Shugart, L. R., Walton, B. T., and Beauchamp, J. J. (1993) Comparison of two freshwater turtle species as monitors of radionuclide and chemical contamination: DNA damage and residue analysis. Environmental. *Toxicology and Chemistry*, 12(8), 1487-1496.

Meyers-Schöne, L., and Walton, B. T. (1994) Turtles as monitors of chemical contaminants in the environment. In Reviews of environmental contamination and toxicology (pp. 93-153). Springer New York.

Miller, E. K., Vanarsdale, A., Keeler, G. J., Chalmers, A., Poissant, L., Kamman, N. C., and Brulotte, R. (2005) Estimation and mapping of wet and dry mercury deposition across northeastern North America. *Ecotoxicology*, 14(1), 53-70.

Morel, François M. M., Kraepiel Anne M. L., and Amyot, M. (1998) The Chemical Cycle and Bioaccumulation of Mercury. *Annual Review of Ecology and Systematics*, 29, 543-566.

New Jersey Department of Environmental Protection (2002) Volume II Exposure and Impacts and Volume III Sources of Mercury to New Jersey's Environment. Source:http://wwwnjgov/dep/dsr/mercury_task_forcehtm.

New Jersey Department of Environmental Protection (2009) New Jersey Mercury Reduction Action Plan. Source: http://www.state.nj.us/dep/dsr/mercury/final-hg-plan11-5.pdf.

New Jersey Department of Environmental Protection (2016) Source:http://wwwstatenjus/dep/fgw/pdf/2016/digfsh16pdf.

Natural Resources Defense Council (2016) Calculations for Mercury in Seafood. Source: https://www.nrdc.org/sites/default/files/mercury-in-tuna-calculation-summary.pdf.

Obropta, C., Ravit, B., and Yeargeau, S. (2008) Kearny Marsh Hydrology Study. Rutgers University. Source:http://cues.rutgers.edu/kearnymarsh/pdfs/53_NJMC_Final_Report_062008.pdf.

Quinn, J. R. (1997) Fields of sun and grass: an artist's journal of the New Jersey Meadowlands. Rutgers University Press.

Schneider, L., Belger, L., Burger, J., Vogt, R. C., and Ferrara, C. R. (2010). Mercury Levels in Muscle of Six Species of Turtles Eaten by People Along the Rio Negro of the Amazon Basin. *Archives Of Environmental Contamination and Toxicology*, 58(2), 444-450.

Senneke, D. (2005) Declared Turtle Trade From the United States. The World Chelonian Trust. Source: http://wwwcheloniaorg/articles/us/USmarket_8htm.

Smith, C. A., Ackerman, J. T., Willacker, J. J., Tate, M. T., Lutz, M. A., Fleck, J. A., and Davis, J. A. (2016) Spatial and temporal patterns of mercury concentrations in freshwater fish across the Western United States and Canada. *Science of the Total Environment*, 568, 1171-1184.

Stafford, C. P., and Haines, T. A. (1997) Mercury concentrations in Maine sport fishes. *Transactions of the American Fisheries Society*, 126(1), 144-152.

Stern, A. H., Gochfeld, M. C., Weisel, and Burger, J. (2001) Mercury and methylmercury exposure in the New Jersey pregnant population. *Archives of Environmental Health: An International Journal*, 56(1), 4-10.

Stone, W. B., Kiviat, E., and Butkas, S. A. (1980) Toxicants in snapping turtles. *New York Fish and Game Journal*, 27, 39-50.

Tsipoura, N., Burger, J., Feltes, R., Yacabucci, J., Mizrahi, D., Jeitner, C., and Gochfeld, M. (2008) Metal concentrations in three species of passerine birds breeding in the Hackensack Meadowlands of New Jersey. *Environmental Research*, 107(2), 218-228.

Tsipoura, N., Burger, J., Newhouse, M., Jeitner, C., Gochfeld, M., and Mizrahi, D. (2011) Lead mercury cadmium chromium and arsenic levels in eggs feathers and tissues of Canada geese of the New Jersey Meadowlands. *Environmental Research*, 111(6), 775-784.

Turnquist, M. A., Driscoll, C. T., Schulz, K. L., and Schlaepfer, M. A. (2011) Mercury concentrations in snapping turtles (Chelydra serpentina) correlate with environmental and landscape characteristics. *Ecotoxicology*, 20(7), 1599-608.

United Nations Environment Programme (2013) Global Mercury Assessment, Sources, Emissions, Releases and Environmental Transport. Source:http://www.unep.org/chemicalsandwaste/Mercury/Informationmaterials/ReportsandPublications/tabid/3593/Default.aspx.

van Dijk, P. P. (2012) Chelydra serpentina. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>.

Ward, D. M., Nislow, K. H., and Folt, C. L. (2010) Bioaccumulation syndrome: identifying factors that make some stream food webs prone to elevated mercury bioaccumulation. *New York Academy of Science*, 1195, 62-83.

Wiener, J. G., and Spry, D. J. (1996) Toxicological significance of mercury in freshwater fish In: Beyer WN Heinz GH Redmon-Norwood AW (eds) Environmental contaminants in wildlife: interpreting tissue concentrations. Lewis Publishers Boca Raton. 297–334.

Wildlife Conservation Society (2011) Turtles in Trouble: The World's 25+ Most Endangered Tortoises and Freshwater Turtles-2011. Source:http://wwwwcsorg/conservation-challenges/natural-resource-use/hunting-and-wildlife-trade/the-turtle-tradeaspx.

Zapata, L., Bock, B., and Palacio, J. (2014) Mercury Concentrations in Tissues of Colombian Slider Turtles, Trachemys callirostris, from Northern Colombia. *Bulletin Of Environmental Contamination and Toxicology*, 92(5), 562-566.

Chapter 4. Mercury and Trophic Position of Snapping Turtles

4.1 Abstract

Stable isotopes provide insight into the feeding ecology of a species, which in turn affects the transfer of contaminants such as mercury throughout the food web. With snapping turtles experiencing increasing harvesting pressure from human consumption, it is crucial to understand the dynamics and transfer of mercury throughout the predator-prey interactions. This study's objective was to determine trophic positions of snapping turtles and their prey, and their association with mercury concentrations. This study also mapped the food webs and determined trophic levels for three study sites with varying histories of mercury exposure. The results of this study show that snapping turtles from two study sites hold the highest trophic positions. Snapping turtles are omnivorous; their diets include a wide range of organisms, mainly depending on the availability of food sources at their habitats. The results of this study found snapping turtles as the top predators at two of the three study sites. No relationship was observed between $\delta^{15}N$, trophic position and mercury concentrations, suggesting mercury accumulation was the driving force behind elevated mercury in selected study sties.

4.2 Introduction

Stable isotope analysis is often used to depict food webs (Aresco et al., 2015; Bezerra et al., 2015; Chateauvert et al., 2015; Di Beneditto et al., 2017; Lara et al., 2012; Middelburg, 2014; Post, 2002). Understanding local predator-prey interactions and energy flows are increasingly important in the environmental management field. Stable isotope analysis (SIA) has emerged as a crucial tool for predicting food web structure and organisms' trophic positions, determining energy pathways, as well as for the quantification of contaminant transfer. Stable isotope analysis provides a glance into the diet of an organism, replacing "snap shot" methods such as feeding observations, fecal collection, stomach flushing, and dissection (Pearson et al., 2013; Rowe, 1992). Use of SIA in this manner assumes an organism's naturally occurring isotopic make up varies in a manner that is traceable in nature, and an organism's tissues reflect the composition of the foods consumed (Lara et al., 2012; Post, 2002).

The stable isotope compositions of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) are essential in determining trophic positions and therefore crucial in constructing food webs. $\delta^{15}N$ often exhibits a constant enrichment of 2.5‰ to 3.4‰ between trophic levels (DeNiro and Epstein, 1978; Minawaga and Wada, 1984; Peterson and Fry, 1987). This pattern is believed to arise from the preferential excretion of the lighter isotope (Peterson and Fry, 1987). Therefore organisms feeding at higher trophic levels will exhibit more strongly positive $\delta^{15}N$ values (Godley et al., 1998). Likewise, but to a lesser degree, $\delta^{13}C$ increases 0‰ to 1‰ per trophic level (DeNiro and Epstein, 1978; Miniwaga and Wada, 1984; Peterson and Fry, 1987). Since $\delta^{13}C$ only shows a slight enrichment, it is not a strong indicator of trophic position, and is more commonly used to identify carbon sources and pathways (DeNiro and Epstein, 1978; Peterson and Fry, 1987).

Stable isotopes have relatively slow turnover rates, allowing researchers to infer diets from days to years, depending on the tissue media studied (Dalerum and Agerbjorn, 2005; Tieszen et al., 1983). Muscle, for example, incorporates diet information over several months, usually between 5 to 7 months (Aresco et al., 2015; Seminoff et al., 2007). Fish studies often use white muscle tissue because it is easy to sample and represents several months of dietary intake (Colborne and Robinson, 2013). Turtle studies have used blood, muscle, carapace, and nail samples to determine dietary intake. Blood provides insight into several weeks of dietary information (Hopkins et al., 2013). Carapace and nails provide a much longer view, up to several years (Hopkins et al., 2013).

The use of stable isotope compositions of carbon and nitrogen to estimate trophic positions and food web structures, along with the quantification of contaminant transfer (such as mercury) have been studied by numerous researchers (Atwell et al., 1998; Bezerra et al., 2015; Cabana and Rasmussen, 1994; Campbell et al., 2003; Rognerud et al., 2002; Tadiso et al., 2011). Mercurys' toxicity and bioavailabitly have made it a contaminant of concern (NJDEP, 2002). Once in an aquatic environment, mercury in the sediment can be methylated by anaerobic methanogenic- or sulfate-dependent bacteria, producing methylmercury (MeHg) (Gochfeld, 2003). MeHg is highly associated with diatoms, allowing its assimilation, retention, bioaccumulation, and biomagnification, making it readily available and persistent in organisms that consume diatoms (Boening, 2000; Morel et al., 1998). As a neurotoxin, MeHg has the ability to pass the blood-brain barrier allowing it to participate in cellular and nuclear processes, making mercury a serious threat to humans (Boening, 2000). Therefore, mercury has been a major focus for human consumption advisories and guidelines recommended by government agencies.

54% of all assessed river and stream miles as well 87% of lakes, reservoirs, and ponds in New Jersey were categorized as impaired due to elevated mercury concentrations (NJDEP, 2016). The common snapping turtle (*Chelydra serpentina serpentina*) is the second largest freshwater turtle in North America, which has made it a target game species with an estimated 655,541 snapping turtles exported in 2009 (van Dijk, 2012). Snapping turtles can live up to 40 years of age, potentially posing a human consumption risk. It is crucial to study the food webs of long-lived predators consumed by humans to assess human consumption risks.

Snapping turtles are considered to be omnivorous, consuming vegetation, invertebrates, fish, and carrion. However, their place in food webs is debated. This study focuses on the food webs with snapping turtle as a terminal predator at 3 study sites with varying degrees of contamination exposure. The goal was to identify where within a food web the snapping turtles were located. This study also examined relationships between stable isotope values, mercury concentrations, and body length of study organisms.

4.3 Methods

4.3.1 Study Sites

Three study sites were selected across a gradient along northern New Jersey representing various levels of human disturbance and contamination sources (Figure 4.1). Sites were also selected based on their accessibility and presence of snapping turtle habitats reachable by foot.

The first study site, Lake Wapalanne is a 12 acre artificial lake created in 1933 (hereafter denoted WAP). WAP is located within the 16,025 acre Stokes Forest in the Kittatinny Mountains, Sussex County, New Jersey. The lake is part of Montclair State University's New Jersey School of Conservation, which serves as an environmental education facility. The lake does not experience much recreational activity except for canoeing by school children. The dominant fish in WAP are sunfish (*Lepomis gobbosus and Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*). WAP is fed by the Big Flat Brook, which was not found to pose any mercury risk (EPA, 2009).

The second study site, Lake Hopatcong, is the largest freshwater body in New Jersey encompassing 2,500 acres within Morris and Sussex Counties (hereafter denoted HOP). In the mid 1800s the lake fed the Morris Canal, a 90 mile waterway that ran from Newark to Philipsburg, for the purpose of transporting coal, iron ore, and zinc ore. Today the lake is heavily used for recreational activities such as fishing, boating, kayaking, jets skiing, and other water sports. The lake has been stocked with rainbow (*Oncorhynchus mykiss*), brook (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*). Natural inhabitants include largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), rock bass (*Ambloplites rupestris*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gobbosus*), chain pickerel (*Esox niger*), channel catfish (*Ictalurus punctatus*), bullhead (*Ameiurus melas*), carp (*Cyprinus carpio*), yellow (*Perca Flavescens*) and white perch (*Morone americana*). The entire lake is considered impaired due to findings of elevated mercury levels in fish (EPA, 2009). Elevated mercury concentrations are attributed to atmospheric deposition (EPA, 2009).

The third study site is the Kearny freshwater marsh, a 344 acre impoundment owned by the New Jersey Meadowlands Commission (NJMC) (herafter denoted KFM) with a long history of pollution. Prior to human alteration the marsh was dominated by white cedar swamp. As the swamp dried the area became dominated by common reed and later filled by rainwater, leachate, and runoff from the surrounding urban areas. KFM has been affected by contaminants from combined sewer overflows, municipal stormwater discharge, regional atmospheric deposition, and improperly closed landfills, most notably the Keegan Landfill (Tsipoura et al., 2008).

Since its establishment in the 1940's to 2008, the 110 acre Keegan Landfill was a major source of contamination to the Kearny freshwater marsh (Tsipoura et al., 2008). Even through its inactive years from 1972 to 2008, the Keegan landfill leached approximately 246,000 liters (65,000 gallons) of contaminated liquids per day into Kearny Marsh (Quinn, 1997). It wasn't until 2008 when NJMC's containment project was completed that the leaching of mercury, lead, chromium and polychlorinated biphenyls (PCBs) were stopped. Several studies have shown high mercury concentrations in sediment, reptile, and birds at this site (Albers et al., 1986; Obropta et al., 2008; Tsipoura et al., 2008, 2011).

KFM stretches from the New Jersey Turnpike along the Belleville Turnpike to the Keegan Landfill on the western edge, and is bordered on the north and south by rail lines. The freshwater marsh has salinity between 1 to 2 ppt (Kiviat and MacDonald, 2002). Water depth across much of the marsh ranges between 2 and 3 feet with reported inhabitants of carp, eel, and sunfish (Kiviat and MacDonald, 2002). The dominant plant species is common reed (*Phragmites australis*). Mulberry (*Morus*), hibiscus (*Hibiscus*), purple loosestrife (*Lythrum salicaria*), jewelweed (*Impatiens capensis*) and cattail (*Typha*) are also present (Kiviat and MacDonald 2004). Carp (*Cyprinus carpio*), eel (*Anguilla rostrata*), and sunsfish (*Lepomis macrochirus*) have been reported to inhabit KFM (Kiviat and MacDonald, 2004).

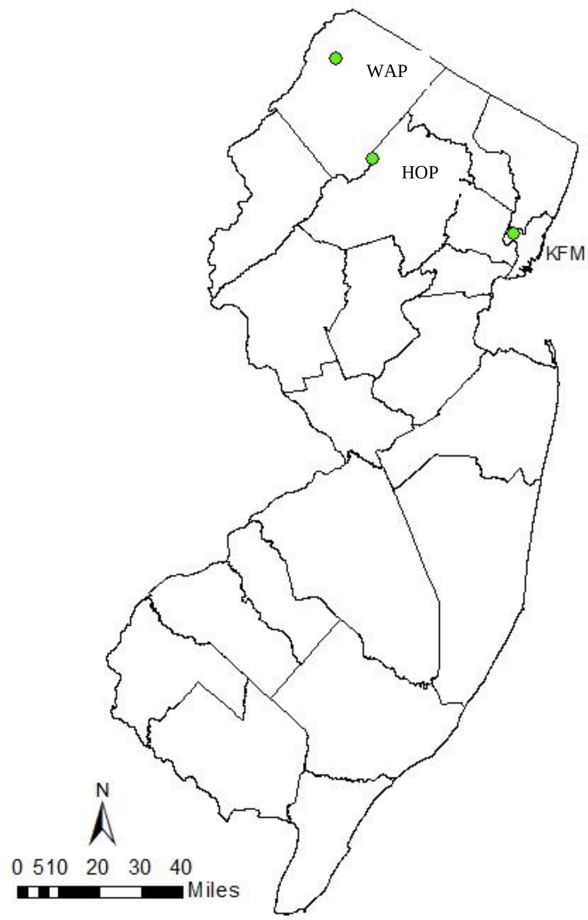

Figure 4.1. Map of study sites Lake Wapalanne (WAP), Lake Hopatcong (HOP) and Kearny Freshwater Marsh (KFM) (left to right).

4.3.2 Sample Collection

All animals and tissue samples were collected under a Montclair State University Institutional Animal Care permit, New Jersey Scientific Collection permit, and New Jersey Fishing, and Salvage permit. Hoop and box traps were placed in sites sutiable as snapping turtle microhabitats (Boundy and Kennedy, 2006; Eskew et al., 2010; Koper and Brooks, 2000). Traps were set for one consecutive week and checked and baited with canned sardines every 24 hours (Hammer, 1969). If the target species was not caught within the first week, traps were placed at new locations. Trapping took place from May to September, 2013 to 2015. Turtles found in traps were measured using a dial caliper (Pittsburgh, Model 47257), weighed using a blance, tagged using pit tags implanted into the turtles left hind leg, sexed, sampled, and released (Boundy and Kennedy, 2006; Milan and Melvin, 2001).

Muscle samples were collected from the tail to avoid injuring or affecting the turtle's mobility when released. Prior to sample collection the incision area was sanitized and numbed using lidocane. Lidocane was superficially injected into the area according to the turtles weight. A sterile blade and biopsy needle were then used to collect a 0.25 g muscle sample. The site of incision was cleaned and closed using vetbond. Turtles were held until the vetbond had settled and incision site looked cleaned and sealed. All samples were stored in sterile 2 mL centrifuge tubes and kept in ice until transferred to the laboratory freezer.

Fish were collected using minnow traps or donated by local licensed fishermen. Species collected were based on their availabilities at the study site and whether they were recorded as prey items in the snapping turtle diets. Once collected, fish were measured and filleted. White muscle tissue was homogenized prior to freezing for mercury analysis.

Macroinverterbrates were collected using dipnets, then picked, sorted, and identified to the lowest taxa possible. Macroinvertebrates were stored in individual plastic bags according to functional feeding groups, where they were kept in water for 4 hours prior to freezing to allow excretion.

4.3.3 Stable Isotope Analysis (SIA)

Stable isotopes samples were freeze-dried for 24 to 48 hours or until samples were completely dry. Samples were ground to a flour-like consistency using a mortar and pestle. Sub-samples of 0.600 to 1.200 mg were packed into 4*6 mm tin capsules. A total of 97 samples were sent to the Colorado Plateau Stable Isotope Laboratory at Northern Arizona University, which conducted Elemental Analysis - Isotope Ratio Mass Spectrometry for analysis of stable isotopes. Stable isotope values were calculated using the following equations:

$$\delta^{13}C = \left[\frac{\left(\frac{^{13}\mathrm{C}}{^{12}\mathrm{C}}\right)_{sample}}{\left(\frac{^{13}\mathrm{C}}{^{12}\mathrm{C}}\right)_{standard}} - 1\right] * \ 1000 \qquad \text{eqn. 1}$$

and

$$\delta^{15}N = \left[\frac{\left(\frac{^{15}\mathrm{N}}{^{14}\mathrm{N}}\right)_{sample}}{\left(\frac{^{15}\mathrm{N}}{^{14}\mathrm{N}}\right)_{standard}} - 1\right] * \ 1000 \qquad \text{eqn. 2}$$

$\delta^{15}N$ signature were converted to trophic position (TP) using the following equations:

$$TP = \left[\frac{(\delta^{15}N_i - \delta^{15}N_{pc})}{3.4}\right] + 1 \qquad \text{eqn. 3}$$

where $\delta^{15}N_i$ represents the average $\delta^{15}N$ value for species *i*, $\delta^{15}N_{pc}$ represents the average $\delta^{15}N$ value for the primary consumer used for analysis, 3.4 is the mean $\delta^{15}N$ trophic enrichment per trophic level, and 1 is the trophic position of the baseline organism or primary consumer.

Baseline organisms were characterized by being short-lived consumers that feed near the base of the food web (Post, 2002). Gastropods are the baseline organism for WAP and HOP (Chumchal et al., 2008 and 2011). Due to the lack of macroinvertebrate variation in KFM, freshwater shrimp were used as the baseline organism (Chumchal et al., 2008).

4.3.4 Mercury Analysis

Samples were transferred to acid-washed test tubes and weighed. The sample size was restricted to approximately 0.25 g wet weight. Carapace, blood and muscle mercury concentrations are reported as wet weight. One mL of a sulfuric acid and nitric acid mixture (in a 4:1 ratio) was added to every sample, then placed in a 58°C water bath until all tissues were dissolved. Samples were then transferred to an ice bath to cool, and 3 mL of 5% potassium permanganate was added to every sample while kept in an ice water bath to slow the rate of reaction. After the reaction ceased, samples were removed from the ice bath and the reaction was allowed to continue overnight at ambient temperature. Five mL of 3% hydroxylamine-hydrochloride were added to every sample as a reducing agent. One mL of stannous chloride (10%) was added to the sample and immediately analyzed by cold vapor atomic absorption spectrophotometry using a MAS-50D mercury analyzer by Bacharach, Inc. For quality assurance purposes, each sample batch included reagent blanks and certified reference material for mercury analysis (NRC-Canada DOLT-2). Certified reference material recovery within 10% of the certified value was used as the batch validation criterion. Analytical blanks were also included in each sample batch to monitor contamination during digestion and sample preparation. A calibration equation was developed using Hg standards with concentrations of 0, 0.03, 0.1 and 0.3 ppm. The linear equation was used to calculate Hg per mass of sample from the absorbance value provided by the instrument. Method detection limit (MDL) was calculated as 3 times the standard deviation of procedural blanks and all samples had Hg concentrations that exceeded the limit.

4.3.5 Statistical Analysis

Data was analyzed using JMP Pro 11.0 (SAS Institute, Cary, NC). The data was log transformed to satisfy the assumption of normal distribution. One-way analysis of variance (ANOVA) was used for the comparison between study sites. If significant difference was indicated, a Tukey-Kramer Honest Significant Difference (HSD) analysis was used to determine which groups were different from each other. Linear regression was used to determine relationships between mercury concentration and isotopic signatures.

4.4 Results

The mean body mass and mean carapace length for HOP snapping turtles (n=8) was 9.27± 3.11 kg and 23.54 ± 9.34 cm, respectively. WAP snapping turtles mean body mass and mean carapace length (n=5) was 10.7 ± 1.37 kg and 28.23 ± 9.30 cm, respectively. Lastly, the mean carapace length for KFM snapping turtles (n=8) was 28.01 ± 4.66 cm. KFM turtles were all collected as road casualties therefore weight data was not collected. Regression analysis showed no significant difference between turtle carapace length (p=0.5260) or weight (p=0.4829) among the 3 study sites.

4.4.1 Stable Isotope Results

KFM snapping turtles had the highest mean $\delta^{15}N$ value and the highest mean $\delta^{13}C$ value, 12.49 ± 3.50‰ and -22.12 ± 3.90‰, respectively (Table 4.1). The HOP mean $\delta^{15}N$ value was 11.89 ± 3.28‰ and the mean $\delta^{13}C$ value was -27.49 ± 1.35‰. Lastly, WAP snapping turtles had a mean $\delta^{15}N$ value of 9.98 ± 3.91 ‰ and mean $\delta^{13}C$ value of -24.08 ± 4.64‰ (Table 1).

The results indicated KFM snapping turtles feed from a wide range of carbon sources (-29.49 to -16.24 ‰) (Table 4.1), as did WAP snapping turtles, which fed from a range of carbon sources between -27.4 to -15.9‰. HOP snapping turtles fed from a much narrower range of carbon sources between -29.6 to -25.64‰, suggesting that these turtles are more heavily dependent on consuming vegetation and specifically C_3 plants. The broader carbon range exhibited by WAP and KFM turtles indicates these turtles feed on a variety of food sources.

Table 4.1. Fish species and snapping turtle mean ± standard deviation (SD), range of $\delta^{15}N$ and $\delta^{13}C$ values (‰), and number of samples (N) for Lake Hopatcong (HOP), Lake Wapanlanne (WAP), and Kearny Freshwater Marsh (KFM).

Species	N	$\delta^{15}N$ Mean ± SD	$\delta^{15}N$ Range	$\delta^{13}C$ Mean ± SD	$\delta^{13}C$ Range
HOP					
Chironomidae	3	2.0 ± 0.02	1.98 to 2.02	-25.25 ± 0.23	-25.52 to -25.12
Snail	3	2.70 ± 0.19	2.55 to 2.92	-28.54 ± 0.26	-28.79 to -28.27
Dragonfly	3	3.67 ± 0.25	3.39 to 3.85	-29.08 ± 0.05	-29.08 to -29.03
Damselfly	3	4.18 ± 0.17	3.99 to 4.29	-30.54 ± 0.20	-30.65 to -30.45
Pumpkinseed	5	14.69 ± 0.41	14.19 to 15.07	-26.76 ± 0.36	-27.19 to -26.21
Bluegill	5	13.77 ± 0.65	13.70 to 14.81	-26.58 ± 1.70	-27.93 to -23.78
Largemouth Bass	5	14.71 ± 3.02	9.32 to 16.37	-25.61 ± 2.60	-27.13 to -20.99
Catfish	5	14.82 ± 0.28	14.48 to 15.12	-28.52± 1.33	-29.51 to -26.26
Chain Pickerel	4	16.27 ± 0.03	16.24 to 16.31	-25.98 ± 0.05	-26.05 to -25.93
Snapping Turtle	8	11.89 ± 3.28	6.41 to 14.92	-27.49 ± 1.35	-29.63 to -25.64
WAP					
Mayfly	1	.22		-27.02	
Scud	3	0.27 ± 0.95	-0.82 to 0.91	-21.92 ± 4.5	-24.62 to -16.73
Sow bugs	3	0.38 ± 0.14	0.25 to 0.52	-25.6 ± 0.16	-25.75 to -25.43
Dragonfly	3	2.32 ± 0.06	2.25 to 2.37	-23.76 ± 0.22	-23.96 to -23.53
Snail	3	2.74 ± 0.11	2.66 to 2.86	-21.07 ± 0.20	-21.29 to -20.91
Alder and Damselfly	1	4.54		-22.21	
Pumpkinseed	5	8.30 ± 0.18	8.13 to 8.54	-22.17 ± 0.51	-22.78 to -21.48
Bluegill	5	7.83 ± 0.443	7.40 to 8.41	-22.02 ± 0.80	-23.29 to -21.34
Largemouth Bass	5	8.97 ± 1.81	5.76 to 10.00	-21.77 ± 1.27	-23.21 to -20.58
Snapping Turtle	5	9.99 ± 3.91	3.83 to 14.27	-24.08 ± 4.64	-27.42 to -15.9
KFM					
Shrimp	3	7.77 ± 0.05	7.72 to 7.81	-21.66 ± 0.24	-21.92 to -21.45
Pumpkinseed	5	10.92 ± 0.08	10.79 to 11.00	-24.48 ± 0.45	-24.91 to -23.8
Snapping Turtle	8	12.49 ± 3.50	7.09 to 16.76	-22.12 ± 3.90	-29.49 to -16.24

$\delta^{13}C$ stable isotope values varied among sites for bluegills ($p=0.0006$), largemouth bass ($p=0.0180$), pumpkinseeds ($p<0.0001$) and snapping turtles ($p=0.0172$). $\delta^{15}N$ stable isotope values varied among sites for bluegills ($p<0.0001$), largemouth bass ($p=0.0066$), and pumpkinseeds ($p<0.0001$). Snapping turtles $\delta^{15}N$ values did not vary significantly among sites. Chain pickerel and catfish were only found in HOP and were not analyzed.

Both bluegill and catfish had a significant relationship between total length and $\delta^{13}C$ values ($p=0.0207$ and 0.0017, respectively). Total body length of bluegills was the only parameter to have a significant correlation with $\delta^{15}N$ values ($p=0.0120$), with length increasing as $\delta^{15}N$ decreased, suggesting a shift in diet for adult bluegills. No other species exhibited a relationship between $\delta^{13}C$ or $\delta^{15}N$ and body length. However, chain pickerel body length and $\delta^{13}C$ isotope values display a weak positive relationship with a 90% confidence ($p=0.0981$).

Mean $\delta^{15}N$ and $\delta^{13}C$ values allow us to estimate the structures of food webs (Figure 4.2a-4.2c). Isotopic signatures show that chain pickerel, catfish, largemouth bass, pumpkinseeds, bluegills, and snapping turtles were positioned at the top of the LKH food web. Predatory macroinvertebrates (damselfly and dragonfly nymphs), scrappers (snails), and collector/gatherers (chironomidae) followed the fish and turtle isotopic signatures (Figure 4.2a).

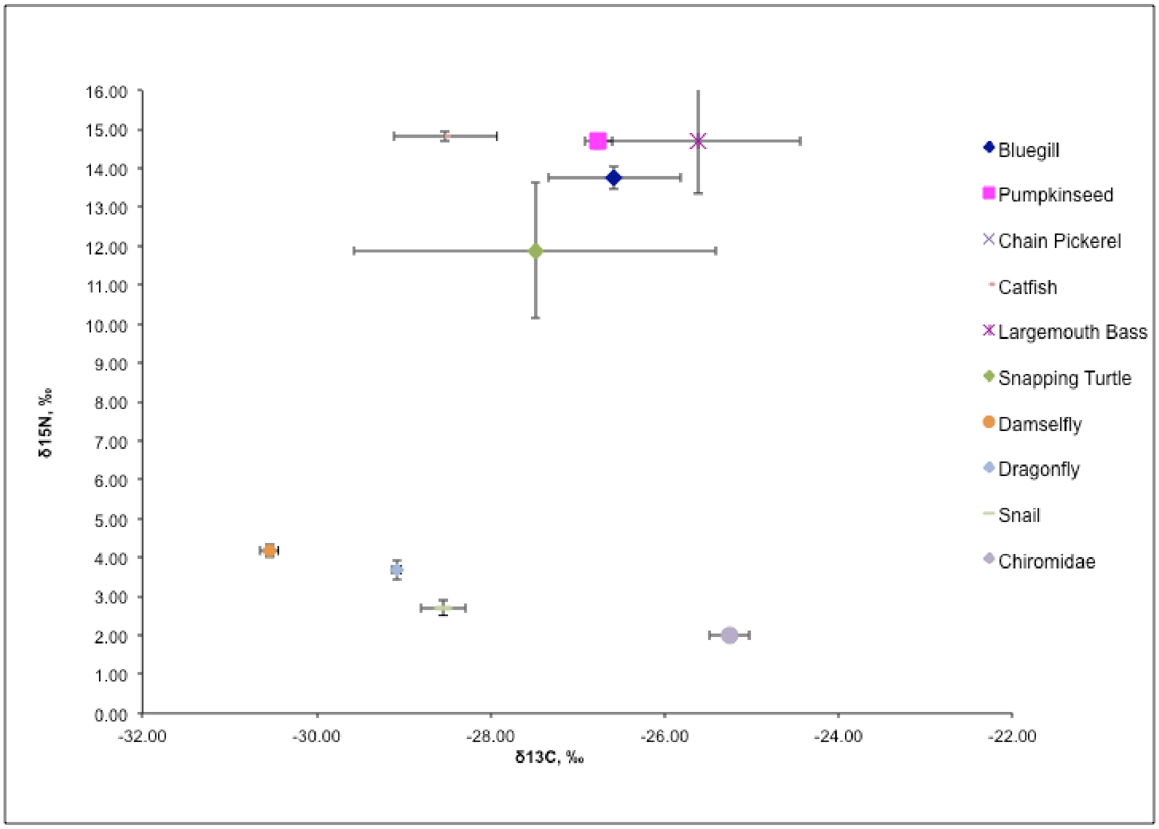

Figure 4.2a. Food web constructed using results of isotopic analysis for Lake Hopatcong (HOP).

The WAP food web seemed be dominated by snapping turtles, largemouth bass, pumpkinseeds, and bluegills. Lower in the food web were the macroinvertebrates, first dominated by scappers (snails), predators (dragonfly nymphs), and lastly collector/gatherers (scud and sowbugs) (Figure 4.2b).

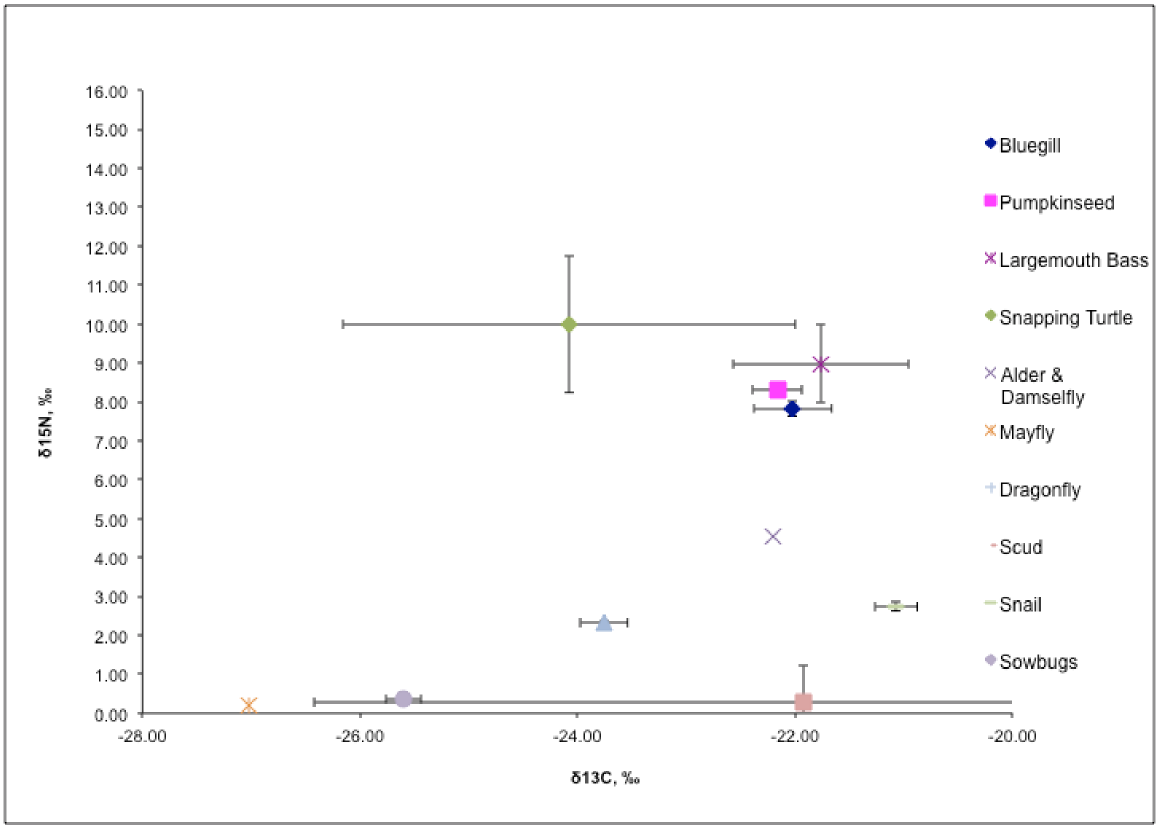

Figure 4.2b Food web constructed using results of isotopic analysis for Lake Wapalanne (WAP).

KFMs food web was composed of 3 species dominated by snapping turtles, pumpkinseeds, and freshwater shrimp (Figure 4.2c). We attribute the lack of diversity to the high degree of development near the site and contaminants supplied from nearby landfills and superfund sites.

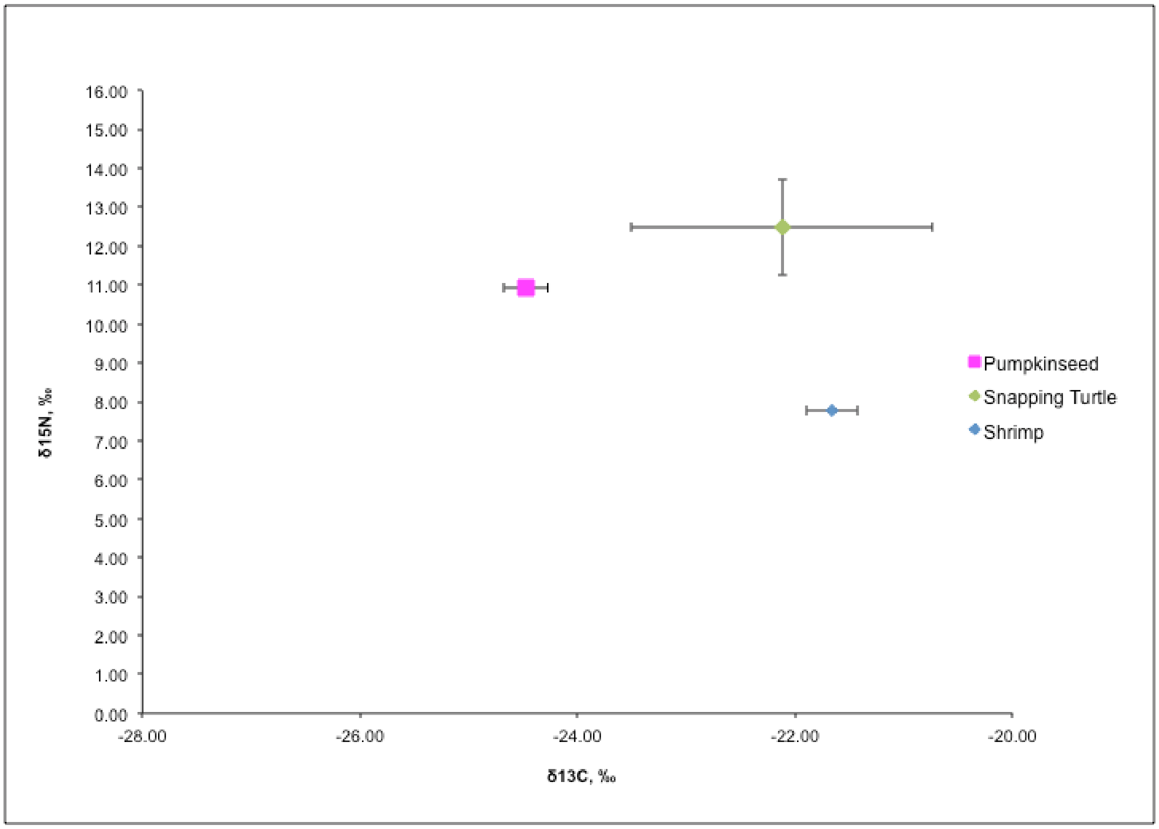

Figure 4.2c. Food web constructed using results of isotopic analysis for Kearny Freshwater Marsh (KFM).

4.4.2 Stable Isotope Analysis and Hg

WAP largemouth bass exhibit an increase in mercury concentration with increase in body length (p=0.0101). Kearny snapping turtles' mercury concentrations also had a significant positive relationship with carapace length (p=0.0160). Inversely, non-site-specific bluegills and pumpkinseeds showed decreasing mercury concentrations with increasing body length (p=0.0037 and <0.0001, respectively). These data suggest shifts in diet preference or consumption rates as these species grow larger with age. Regression for size and nitrogen isotopes ratios showed bluegills $\delta^{15}N$ signature to decrease with increasing body length ($p=0.0120$), which correlates with their decreasing mercury concentration with length as well.

In order to attribute the increase in mercury concentration to diet, there should be a positive relationship between mercury concentration and $\delta^{15}N$ signature. Further analysis resulted in significant correlations between mercury and $\delta^{15}N$ for snapping turtles ($p=0.0306$), while overall no other species exhibited correlations between mercury concentrations and $\delta^{15}N$. Incorporating site as a variable resulted in HOP bluegills and WAP snapping turtles showing increasing mercury concentrations with increasing $\delta^{15}N$ signature ($p=0.0288$ and 0.0242, respectively).

4.4.3 Trophic Position

Snapping turtles had the highest trophic level at WAP and KFM amongst all the organisms tested (Figure 3b – 3c). In HOP, snapping turtles were a trophic level below sunfish with a TP value of 3.7038 (Table 4.2 and Figure 4.3a). In WAP, snapping turtles held the highest TP of 3.1313 (Table 4.2 and Figure 4.3b). The second highest TP was held by largemouth bass with a TP of 2.8332 (Table 4.2 and Figure 4.3c). After eliminating largemouth bass data for the young of the year according to total length measurements, largemouth bass trophic position increased to 3.0692, which is still below that of snapping turtles. KFM snapping turtles had the highest TP within the study site at 2.3894, but was the lowest TP for snapping turtles among the 3 study sites (Table 4.2).

Table 4.2. Species by study site and their calculated trophic position.

Species	**TP**
HOP	
Chironomidae	0.7951
Snail	1.0009
Dragonfly	1.2863
Damselfly	1.4363
Snapping Turtle	3.7038
Bluegill	4.2547
Pumpkinseed	4.5259
Largemouth Bass	4.5310
Catfish	4.5643
Chain Pickerel	4.9899
WAP	
Mayfly	0.2588
Scud	0.2735
Sowbugs	0.3059
Dragonfly	0.8754
Snail	1.0000
Alder and Damselfly	1.5294
Bluegill	2.4978
Pumpkinseed	2.6345
Largemouth Bass	2.8332
Snapping Turtle	3.1313
KFM	
Shrimp	0.9990
Pumpkinseed	1.9271
Snapping Turtle	2.3894

A preliminary gut content analysis of road casualty turtles reflects a wide variety of consumed foods including vegetation, shells, crayfish, and fish. In addition, snail operculums were observed in the turtles holding bins while turtles were held prior to sample collection, which was likely a result of excretion.

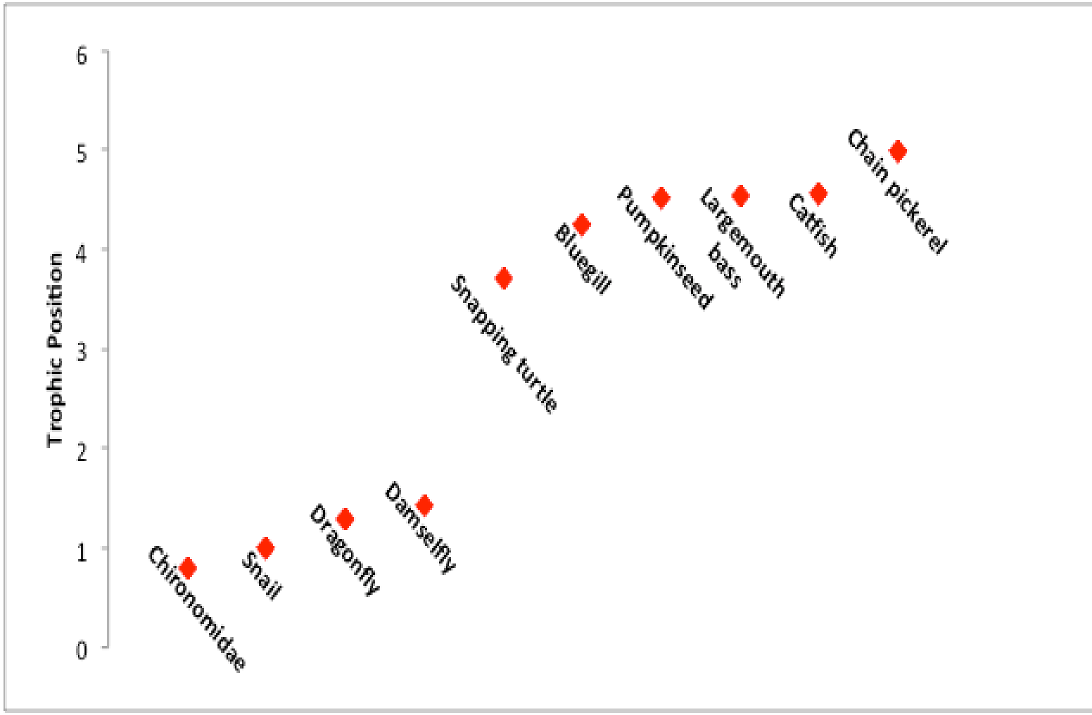

Figure 4.3a. Trophic positions for each species at Lake Hopatcong (HOP).

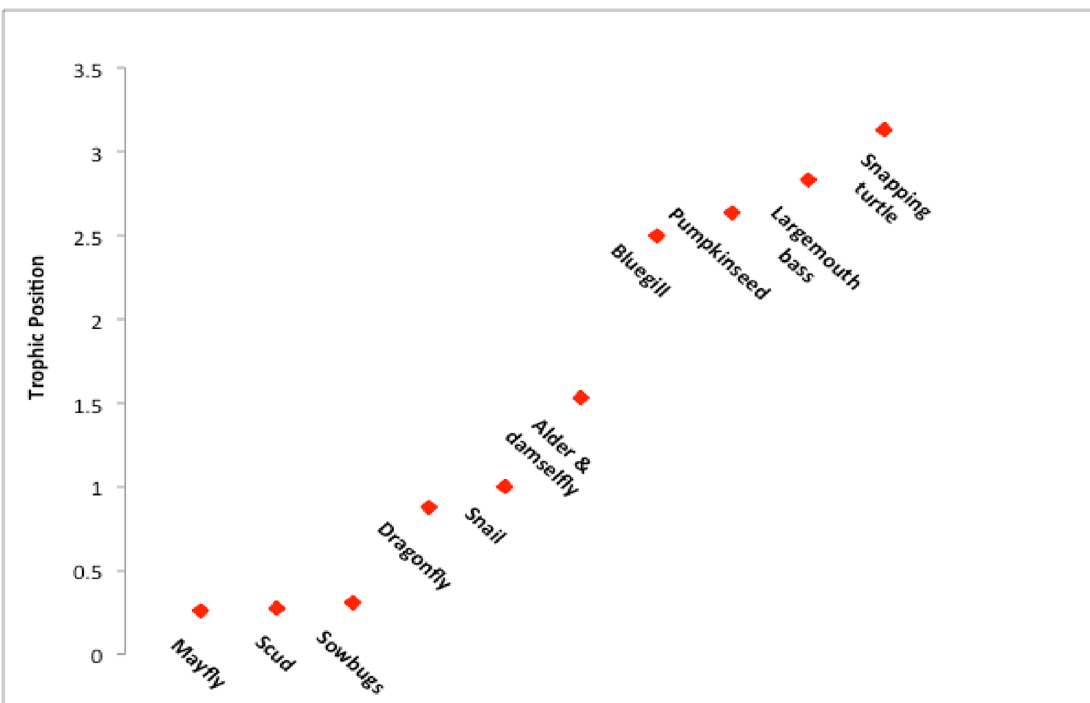

Figure 4.3b. Trophic positions for each species at Lake Wapalanne (WAP).

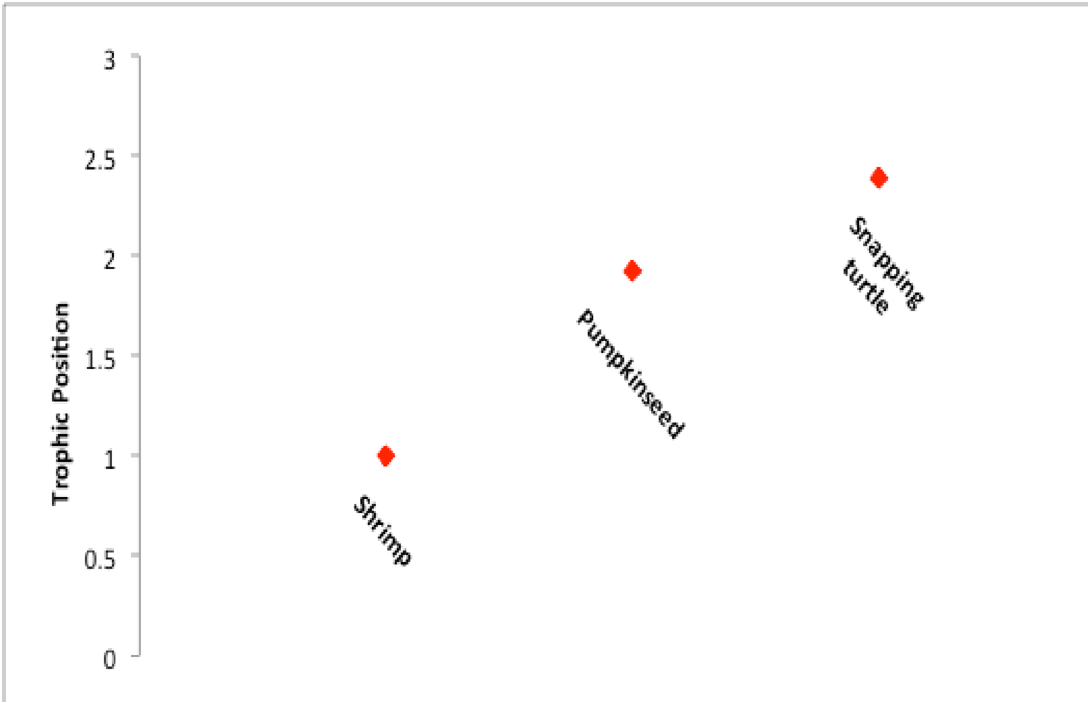

Figure 4.3c. Trophic positions for each species at Kearny Freshwater Marsh (KFM).

4.5 Discussion

Although carbon isotope ratios provide less information on trophic levels they can provide insight to consumers' carbon sources (DeNiro and Epstein, 1978; Peterson and Fry, 1987). C_3 and C_4 plants have distinct photosynthetic processes and produce distinct carbon signatures in their consumers (Ometto et al., 2005). C_3 plants have a mean $\delta^{13}C$ value of -27 ‰, while C_4 plants produce a mean $\delta^{13}C$ signature of -12‰ (Boutton, 1991; Gannes et al., 1998; Ometto et al., 2005; Pereira et al., 2007). This study found HOP snapping turtles to have a very narrow carbon range between -29.6 to -25.64 ‰, signaling that HOP snapping turtles limit themselves to, or inhabit, an area with a narrow range of C_3 plants. HOP turtles also had the lowest mean mercury concentration (0.0722 ppm), which could represents a less carnivorous diet. Lara et al. (2012) suggest turtles with $\delta^{13}C$

values closest to those of C_3 plants (-38 to -24 ‰) have C_3 plants play as a major part of their diets. WAP (-27.4 to -15.9 ‰) and KFM (-29.49 to -16.24 ‰) $\delta^{13}C$ values suggest a wider variation of carbon sources. Turtles at these two sites also have higher mercury concentrations in their muscles, 0.1026 ppm and 0.2412 ppm, respectively, suggesting a more carnivorous diet.

$\delta^{13}C$ signatures varied significantly between sites for bluegill ($p=0.0006$), largemouth bass ($p=0.0180$), pumpkinseed ($p<0.0001$), and snapping turtles, as did $\delta^{15}N$ for bluegill ($p=0.0001$), largemouth bass ($p=0.0066$), and pumpkinseeds ($p<0.0001$). The distinct signatures of bluegill, largemouth bass, and pumpkinseeds across all sites represent different diets and different trophic positions among the 3 study sites (Table 2). Trophic position can be influenced by a list of variables including species age and seasonality, or physical and chemical characteristics of the body of water in which the organism lives (Atwell et al., 1998; Hogan et al., 2007; Kelly et al., 1995;; Zhang et al., 2012). Additionally, bluegill and pumpkinseed were the only species to exhibit a relationship between $\delta^{15}N$ and mercury concentrations, suggesting mercury increases with a more carnivorous diet in these two species of sunfish. The same trends were also observed at other studies (Al- Reasi et al., 2007; Atwell et al., 1998; Cabana and Rasmussen, 1994; DaSilva et al. 2005). This observation suggests bioaccumulation was a major mechanism for elevated mercury levels in these two species.

KFM snapping turtles were the only population with a relationship between carapace length and mercury concentration in muscle. This could suggest that the mercury source is constant within the food web, leading to accumulation of mercury over time. However, the lack of correlation between mercury and $\delta^{15}N$ suggests that biomagnification was not likely to take place at this site with only three dominant species included in the analysis.

Mercury and carapace length correlations reported in the published literature are inconsistent (Turnquist et al., 2011). Golet and Haines (2001), Schneider et al. (2009) and Helwig and Hora (1983) found no relationship between muscle mercury concentration and body size, including carapace length and weight. However, a study in New York found turtles in 2 of 10 study sites to exhibit decreasing mercury concentrations with increasing size (Turnquist et al., 2011). A study by Schneider et al. (2009) found juveniles of 6 South American turtle species to have similar mercury concentrations as adults. These differences might be due to variation in habitats and individuals' food preferences.

4.6 Conclusions

Snapping turtles are omnivorous; their diets include a wide range of organisms, mainly depending on the availability of food sources at their habitats. The results of this study found snapping turtles as the top predators at two of the three study sites. No relationship was observed between $\delta^{15}N$, trophic position and mercury concentrations, suggesting mercury accumulation was the driving force behind elevated mercury in selected study sties.

4.7 Literature Cited

Albers, P. H., Sileo, L., and Mulhern, B. M. (1986) Effects of environmental contaminants on snapping turtles of a tidal wetland. *Archives of Environmental Contamination and Toxicology*, 15(1), 39-49.

Al- Reasi, H. A., Ababneh, F. A., and Lean, D. R. (2007) Evaluating mercury biomagnification in fish from a tropical marine environment using stable isotopes (δ13C and δ15N). *Environmental Toxicology and Chemistry*, 26(8), 1572-1581.

Aresco, M. J., Travis, J., and MacRae, P. S. (2015) Trophic interactions of turtles in a North Florida lake food web: prevalence of omnivory. *Copeia*, 103(2), 343-356.

Atwell, L., Hobson, K. A., and Welch, H. E. (1998) Biomagnification and bioaccumulation of mercury in an arctic marine food web: insights from stable nitrogen isotope analysis. *Canadian Journal of Fisheries and Aquatic Sciences*, 55(5), 1114-1121.

Bezerra, M. F., Lacerda, L. D., Rezende, C. E., Franco, M. A. L., Almeida, M. G., Macêdo, G. R., Pires, T.T., Rostan, G., and Lopez, G. G. (2015) Food preferences and Hg distribution in *Chelonia mydas* assessed by stable isotopes. *Environmental Pollution*, 206, 236-246.

Boening, D. W. (2000) Ecological effects, transport, and fate of mercury: a general review. *Chemosphere*, 40(12), 1335-1351.

Boundy, J. and Kennedy, C. (2006) Trapping Survey Results for the Alligator Snapping Turtle (*Macrochelys temmickii*) in Southeastern Louisiana, with comments on Exploitation. *Chelonian Conservation and Biology*, 5, 3-9.

Boutton, T. W. (1991) Stable carbon isotope ratios of natural materials: II. Atmospheric, terrestrial, marine, and freshwater environments. *Carbon isotope techniques*, 1, 173.

Cabana, G., and Rasmussen, J. B. (1994) Modelling food chain structure and contaminant bioaccumulation using stable nitrogen isotopes. *Nature*, 372(6503), 255-257.

Campbell, L. M., Hecky, R. E., and Wandera, S. B. (2003) Stable isotope analyses of food web structure and fish diet in Napoleon and Winam Gulfs, Lake Victoria, East Africa. *Journal of Great Lakes Research*, 29, 243-257.

Châteauvert, J. L., Bulté, G., Poulain, A. J., Campbell, L. M., and Blouin-Demers, G. (2015) Dietary Reliance on Benthic Primary Production as a Predictor of Mercury Accumulation in Freshwater Fish and Turtles. *Water, Air and Soil Pollution*, 226(10), 337.

Chumchal, M. M., Drenner, R. W., Fry, B., Hambright, K. D., and Newland, L. W. (2008) Habitat-specific differences in mercury concentration in a top predator from a shallow lake. *Transactions of the American Fisheries Society*, 137(1), 195-208.

Chumchal, M. M., Rainwater, T. R., Osborn, S. C., Roberts, A. P., Abel, M. T., Cobb, G. P., Smith, P. N., and Bailey, F. C. (2011) Mercury speciation and biomagnification in the food web of Caddo Lake, Texas and Louisiana, USA, a subtropical freshwater ecosystem. *Environmental Toxicology and Chemistry*, 30(5), 1153-1162.

Colborne, S. F., and Robinson, B. W. (2013) Effect of nutritional condition on variation in δ13C and δ15N stable isotope values in Pumpkinseed sunfish (*Lepomis gibbosus*) fed different diets. *Environmental Biology of Fishes*, 96(4), 543-554.

Dalerum, F., and Angerbjörn, A. (2005). Resolving temporal variation in vertebrate diets using naturally occurring stable isotopes. *Oecologia*, 144(4), 647-658.

Da Silva, D. S., Lucotte, M., Roulet, M., Poirier, H., Mergler, D., Santos, E. O., and Crossa, M. (2005) Trophic structure and bioaccumulation of mercury in fish of three natural lakes of the Brazilian Amazon. *Water, Air, and Soil Pollution*, 165(1), 77-94.

DeNiro, M. J., and Epstein, S. (1978) Influence of diet on the distribution of carbon isotopes in animals. *Geochimica et cosmochimica acta*, 42(5), 495-506.

Di Beneditto, A. P. M., Siciliano, S., and Monteiro, L. R. (2017) Herbivory level and niche breadth of juvenile green turtles (Chelonia mydas) in a tropical coastal area: insights from stable isotopes. *Marine Biology*, 164(1), 13.

Environmental Protection Agency (2009) TMDL Report. https://iaspub.epa.gov/waters10/attains_impaired_waters.tmdl_report?p_tmdl_id=37909&p_report_type=

Environmental Protection Agency (2012) https://iaspub.epa.gov/waters10/attains_index.control?p_area=NJ#causes.

Eskew, E. A., Price, S. J. and Dorcas, M. E. (2010) Survival and recruitment of semi-aquatic turtles in an urbanized region. *Urban Ecosystems*, 13, 365-373.

Gannes, L. Z., Del Rio, C. M., and Koch, P. (1998) Natural abundance variations in stable isotopes and their potential uses in animal physiological ecology. *Comparative biochemistry and physiology Part A: Molecular and integrative physiology*, 119(3), 725-737.

Gochfeld, M. (2003) Cases of mercury exposure bioavailability and absorption. *Ecotoxicology and Environmental Safety*, 56: 174–179.

Godley, B. J., Thompson, D. R., Waldron, S., and Furness, R. W. (1998) The trophic status of marine turtles as determined by stable isotope analysis. *Marine Ecology Progress Series*, 166, 277-284.

Golet, W. J., and Haines, T. A. (2001) Snapping turtles (*Chelydra serpen*tina) as monitors for mercury contamination of aquatic environments. *Environmental Monitoring and Assessment*, 71(3), 211-220.

Hammer, D.A. (1969) Parameters of a marsh snapping turtle population, Lacreek Refuge, South Dakota. *Journal Wildlife Management*, 33(4), 995-1005.

Helwig, D. D., and Hora, M. E. (1983) Polychlorinated biphenyl, mercury, and cadmium concentrations in Minnesota snapping turtles. *Bulletin of Environmental Contamination and Toxicology*, 30(1), 186-190.

Hogan, L. S., Marschall, E., Folt, C., and Stein, R. A. (2007) How non-native species in Lake Erie influence trophic transfer of mercury and lead to top predators. *Journal of Great Lakes Research*, 33(1), 46-61.

Hopkins, W. A., Bodinof, C., Budischak, S., and Perkins, C. (2013) Nondestructive indices of mercury exposure in three species of turtles occupying different trophic niches downstream from a former chloralkali facility. *Ecotoxicology*, 22(1), 22-32.

Kelly, C. A., Rudd, J. W., St Vincent, L. L., and Heyes, A. (1995) Is total mercury concentration a good predictor of methyl mercury concentration in aquatic systems?. In Mercury as a Global Pollutant (pp. 715-724). Springer Netherlands.

Kiviat, E., and MacDonald, K. (2002) Hackensack Meadowlands, New Jersey, biodiversity: A review and synthesis. New York: Hudsonia, Ltd.

Kiviat, E., and MacDonald, K. (2004) Biodiversity patterns and conservation in the Hackensack Meadowlands, New Jersey. *Urban Habitats*, 2(1), 28-61.

Koper, N., and Brooks, R. J. (2000) Environmental constraints on growth painted turtles (*Chrysemys picta*). *Herpetologica,* 56, 421-432.

Lara, N. R. F., Marques, T. S., Montelo, K. M., de Ataídes, Á. G., Verdade, L. M., Malvásio, A., and de Camargo, P. B. (2012) A trophic study of the sympatric Amazonian freshwater turtles Podocnemis unifilis and Podocnemis expansa (Testudines, Podocnemidae) using carbon and nitrogen stable isotope analyses. *Canadian Journal of Zoology*, 90(12), 1394-1401.

Middelburg, J. J. (2014) Stable isotopes dissect aquatic food webs from the top to the bottom. *Biogeosciences*, 11(8), 2357.

Milan, J. C., and Melvin, S. (1997) Spotted turtle population ecology and habitat use in central Massachusetts, Proc. Conservation Restoration and Management of Tortoises and Turtles, USA, 480.

Minagawa, M., and Wada, E. (1984) Stepwise enrichment of 15 N along food chains: further evidence and the relation between δ 15 N and animal age. *Geochimica et cosmochimica acta*, 48(5), 1135-1140.

Morel, François M. M., Kraepiel Anne M. L., and Amyot, M. (1998) The Chemical Cycle and Bioaccumulation of Mercury. *Annual Review of Ecology and Systematics*, 29, 543-566.

New Jersey Department of Environmental Protection (2002) Volume II Exposure and Impacts and Volume III Sources of Mercury to New Jersey's Environment. Source:http://www.nj.gov/dep/dsr/mercury_task_force.htm

New Jersey Fish and Wildlife Digest (2016) Licenses information and regulations http://www.eregulations.com/wp-content/uploads/2016/12/17NJFW-LR.pdf.

Obropta, C., Ravit, B., and Yeargeau, S. (2008) Kearny Marsh Hydrology Study. Rutgers University. Source:http://cues.rutgers.edu/kearnymarsh/pdfs/53_NJMC_Final_Report_062008.pdf

Ometto, J. P. H., Flanagan, L. B., Martinelli, L. A., and Ehleringer, J. R. (2005) Oxygen isotope ratios of waters and respired CO2 in Amazonian forest and pasture ecosystems. *Ecological Applications*, 15(1), 58-70.

Pearson, S. H., Avery, H. W., Kilham, S. S., Velinsky, D. J., and Spotila, J. R. (2013) Stable isotopes of C and N reveal habitat dependent dietary overlap between native and introduced turtles Pseudemys rubriventris and Trachemys scripta. *PloS one*, 8(5), e62891.

Pereira, A. L., Benedito, E., and Sakuragui, C. M. (2007) Spatial variation in the stable isotopes of 13C and 15N and trophic position of Leporinus friderici (Characiformes, Anostomidae) in Corumbá Reservoir, Brazil. *Anais da Academia Brasileira de Ciências*, 79(1), 41-49.

Peterson, B. J., and Fry, B. (1987) Stable isotopes in ecosystem studies. *Annual Review of Ecology and Systematics*, 18(1), 293-320.

Post, D. M. (2002) Using stable isotopes to estimate trophic position: models, methods, and assumptions. *Ecology*, 83(3), 703-718.

Quinn, J. R. (1997) Fields of sun and grass: an artist's journal of the New Jersey Meadowlands. Rutgers University Press.

Rognerud, S., Grimalt, J. O., Rosseland, B. O., Fernandez, P., Hofer, R., Lackner, R., Lauritzen, B., Lien, L., Massabuau, J. C. and Ribes, A. (2002) Mercury and organochlorine contamination in brown trout (*Salmo trutta*) and arctic charr (*Salvelinus alpinus*) from high mountain lakes in Europe and the Svalbard archipelago. *Water, Air and Soil Pollution: Focus, I* (2), 209-232.

Rowe, J. W. (1992) Dietary habits of the Blanding's turtle (*Emydoidea blandingi*) in northeastern Illinois. *Journal of Herpetology,* 26, 111–114.

Schneider, L., Belger, L., Burger, J., Vogt, R. C., and Ferrara, C. R. (2010) Mercury Levels in Muscle of Six Species of Turtles Eaten by People Along the Rio Negro of the Amazon Basin. *Archives Of Environmental Contamination and Toxicology*, 58(2), 444-450.

Seminoff, J. A., Bjorndal, K. A., and Bolten, A. B. (2007) Stable carbon and nitrogen isotope discrimination and turnover in pond sliders *Trachemys scripta*: insights for trophic study of freshwater turtles. *Copeia*, (3), 534-542.

Tadiso, T. M., Borgstrøm, R., and Rosseland, B. O. (2011) Mercury concentrations are low in commercial fish species of Lake Ziway, Ethiopia, but stable isotope data indicated biomagnification. *Ecotoxicology and environmental safety*, 74(4), 953-959.

Tieszen, L. L., Boutton, T. W., Tesdahl, K. G., and Slade, N. A. (1983) Fractionation and turnover of stable carbon isotopes in animal tissues: implications for δ13C analysis of diet. *Oecologia*, *57*(1-2), 32-37.

Tsipoura, N., Burger, J., Feltes, R., Yacabucci, J., Mizrahi, D., Jeitner, C., and Gochfeld, M. (2008) Metal concentrations in three species of passerine birds breeding in the Hackensack Meadowlands of New Jersey. *Environmental Research*, 107(2), 218-228.

Tsipoura, N., Burger, J., Newhouse, M., Jeitner, C., Gochfeld, M., and Mizrahi, D. (2011) Lead, mercury, cadmium, chromium, and arsenic levels in eggs, feathers, and tissues of Canada geese of the New Jersey Meadowlands. *Environmental Research*, 111, 775-784.

Turnquist, M. A., Driscoll, C. T., Schulz, K. L., and Schlaepfer, M. A. (2011) Mercury concentrations in snapping turtles (*Chelydra serpentina*) correlate with environmental and landscape characteristics. *Ecotoxicology*, 20(7), 1599-608.

van Dijk, P. P. (2012) Chelydra serpentina. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>.

Zhang, L., Campbell, L. M., and Johnson, T. B. (2012) Seasonal variation in mercury and food web biomagnification in Lake Ontario, Canada. *Environmental Pollution*, 161, 178-184.

Chapter 5. The Commercial Harvest of Snapping Turtles In New Jersey

5.1 Abstract

There is a growing concern that the harvest of turtles for human consumption is a major contributor to the declining turtle populations. Snapping turtles (*Chelydra serpentina serpentina*) are the most commonly harvested turtle species for human consumption in the U.S., and most often the least regulated. The State of New Jersey allows both recreational and commercial harvest of snapping turtles throughout the state, but little is known about the harvest practices. This study analyzed the commercial harvest program of snapping turtles in New Jersey using a questionnaire. The survey was mailed to snapping turtle commercial harvesters to determine their willingness to pay for commercial harvesting privileges, to assess commercial harvesting practices, and to estimate the rate of the harvest. There were a total 25 respondents, of which 36% sold the turtles. The reported sale totaled 1,469 snapping turtles during the 2014 harvest season, generating a yearly income ranging from $0 to $3,000. The average willingness to pay (WTP) to keep the commercial harvest permit was $29.22, while the median WTP value was $10. Most respondents agreed (76%) there should be a minimum size requirement for harvested snapping turtles. Respondents also agreed (72%) that there should be a permit required for anyone to catch snapping turtles. Not surprisingly, the majority of respondents disagreed (92%) with the possible closure of the harvest program.

5.2 Introduction

Turtles face many threats from habitat loss to predation and harvesting. Turtles have been exploited for medicine, turtle farms, pet trade, expositions, zoos, and human consumption. Over the last two decades there has been a growing concern over the decline of many turtle species around the world (Klemens and Thourbjanarson, 1995). The consumption of turtles, although a worldwide practice, is the most common in Southeast Asia. As a result, 68% of the turtle species found in Southeast Asia are now imperiled and many are on the brink of extinction (Wildlife Conservation Society, 2011). This decline is referred to as the Asian Turtle Crisis. As native turtle populations began to severely decline in Southeast Asia, mainly due to exploitation, the market turned to global sources, including the United States. In response to the overseas demand, private turtle farms have opened for business in the United States, primarily in Louisiana and Oklahoma, but their success has been limited due to their dependence on wild caught turtles to restock the populations and the occurrence of Salmonella outbreaks within captive breed turtles (Florida Fish & Wildlife Conservation Commission, 2012). These limitations have led to the continued dependence and demand for wild caught turtles to supply the local and global market. The demand for turtles comes not only from Asian countries but also from within the United States. The harvest of turtles for human consumption has been in practice in the United States since pre-colonial times. In the early 1900s, prior to the listing of sea turtles under the Endangered Species Act, the demand for sea turtle meat was present throughout the U.S. Alligator snapping turtles and diamondback terrapins were the other species also hunted to near extinction in the U.S. (Roman and Bowen, 2000).

The turtle trade market is considered to be the main cause of wild turtle population declines in the United States (Dixon, 2000; Gibbons et al., 2000). Turtle harvesting and export regulations allow the unlimited catch and export of certain turtle species, which leads to the legal export of an estimated 10 million turtles annually (USFWS, 2010). Furthermore, there is a lack of information available on the number and origin of turtles harvested and exported. This makes it extremely challenging to evaluate the magnitude and impact of the trade on wild turtle populations (Ceballos and Fitzgerald, 2004).

The common snapping turtle (*Chelydra serpentina serpentina*) is the second largest freshwater turtle in North America, which has made it a target game species with a reported number of 655,541 snapping turtles exported in 2009 (van Dijk, 2012) (Table 5.1). Although many of the exported turtles might have originated from commercial turtle farms, it is estimated that approximately 39% of the snapping turtles exported are wild caught, making snapping turtles the most commonly exported turtle species in the United States (Senneke, 2005).

Table 5.1. U.S. Export of the Common Snapping Turtle, 1990-2009 (van Dijk, 2012)

Year	**1990**	**1995**	**2003**	**2005**	**2008**	**2009**
Number export	3,122	17,495	129,499	320,940	497,107	655,541

The harvest of long-lived organisms, such as snapping turtles, is argued to be unsustainable, and any commercial harvesting of wild turtles can severely cause local turtle populations to decline (Congdon et al., 1994; Zimmer-Shaffer et al., 2014). Congdon et al. (1994) studied a stable population of snapping turtles in Michigan for over 19 years and constructed a life table and population simulation. They concluded that it would take 2,000 years for a non-harvested population to double in size, and an increase in adult mortality by 10% annually would halve the population in 10 years (Congdon et al., 1994). Two additional long-term studies in Canada also found populations could not tolerate a harvest of more than 10% of the population (Brooks et al., 1991). Gibbs and Amato (2000) found no reports of a sustainable harvest for wild turtles, and Congdon et al. (1994) advised against sustained harvests of long-lived organisms based on the concept of sustained yield. Other studies suggest even a 3% increase in adult mortality can impact populations' stability and growth (Beaudry et al., 2010; Gibbs and Shiver, 2002; Wood and Herlands, 1997).

The International Union for Conservation of Nature (IUCN) classifies snapping turtle conservation status as of least concern. However, in Canada and Minnesota snapping turtles are considered a special concern species. As the demand for turtle meat increased, some states have terminated or implemented stricter regulations on the commercial harvest of snapping turtles including Alabama, Illinois, Maine, New Hampshire, Oklahoma, West Virginia, Nebraska, South Dakota, Mississippi, and North Carolina. However, to date, 25 states remain active in commercial harvest of snapping turtles including New Jersey.

5.2.1 Snapping Turtle Harvest in New Jersey

Snapping turtles are one of the 12 native turtle species in New Jersey and the only turtle species commercially and recreationally harvested in the state. The state currently allows both recreational and commercial harvesters to collect turtles throughout the year, with the exception of the nesting season from May 1 to June 15. Commercial harvesting permits costs $2 in addition to holding a valid fishing license, which costs $22.50 per person per year. Harvesters are required to submit a monthly report including the number of snapping turtles caught and the body of water where they were harvested (New Jersey Fish and Wildlife Digest, 2011). In 2016, the New Jersey Department of Environmental Protection (NJDEP) implemented a size limit restriction of 12 inches. However, there is no limit on number of turtles harvested, and no limits based upon weight, sex, or location harvested (NJDEP, 2016).

There is a lack of knowledge on commercial harvest practices in New Jersey. This study distributed a survey to gather information from commercial harvesters on their practices and their willingness to adopt new regulations in efforts to conserve wild snapping turtle populations.

5.3 Methods

A survey questionnaire for commercial harvesters was developed in collaboration with the Bureau of Freshwater Fisheries within the NJDEP Division of Fish and Wildlife, and approved by Montclair State University's Institutional Review Board (IRB permit #001422). The survey used contingent value (CV) analysis to analyze variables that might influence the harvesting of snapping turtles and to understand the impact that an increase in commercial harvesting license fees might have on snapping turtle harvest practices in New Jersey. The survey was reviewed by the NJDEP, and then tested by a focus group at the 2014 Wildlife Conservation Conference. Surveys were then distributed to 75 registered commercial snapping turtle harvesters. The survey was accompanied by a letter of explanation stating that the survey was voluntary, and only individuals 18 years or older were allowed to participate. The survey was mailed in September 2014, and a reminder was sent in December 2014.

The survey included basic questions in order to gather information on the rate of harvesting, harvesting practices, and the requirements of the individuals or companies purchasing the harvester's catch. The survey also included sequential bid survey questions to determine how much harvesters would be willing to pay for a license. Demographic information was also requested including age, gender, and income (Broberg and Brännlund, 2008).

5.3.1 Statistics for Survey Data

The survey responses were analyzed as the probability of an individual to pay a certain amount for the natural resource being harvested (Hanemann, 1984). Due to the small sample size, we performed the non-parametric Wilcoxon Signed Rank test using JMP 11 (SAS Institute, Cary, NC).

5.4 Results

The numbers of commercial harvesting permits issued and reported harvested numbers of turtles have both experienced an increasing trend between 2009 and 2012 (Figures 5.1 and 5.2). This trend can have severe impacts on the sustainability of the snapping turtle populations in New Jersey. In 2012, NJDEP issued 111 commercial harvest permits for snapping turtles. Although it is clearly stated on the permit application that a monthly harvest report is required to document the number of snapping turtles harvested and the water bodies where turtles were collected, many harvesters fail to submit reports or submit questionable data. Harvesters who fail to submit their monthly reports by the end of the year are denied the renewal of their harvest license for the next season.

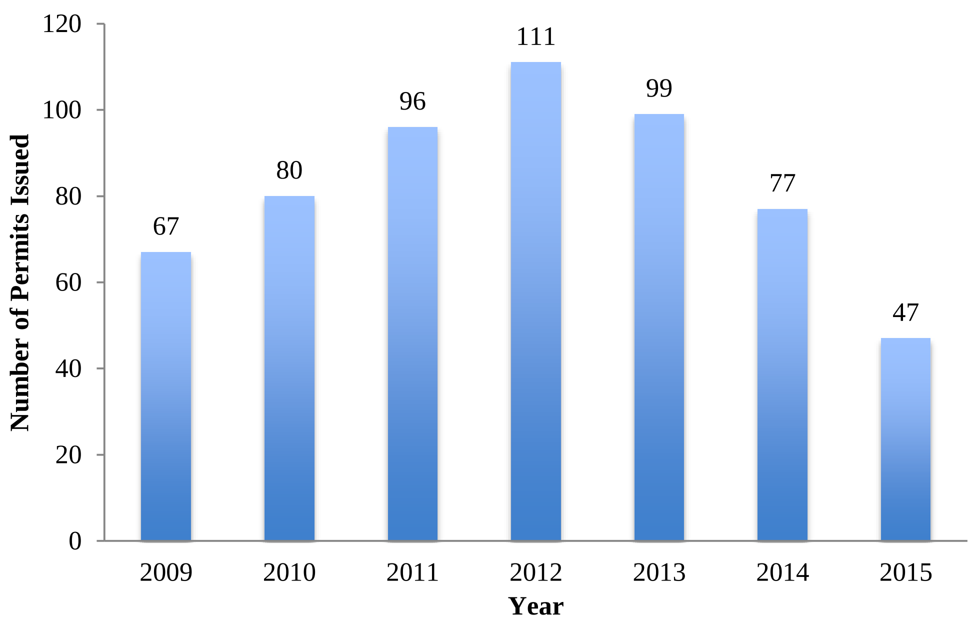

Figure 5.1. Numbers of commercial harvesting permits issued in New Jersey.

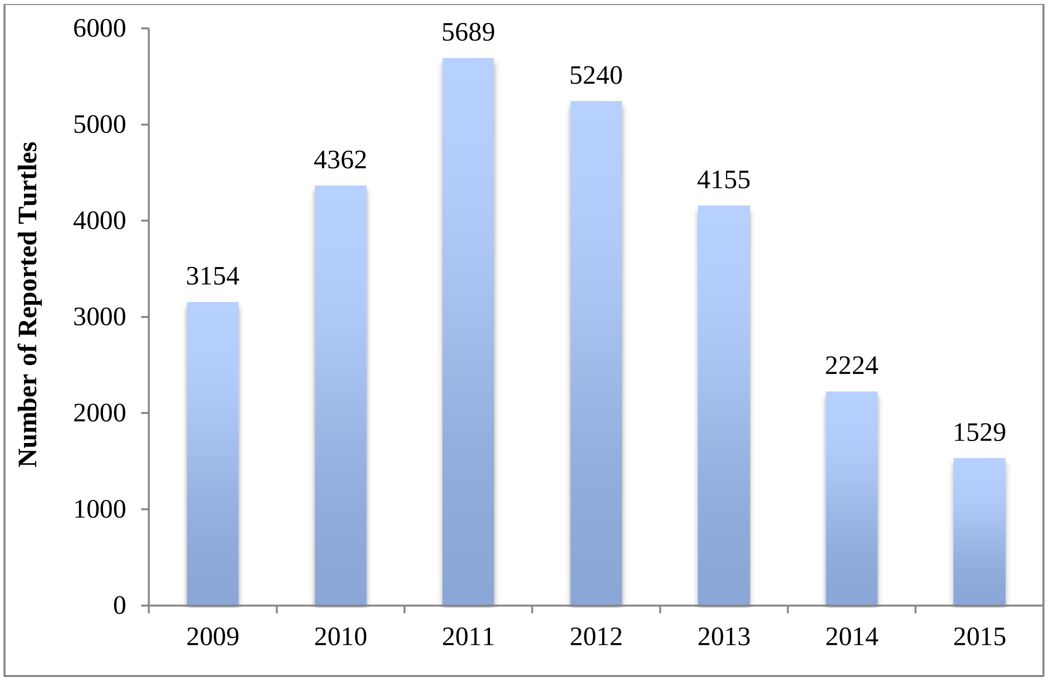

Figure 5.2. Number of reported turtles commercially harvested in New Jersey.

5.4.1 Demographics

There were a total of 25 respondents resulting in a 34% response rate. Respondents were all males, although the survey was also sent out to two females who held commercial harvesting permits. Approximately 64% of respondents were older than 41 years of age (Table 5.2). Most respondents completed high school (52%), while 44% had a bachelor's degree or some college-level education, and 4% completed only primary school. Nearly 33.3% of respondents had incomes exceeding $75,000 per year. Caucasian was the most common ethnicity (96%). Native Americans represented the remaining 4% (Table 5.2).

Table 5.2. Respondent's demographic information.

Demographic parameter	Respondents (%)
Gender	
Male	100
Female	0
Age	
18-25	12
26-40	24
41+	64
Level of Education	
Elementary	4
High School	52
Some College	8
College	36
Annual Income	
Less than 25,000	16.7
25,000-54,999	33.3
55,000-74,999	16.7
75,000+	33.3
Ethnicity	
Caucasian	96
Native American	4

5.4.2 Harvesting Trips

Harvesters were asked how many trips they took per year, the distance they traveled, and the reason for their trips. Harvesters took 30 to 100 trips per year, with an average of 30 trips each year, with a mean travel distance of 46.5 miles and a mean duration of 6.3 hours. Eighty-eight percent of harvesters stated that the primary and sole purpose of their trips was to catch snapping turtles. Eight percent conducted both fishing and snapping turtle collection. Four percent conducted fishing, snapping turtle collection, and hiking. Most often harvesters made trips by themselves (72%) or with a friend (24%), and less often with a group of 3 or more (4%). The majority of harvesters reported never encountering another snapping turtle harvester during their trips (68%). On occasion, they would encounter other harvesters at a frequency of once per month (4%), once per week (4%), or on a daily basis (4%).

5.4.3 Harvest Practices

Harvesters were asked how long they have been participating in the commercial harvest of snapping turtles. Responses ranged from 1 to 56 years with a mean of 20 years. 82% stated they planned to apply for next season's commercial snapping turtle harvesting permit, while 18% stated they did not plan to renew their permits. Harvesters were also asked the reason for participating in the commercial harvest. 36.4% of participants reported they enjoyed being outside, 30.3% became involved through friends or relatives, 18.2% were long-term harvesters, and 18.2% participated to earn extra income. Most harvesters used hoop traps (40%), box traps (20%) or capture turtles by hand (8%). The remaining 32% used a mix of these techniques. Harvesters set an average of 15 traps per day, with a range of 2 to 50 traps. All harvesters reported they check their traps every 24 hours.

Harvesters were asked how many turtles they caught per day on a successful day of trapping. Responses ranged from 1 to 100 turtles, with a mean of 13.2 turtles per day to be considered "successful." Harvesters reported collecting 0 to 409 turtles during one harvest season. Most respondents stated the populations they harvested have remained stable (75%). 21% stated that the population has decreased, and only 4% stated that the population has increased. Harvesters also stated that between 0 and 70% of their catch consisted of female turtles, with a mean value of 29% females. Most turtles caught were sold (36%), consumed (24%), or released (4%). The fate of the remaining 36% was a mix of consumption, sale, or kept as a pet. Of those harvesters that sold their catch, most turtles were sold to processing factories (47%), seafood vendors (16%), and local restaurants (11%). For those harvesters who sold the catch to seafood vendors and local restaurants, buyers paid \$0.65 to \$2.50 per pound of turtle, with female turtles fetching a higher price (Table 5.3).

Table 5.3. The minimum, maximum, and average price (USD) per pound paid by snapping turtle buyers.

	Turtle Factory	**Seafood Vendor**	**Restaurant**
Min	\$0.65	\$0.65	\$1.00
Max	\$2.00	\$2.00	\$2.50
Ave	\$1.14	\$1.22	\$2.00

Fifty-two percent of harvesters reported that buyers required turtles to be alive at the time of purchase, while only 5% of harvesters had buyers that required turtles to be dead. Forty-six percent of harvesters reported buyers that required a carapace lengths longer than 11 inches and had a preferred sex, most often females. If turtles were not alive, buyers preferred the turtles to be cleaned or prepared (7.1%).

Prior to making it to market most turtles were kept alive in water (57%), and for durations less than a week (47.4%) or up to 1 to 2 weeks (47.4%). Turtles were also kept alive and dry (29%), or dead and frozen (10%). Only 5% of harvesters kept turtles for 4 or more weeks.

5.4.4 Willingness to Pay (WTP)

Harvesters were asked their opinions on the current price of the commercial permit. 64% agreed that the permit price is too low and 36% disagreed. A sequential bid question on the price that harvesters are willing to pay to keep their commercial harvesting permit resulted in 40% willing to pay $5, 35% willing to pay $10, 5 % willing to pay $15, and 20% willing to pay $30 or more. Harvesters were also allowed to state in an open ended question how much they would be willing to pay for their commercial harvesting permit. Responses ranged from $1 to $200. The average WTP was $29.22, while the median WTP was $10. In the same manner, harvesters were asked the income made from the sale of their catch, and answers ranged from $0-$3,000 with a mean of $648.

Due to the small sample size, we performed the non-parametric Wilcoxon Signed Rank test and concluded that the WTP is significantly different from the current cost of a commercial harvesting permit at $2 ($p=0.0002$). The demographic variables of participants such as gender, age, ethnicity, education and income, were found to have no correlation with the maximum WTP. The WTP increased with the number of turtles that the individual caught during the previous year. However, the small sample size of this survey did not allow for conducting an unbiased regression analysis.

5.4.5 Regulations

Several commonly employed harvesting regulations were included in the survey to determine harvesters' willingness to comply. Most respondents disagreed with potential new regulations for the snapping turtle harvest (Table 5.4). Most respondents agreed that there should be a minimum size requirement for the turtles (76%), and a permit required for anyone wishing to harvest snapping turtles (72%). The majority of respondents disagreed (92%) with the possible closure of the harvest (Table 5.4).

Table 5.4. Summary of ranking responses from strongly agree to strongly disagree to potential regulations for snapping turtle commercial harvesting program in New Jersey.

Suggested Regulations	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The number of turtles that can be caught should be limited	36%	24%	32%	4%	4%
The number of female turtles caught should be limited	28%	20%	16%	20%	16%
The number of turtles that can be collected from specific water bodies should be limited	36%	24%	28%	0%	12%
There should be a minimum size required for turtles harvested	8%	0%	16%	32%	44%
There should be a permit required for any one catching snapping turtles	16%	4%	8%	24%	48%
The snapping turtle permit price should be increased	20%	8%	36%	28%	8%
Permit price should be increased to deter newcomers and inexperienced persons from targeting turtles	21%	21%	25%	17%	16%
The commercial harvesting of turtles should be stopped	80%	12%	8%	0%	0%
There should be restrictions on the harvest of turtles to fishing license holders	33%	8%	25%	13%	21%
There should be a special permit for recreational harvesting of snapping turtles for personal use	40%	12%	28%	4%	12%
The number of traps, hooks, nets that can be set to catch snapping turtle should be limited	56%	8%	12%	8%	16%
The snapping turtle harvesting season should be shortened	56%	20%	8%	12%	4%
A snapping turtle dealer permit should be required for anyone who wants to sell turtles	46%	12%	17%	4%	21%

5.5 Discussion

5.5.1 Demographics

Although all survey respondents were male and nearly 97% of respondents were Caucasian, the demographics of participants were representative of the population of commercial harvesters of snapping turtles in the State of New Jersey (National Survey of Fishing, 2011). The National Survey (2011) for New Jersey estimated that males comprised nearly 80% of the resident angler population and 95% was Caucasian. In this study, 52% of respondents reported having a high school education, which is double that reported in the National Survey for New Jersey. The percentages of respondents in this study with some college-level education or a college degree are 19% and 5% lower, respectively, than the respondents of the 2011 National Survey. Since the age and income-intervals were dissimilar in our survey and the 2011 National Survey for New Jersey, an exact comparison was not possible.

5.5.2 Harvesting Trips

According to the 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, anglers average of 12 days of fishing per year and hunters averaged 26 days of hunting per year. Analogous to the national survey’s hunting days, the results of this study showed snapping turtle harvesters average of 30 trips per year. The National Survey angler data states that 88% of anglers only fished during their trips. Similarly, 88% of turtle harvesters stated that the primary and sole purpose of their trips was to catch snapping turtles.

5.5.3 Harvest Practices

The results of this study suggested the most successful harvesters deployed hoop traps, setting approximately 10 or more traps per trip. From the 25 respondents, 17 had participated in the 2014 harvest season and harvested between 30 to 409 turtles. In aggregate, the 17 respondents caught 1,494 turtles during the 2014 harvesting season, averaging approximately 88 turtles per person. On average 29% of the 2014 reported catch were female snapping turtles. This would lead to approximately 517 females and 989 males being harvested during the 2014 season.

The results of this study demonstrated that snapping turtle buyers offered approximately $0.75 to a dollar more per pound for female turtles. This could be an incentive for harvesters to target female turtles and trap heavily right before and soon after the harvesting closing window when females are most actively searching for nesting sites. The additional revenue might also be the reason why 48% of harvesters disagreed with limiting the number of females turtles that can be harvested in a season. However, research has found that harvesting even a small percentage of a population can cause significant impacts to a population (Brooks et al., 1991; Congdon et al., 1994; Gibbs and Amato, 2000). The loss of female turtles can be the most detrimental, leading to a population decline (Brooks et al., 1991; Heppell, 1998).

5.5.4 Willingness to Pay

Respondents stated earning $0 to $10,000 from turtle sales, with an average of $30 per year. The zero income was due to the harvesters who either consumed their own catch, kept the turtles as pets, or released their catch. Respondents reported 1,469 turtle were sold, 390 turtles were used for consumption, 130 were kept as pets, and 3 were released. Some respondents participated in more than one of these activities.

Assuming an average turtle weighs 16 pounds and the maximum sale price is $2.50 per pound, the reported 1,469 turtles sold by the 12 participants would have generated an overall income of $58,760 per year. With the minimum sale price of $0.65 per pound, the turtles would have generated an overall income of $15,278 per year. With the average price of $1.18 per pound, an overall income of $27,735 would have been generated at approximately $2,100 per harvester per season. However, two respondents reported earning $8,000 and $10,000 from selling their snapping turtle harvests, considerably higher than the other respondents.

5.5.5 Regulations

The majority of harvesters disagreed with most of the proposed regulations, with the exception of the regulations stating "There should be a minimum size of the snapping turtles that can be taken" (Table 5.4). Harvesters likely agreed with a minimum size requirement because buyers have already imposed a size limit. Many buyers required turtles to be larger than 11-12 inches. Size limitation for harvested turtles is a common regulatory practice in many states. Connecticut and Michigan impose a carapace size limit of 13 inches (CDEEP, 2016; MDNR, 2016). New York and Minnesota impose a carapace size limit of 12 inches (NYDEC, nd; MNDNR, 2008), and Maryland imposes a size limit of 11 inches (MDNR, 2009). In 2016, 2 years after our survey, New Jersey implemented a size limit of 12 inches for snapping turtles (NJDEP, 2016).

Harvesters agreed with the statement “There should be a permit required for anyone catching snapping turtles.” The majority of harvesters also agreed or were neutral on “The permit prices for a person that is interested in catching snapping turtle should be increased.” This could be because the commercial permit of $2 was considered low by the harvesters. This was further confirmed by the average WTP to keep harvesting privileges to be just under $30, meaning that harvesters would rather pay a higher price for their permits than to relinquish their access to the harvest.

5.5.6 Recommendations

The results of this study show 21% of harvesters believed snapping turtle populations were declining. Further studies and monitoring of the snapping turtle population should be conducted to better understand the current status and trend of snapping turtle populations in the State of New Jersey. Special focus should be paid to a population’s sex ratio. Lack of sexually mature adults and skewed sex ratios are both signs of population decline and excessive pressure on wild populations (IDNR, 2013).

In 2016 the State of New Jersey expanded the closed season for harvesting during the nesting season, however, further consideration should be taken to prevent harvesting during the mating season (March and April). A longer closed harvesting season will allow turtles to mate and nest prior to being harvested, increasing the probability of reproductive success. If implemented, this potential regulation should not elicit strong resistance by the harvesters as most turtles were reported to be harvested between July and October.

Regulating daily or seasonal maximum number of takes can also increase the long-term stability of the snapping turtle populations. For example, Alabama allows 10 turtles per day, and North Carolina allows 10 turtles per day for up to 100 per season. States that have daily limits often allow unlimited take of snapping turtle from privately-owned waters with permission granted by owner (Mali et al., 2014). To suggest harvest limits for harvesting programs in New Jersey, it is essential to first conduct scientific studies in order to estimate the population sizes. As discussed, harvesters receive a higher payment for female turtles, therefore, harvesters might target female turtles. This could lead to severe detrimental impacts on the population (Congdon et al., 1994). Requiring harvesters to report the number of females caught would aid in monitoring skewness in the harvest. It would also benefit biologists by keeping a record of sex ratios in populations, assist with determining when sex skewedness occurs, and if it is a sign of population decline.

New Jersey currently requires commercial harvesters to submit monthly harvest reports, and all reports must be post-marked by October 31 of the year. Data could be available in a more timely manner if harvesters are required to submit a monthly report at the end of each month rather than submitting all monthly reports at the end of the year. Additionally, an online reporting database would be more convenient for harvesters and more efficient for data analysis. The reporting database could also include a mapping function and request harvesters to provide a precise harvesting location, information on the size and sex of the turtles as well as information about the buyers. The turtle harvest permit application and renewal process could also be moved online, reducing staff needs and data entry time.

5.6 Conclusions

The results of this study provide insight into snapping turtle commercial harvest practices and turtle markets in New Jersey. Overall, survey respondents demonstrated a preference for sustainable harvesting and conservation of snapping turtles, agreed to the implementation of a carapace size limit, and are willing to pay a higher fee for the continuation of harvesting privileges. The results of this study can be used to direct policy decisions on how to best regulate the snapping turtle harvest in the State of New Jersey. Data can be incorporated into the revision of regulation policy, compliance requirements and conservation program of snapping turtles.

5.7 Literature Cited

Beaudry, F., Demaynadier, P. G., and Hunter, M. L. (2010) Identifying hot moments in road-mortality risk for freshwater turtles. *The Journal of Wildlife Management*, 74, 152-159.

Broberg, T., and Brännlund, R. (2008) An alternative interpretation of multiple bounded WTP data—Certainty dependent payment card intervals. *Resource and energy economics*, 30(4), 555-567.

Brooks, R. J., Brown, G. P., and Galbraith, D. A. (1991) Effects of a sudden increase in the natural mortality of adults in a population of the Common Snapping Turtle (*Chelydra serpentina*). *Canadian Journal of Zoology*, 69, 1314-1320.

Ceballos, C. P., and Fitzgerald, L. A. (2004) The trade in native and exotic turtles in Texas. *Wildlife Society Bulletin*, 32(3), 881-891.

Connecticut Department of Energy and Environmental Protection (2016) Snapping Turtle Regulations. Source:http://www.ct.gov/deep/cwp/view.asp?a=2700&q=531694&deepNav_GID=1633

Convention On International Trade In Endangered Species Of Wild Fauna And Flora (2011) Tortoises And Freshwater Turtles (Decision 15.59). https://www.cites.org/eng/com/ac/25/E25-19.pdf.

Congdon, J. D., Dunham, A. E., and van Loben Sels, R. C. (1994) Demographics of Common Snapping Turtles (Chelydra serpentina): Implications for conservation and management of long-lived organisms. *American Zoologist*, 34, 397-408.

Dixon, J. R. (2000) Amphibians and reptiles of Texas. Second edition. Texas A&M University Press, College Station, USA.

Florida Fish and Wildlife Conservation Commission (2012) Three turtle farmers charged and two arrested for illegal turtle trafficking. Source: http://www.justice.gov/usao/fls/PressReleases/120503-02.html.

Gibbons, J. W., Scott, D. E., Ryan, T. J., Buhlmann, K. A., Tuberville, T. D., Metts, B. S., Greene, J. L., Mills, T., Leiden, Y., Poppy, S., and Winne, C. T. (2000) The global decline of reptiles, Déjà Vu amphibians. *Bioscience*, 50, 653–666.

Gibbs, J. P., and Amato, G. D. (2000) Genetics and demography in turtle conservation. *Turtle Conservation. Smithsonian Institution Press, Washington, DC*, 207-217.

Gibbs, J. P., and Shriver, W. G. (2002) Estimating the effects of road mortality on turtle populations. *Conservation Biology*, 16, 1647–1652.

Hanemann, W. M. (1984) Welfare evaluations in contingent valuation experiments with discrete responses. *American journal of agricultural economics*, 66(3), 332-341.

Heppell, S. S. (1998) Application of life-history theory and population model analysis to turtle conservation. *Copeia*, 367-375.

Klemens, M. W., and Thorbjarnarson, J. B. (1995) Reptiles as a food resource. *Biodiversity and Conservation*, 4, 281-298.

Mali, I., Wang, H. H., Grant, W. E., Feldman, M., and Forstner, M. R. J. (2015) Modeling Commercial Freshwater Turtle Production on US Farms for Pet and Meat Markets. *PLoS ONE*, 10(9).

Maryland Department of Natural Resources (2009) Snapping Turtle Workgroup. Source:http://dnr.maryland.gov/fisheries/Pages/mgmt-committees/stwg-index.aspx.

Michigan Department of Natural Resources (2016) Fishing Guide. Source:http://www.michigan.gov/documents/dnr/2016-2017MIFishingGuide_515573_7.pdf

Minnesota Department of Natural Resources (2008) Minnesota Administrative Rules, Frogs and Turtles. Source: https://www.revisor.mn.gov/rules/?id=6256.0500.

National Survey (2011) U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

New Jersey Fish and Wildlife Digest (2011) Licenses information and regulations. http://www.state.nj.us/dep/fgw/pdf/2011/digfsh11-regs.pdf.

New Jersey Department of Environmental Protection (2016) Source:http://wwwstatenjus/dep/fgw/pdf/2016/digfsh16pdf.

New York Department of Environmental Conservation (ND) Reptile and Amphibian Hunting Seasons. Source:http://www.dec.ny.gov/outdoor/31339.html.

Roman, J., and Bowen, B. W. (2000) The mock turtle syndrome: genetic identification of turtle meat purchased in the southeastern United State of America. *The Zoological Society of London*, 3, 61-65.

Senneke, D. (2005) Declared Turtle Trade From the United States. The World Chelonian Trust. Source: http://www.chelonia.org/articles/us/USmarket_8.htm.

U.S. Fish and Wildlife Service (2010) U.S. Turtle Exports and Federal Trade Regulation: A Snapshot. Source https://www.fws.gov/international/pdf/archive/workshop-terrestrial-turtles-us-turtle-exports-and-federal- trade-regulation.pdf.

van Dijk, P. P. (2012) Chelydra serpentina. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>.

Wildlife Conservation Society (2011) Turtles in Trouble: The World's 25+ Most Endangered Tortoises and Freshwater Turtles-2011. Source:http://wwwwcsorg/conservation-challenges/natural-resource-use/hunting-and-wildlife-trade/the-turtle-tradeaspx.

Wood, R. C., and Herlands, R. (1997) Turtles and tires: the impact of roadkills on northern diamondback terrapin, *Malaclemys terrapin terrapin*, populations on the Cape May Peninsula, Southern New Jersey, USA. In: Van Abbema J. (Ed.), Proceedings of Conservation, Restoration, and Management of Tortoises and Turtles – An International Conference. 11-16 July, 1993, State University of New York, Purchase. New York Turtle and Tortoise Society, New York: 46-53.

Zimmer-Shaffer, S. A., Briggler, J. T., and Millspaugh, J. J. (2014) Modeling the Effects of Commercial Harvest on Population Growth of River Turtles. *Chelonian Conservation and Biology*, 13(2), 227-236.

Chapter 6. Assessing Recreational Harvest of Snapping Turtles In New Jersey

6.1 Abstract

There is growing concern that the harvest of turtles for human consumption is contributing to turtle population declines. In recent years, there has been an increased demand for wild caught turtles in the United State to supply the global market. With the increased demand there have been policy responses to arrest the steady decline in turtle populations reflected in number of new and stricter state laws. Snapping turtles (*Chelydra serpentina serpertina*) are the most commonly harvested turtle species in the U.S. for human consumption and most often the least regulated. The state of New Jersey allows both recreational and commercial harvests of snapping turtles throughout the state. This study aims to analyze the recreational harvest of snapping turtles in New Jersey using an on-line survey approach. The survey notification was sent out to fishing license holders via email; 747 completed responses were received. Over 20% of respondents reported intentionally catching snapping turtles, and approximately 18% consumed the turtles caught. The mean amount survey participants were willing to pay for a permit allowing them to keep their recreational harvesting privilege was $13.31 per permit. This study utilized an ordinal logit model to evaluate the respondents' Willingness to Pay (WTP) for recreational harvesting privileges. The results also suggest that perceptions pertaining to the adequacy of permit costs, gender, and income levels played an important role in

determining WTP. The results of this study provide a better understanding of the harvest of snapping turtles, and can be used to aid proper harvest management decisions.

6.2 Introduction

Over the last two decades there has been a growing concern over the decline of many turtle species around the world (Klemens and Thourbjanarson, 1995). Turtles face many threats ranging from habitat loss to predation to harvesting. Turtles have been used for medicine, turtle farms, pet trade, expositions, zoos, and the most recently for human consumption as food. The consumption of turtles, although a worldwide practice, is most common among the residents of Southeast Asia. As a result, 68% of the turtle species found in Southeast Asia are imperiled and many are on the brink of extinction. This decline is often referred to as the Asian Turtle Crisis (Wildlife Conservation Society, 2011). As native turtle populations began to severely decline in Southeast Asia, the market turned to global sources including the United States (Behler, 1997). In response to the overseas demand, private turtle farms have been opened in the United States primarily in Louisiana (Mali et al., 2015). However, their success has been limited due to their dependence on wild caught turtles for brooding stocks, low captive breeding success, and the occurrence of Salmonella outbreaks within captive bread turtles (Florida Fish & Wildlife Conservation Commission, 2012; Zhou and Jiang, 2004). These limitations have led to increased demand for wild caught turtles for human consumption. The demand for turtles comes not only from Asian countries, but also from within the United States. The United States had been harvesting turtles since the early 1900s, prior to the listing of sea turtles under the Endangered Species Act, primarily for human consumption. Alligator snapping turtles and diamondback terrapins were almost hunted to extinction in the U.S. (Roman and Bowen, 2000).

Unfortunately, to date, turtle harvesting and export regulations remain loose, which leads to the legal export of an estimated 10 million turtles annually (USFWS, 2010). Furthermore, there is limited information available on the number of turtles harvested and exported. This makes it extremely challenging to evaluate the magnitude and impact of the trade on wild populations (Ceballos and Fitzgerald, 2004). However, experts believe the turtle trade market is the main cause of wild turtle population declines in the United States (Dixon, 2000; Gibbons et al., 2000). With 655,541 snapping turtles exported in 2009, the snapping turtle (*Chelydra serpentina serpentina*) is the most targeted freshwater turtle in North America (U.S. Fish and Wildlife Service, 2010) (Table 6.1). Although many of the turtles exported might have originated from commercial turtle farms, it is estimated that approximately 39% of the snapping turtles exported were wild caught (Senneke, 2005), making snapping turtles the most commonly exported turtle species in the United States (Convention On International Trade In Endangered Species Of Wild Fauna And Flora, 2011). The harvest of long-lived organisms, such as snapping turtles, is argued to be unsustainable, and any harvesting of wild turtles can severely impact populations causing local turtle populations to decline (Congdon et al., 1994; Zimmer-Shaffer et al., 2014).

Table 6.1. U.S. exports of the common snapping turtle from 1990 to 2009 (van Dijk, 2012).

Year	**1990**	**1995**	**2003**	**2005**	**2008**	**2009**
Export number	3,122	17,495	129,499	320,940	497,107	655,541

The International Union for Conservation of Nature (IUCN) classifies the common snapping turtle conservation status as of least concern. Yet, in Canada snapping turtles are considered a special concern species (Committee on the Status of Endangered Wildlife in Canada, 2008). As the demand for turtle meat increases and the status of the species becomes questionable, some states in the U.S. have limited or terminated the commercial harvest of the species including Alabama, Illinois, Maine, New Hampshire, Oklahoma, West Virginia, Nebraska, South Dakota, Mississippi, and North Carolina (Giese, 2012). Today, 25 states allow the commercial harvest of snapping turtles, including the State of New Jersey.

Research has found that harvesting even a small percent of the turtle population can result in a population decline (Brooks et al., 1991; Congdon et al., 1994; Gibbs and Amato, 2000). Congdon et al. (1994) studied a non-harvested population of snapping turtles in Michigan for over 18 years, providing a life table and population simulation. The study results suggest it would take 2,000 years for a non-harvested population to double in size. The same study also documented that an increase in adult mortality by 10% annually would halve the population in 10 years. Another long-term study in Canada by Brooks et al. (1991) also found populations could not tolerate a harvest of more than

10% of the population. Gibbs and Amato (2000) found no reports of a sustainable harvest for wild turtles. Congdon et al., (1994) advises that there are strong arguments against sustained harvests of long-lived organisms based on the concept of sustained yield. Other studies suggest even a 3% or less increase in adult mortality can impact population stability and growth (Beaudry et al., 2010; Gibbs and Shiver, 2002; Wood and Herlands, 1997). For example, Wood and Herlands (1997) describe their 7 years of efforts to salvage, hatch, and headstart diamondback terrapin roadkill eggs as “merely slowing down the local population crash.” Similarly, Gibbs and Shiver (2002) conclude road mortality by itself can cause population instability and decline. These studies clearly demonstrate turtle harvesting programs are a threat to sustainable wild turtle populations.

6.2.1 Snapping Turtle Harvest in New Jersey

Snapping turtles are one of the 12 native turtle species in New Jersey and the only turtle species commercially and recreationally harvested in the state. With no turtle farms operating in New Jersey, commercial harvesting likely puts pressure on the wild populations. The state currently allows both recreational and commercial harvesters to collect snapping turtles. At the time of this study the harvest of snapping turtles was allowed throughout the year, with the exception of the nesting season from May 1 to June 15. Prior to the 2016 harvesting season, New Jersey’s Department of Environmental Protection (NJDEP) regulations state “Any person with a valid fishing license or those entitled to fish without a license may take up to three snapping turtles a day either by traps or with hands, either adults or juvenile, with no reporting requirement” (NJDEP, 2011). This regulation left fishing license holders, also known as recreational harvesters, largely unregulated.

The New Jersey commercial snapping turtle harvest program is lightly regulated. The commercial harvesting permit for snapping turtles is available to any one holding a valid fishing license for the cost of $2.00 in addition to the fishing license fee of $22.50. Although harvesters are required to submit a monthly report with the number of snapping turtles caught and the location where they were harvested, many harvesters fail to submit reports or submit questionable data. Harvesters who fail to submit their monthly reports by the end of the year are prohibited from renewing their license. Unfortunately, the data submitted by harvesters is not verified and data collected is considered conservative by many leading experts.

Meanwhile, the commercial harvest has no regulations limiting the number of snapping turtles collected, their size, weight, or sex, and no limits specific to the water bodies from which turtles are harvested. These lax regulations have led to an increasing trend in the number of snapping turtles harvested, with a peak of 5,689 turtles harvested in 2011. Commercial harvesters reported taking 449 fewer snapping turtles in 2012 than in 2011, and 1,500 less in 2013. With the increase in harvest pressure from previous years, this trend could indicate a decline in wild snapping turtle populations as a result of an unsustainable snapping turtle harvest in New Jersey.

With no registration or reporting requirements for the recreational harvest, there is a lack of understanding on snapping turtle harvest practices in New Jersey. The objective of this study is to gather information from recreational harvesters, gain insights into their practices, and identify their willingness to pay increased license fees in efforts to conserve wild snapping turtle populations. This study makes two significant contributions to the conservation planning and angler impact assessment literature. First, the paper develops a survey approach to assess market instruments based conservation planning efforts, in terms of increased license fee in a self-reporting context. Second, while it is implicit that any new regulation regarding conservation planning involves an opportunity cost to government in terms of monitoring and implementation, this paper demonstrates the benefit of investing in snapping turtles conservation efforts through a not-top-heavy regulatory approach. This study, thus, is not only important in determining harvester's willingness to pay, regulations to which they would be most receptive, and in estimating the number of snapping turtles recreationally harvested, but also provides additional insights that can improve conservation management and planning of snapping turtles in particular, and harvested turtle species in general.

6.3 Materials and Methods

In collaboration with the Bureau of Freshwater Fisheries within the New Jersey Department of Environmental Protection Division of Fish and Wildlife (NJDEP), a survey was developed for fishing license holders in order to better understand the recreational snapping turtle harvest practices, and harvester willingness to pay a permit fee to keep recreational harvesting rights. The survey used the contingent value (CV) method to estimate the non-market values of fishing license holders' privilege to recreationally harvest snapping turtles.

The survey was pre-tested in focus groups composed of college students, formal and informal educators, wildlife conservation groups, and hunting and trapping organizations. Prior to its launch, the survey was also reviewed by the NJDEP. The NJDEP posted the survey on their website and announced the survey via email to fishing license permit holders. The survey was accompanied by a note stating the survey was voluntary, and only individuals 18 years or older were allowed to participate. The survey was launched on December 23, 2014 and closed on February 28, 2015.

The survey consisted of 4 sections. The first section provided background information on the harvest and snapping turtles in New Jersey. The second section asked respondents for information on their recreational harvesting practices, if any. This section included basic questions in order to gather information on the rate of recreational harvesting, harvesting practices, and whether the catch was opportunistic or targeted. The third section included willingness to pay (WTP) options and ranking options for potential snapping turtle regulation in order to determine level of compliance by respondents. To determine how much fishing license holders would be willing to pay for a license, respondents were asked a bid format question “What amount would you be willing to pay to keep your snapping turtle harvesting privileges of taking 3 snapping turtles a day during the open season?” Response bid values were $5, $10, $15 and $30. Respondents were also provided with an opened ended question “Please state the maximum amount you would be willing to pay to maintain your snapping turtle harvesting privileges” to determine maximum WTP over and above these bids. The fourth section requested demographic information including age, gender, income, and level of education.

6.3.1 Theoretical Framework

The ordinal logit model framework falls under the category of proportional odds models, wherein the cumulative logit L_j takes the form:

$$L_j(x) = \alpha_j + \beta' x, \qquad j = 1, \dots, J-1 \qquad (1)$$

where the L_j values are the cutpoint parameters, the cumulative probability function $L_j(x)$ is increasing in j, and the responses from categories 1 to j form a single category and these from j+1 to J form a second category (Agresti, 1996). Furthermore, the model satisfies

$$L_j(x_1) - L_j(x_2) = Log\left[\frac{P(Y \leq j|x_1)/P(Y > j|x_1)}{P(Y \leq j|x_2)/P(Y > j|x_2)}\right] = \beta'(x_1 - x_2) \qquad (2)$$

The response curves for the different categories j have the same shape but differ in terms of their intercepts (Agresti, 1996). Taking the exponential of the respective coefficients gives the proportional odds ratios for the ordered logit model. Given the nature of the response the ordinal logit model is used to analyze the data, because it appropriately captures the ordinal nature of the response variable.

6.4 Results and Discussion

6.4.1 Demographics

We received responses from 747 participants. Respondents were mostly males (89%) while females compromised 11% of participants. The 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, published jointly by the U.S. Department of Interior, U.S. Fish and Wildlife Service and the U.S. Department of

Commerce, and U.S. Census Bureau, provided a brief snapshot of demographic characteristics of New Jersey (National Survey, 2011). The report estimated that males comprise 80% of the resident angler population. The proportion of males in our survey respondents was slightly higher. Approximately 81.5% of respondents were older than 41 years of age. Four percent of the participants between 18 and 25 years of age. Respondents between the ages of 26 to 40 composed 14.5% of the participants. Since the age-intervals were different in our survey from the 2011 National Survey, an exact comparison was not possible. However, the National Survey proportion of respondents older than 35 years was approximately 71%. Thus, our respondent profile had a higher average age than the population captured in the 2011 National Survey.

Most respondents had some college-level education or had completed college (82.8%), while 16.4% completed high school and 0.8% had completed only primary school. Our respondent profile has a higher proportion of individuals with college education than the 2011 National Survey (68%). Nearly 57% of respondents had annual incomes exceeding \$75,000 a year. Individuals with incomes of \$55 000 to \$74999, \$25,000 to \$54,999, and less than \$25,000 comprised 21.6%, 15.5%, and 6.1%, of the respondents, respectively. The proportion of resident anglers estimated to have an annual household income in excess of \$75 000 was 59% in the 2011 National Survey. Respondent were mainly Caucasians (93%). Asian Pacific Islanders were represented by 1.9%, Native American by 1%, African American by 0.4%, and Hispanics by 0.08% of respondents. This is similar to the 2011 National Survey 2011, which reported 95% of the resident angler population in New Jersey was Caucasian.

Table 6.2. Summary of respondent's demographic information.

Demographic parameter	Respondents (%)
Gender	
Male	88.8
Female	11.2
Age	
18-25	4
26-40	14.5
41+	81.5
Level of Education	
Elementary	0.8
High School	16.4
Some College	25.8
College	57
Income	
Less than 25 000	6.1
25 000-54 999	15.5
55 000-74 999	21.6
75 000+	56.8
Ethnicity	
Caucasian	92.8
Asian Pacific Islander	1.9
Native American	1
Hispanic	0.8
African American	0.4
Other	3

6.4.2 Respondent's Awareness Regarding Recreational Harvest

Of the 747 respondents, 239 (31.9%) were aware of the recreational harvest of snapping turtles in New Jersey. Within this group, 128 (53.6%) stated they would not be collecting snapping turtles during the 2015 open harvest season. Forty-eight (20.1%) respondents said they would participate in the 2015 recreational harvest. Within this group, 46 (95.8%) had collected snapping turtles in previous years for various reasons including for consumption. Among the 239 respondents who were aware of the harvesting program, 20 (8.4%) had consumed their catch, 10 (4.2%) sold their catch, 8 (3.3%) kept snapping turtles as pets, and the remaining either released or did not state what was done with turtles caught during the June 2013- May 2014 open harvest season.

Of the 747 respondents, 508 (68%) stated they were not aware of the recreational harvest provisions in New Jersey. Within this group, 385 (75.8%) responded that they will not be collecting snapping turtles, 105 (20.7%) did not respond to this question, and 18 (3.5%) stated that they will collect snapping turtle during the next season. From the 18 respondents stating their intention to collect snapping turtles, 13 (72.2%) had previously collected snapping turtles either purposefully or accidentally, and 5 (2.8%) had never collected snapping turtles.

Respondents who were unaware of the recreational harvest still reported collecting snapping turtles. 57 (11.2%) unaware respondents consumed their catch, 12 (2.4%) sold their catch, and 13 (3.3%) kept the turtles as pets. Of the 210 (41.3%) unaware respondents who caught snapping turtles accidentally, 19 (9.1%) reported consuming their catch.

Forty-nine (20.5%) respondents aware of the recreational harvest and 17 (3.3%) unaware respondents reported actively harvesting snapping turtles. We estimated that these respondents harvested 600 turtles from 2013 to 2014.

We estimated respondents collected 2,285 snapping turtles between 2013 and 2014. Most of the turtles collected were reported as released (62%) while the remaining 852 turtles were consumed, sold, kept as pets, or unstated. Most snapping turtles were caught on fishing trips (73.8%), which also led to most snapping turtles being caught by fishing hook (52.6%) or by hand (26.1%). Targeting snapping turtles was the second most common (10.3%) reason for trips, and these often involved the use of turtle traps as a catching method (88%). Those respondents who used traps were most likely to take snapping turtles (63.6%) rather than release them (36.4%).

6.4.3 Suggested Regulations

Respondents were asked to rank potential snapping turtle regulations on a scale of 1 to 5 based on how strongly they agreed with each proposed regulation (Table 6.3). Most respondents agreed that the overall number of snapping turtles (53.3%), the number of female snapping turtles (57.4%), and the number of snapping turtles caught from specific water bodies per season should be limited (48.2%). Most respondents also agreed that there should be a minimum size requirement for carapace length for harvesting snapping turtles. Potential permit requirements and permit price changes were also presented to the respondent. Less than half (48.8%) of respondents agreed or strongly agreed that there should be a special permit required for recreational harvest of snapping turtles, and 53.4% agreed or strongly agreed the recreational harvest should be regulated.

Respondents were also asked for their opinions on the commercial harvest of snapping turtles. Only 34.8% suggested the commercial harvesting of snapping turtles should be closed while 32.7% wanted the harvest to remain opened, and 32.5% were neutral in their responses. The majority of respondents (58.2%) agreed that the commercial harvesting permit fee should be increased.

Table 6.3. Summary of ranks from strongly agree to strongly disagree as they influence their level of compliance with potential snapping turtle regulations.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Number of turtles that can be caught per season should be limited	3.9%	4.0%	11.4%	27.4%	53.3%
Number of female turtles that can be caught per season should be limited	2.4%	3.7%	12.9%	23.6%	57.4%
Number of turtles that can be collected per season from specific waterbodies should be limited	3.6%	5.9%	16.1%	26.2%	48.2%
There should be a minimum size limit on snapping turtles that can be taken under a recreational fishing license	4.0%	5.0%	11.6%	26.4%	53%
There should be a special permit that allows for recreational harvesting of snapping turtles in addition to fishing license	19.6%	14.1%	22.3%	14.1%	30%
There should be restrictions on the harvest of turtles by fishing license holders	11.3%	11.5%	25.7%	12.4%	34.7%
There should be a special permit required for anyone catching snapping turtles whether for recreational or commercial purposes	12.1%	12.4%	16.6%	14.4%	38.0%
The permit price for taking snapping turtles should be increased	12.6%	10.2%	19%	18.5%	39.7%
Permit prices should be increased to deter newcomers and inexperienced persons from targeting snapping turtles	21.9%	18.1%	22.4%	10.1%	27.5%
The number of traps, hooks, and nets that each licensee/permittee can set to catch snapping turtles should be limited	7.2%	9.3%	16.6%	9.3%	57.6%
The snapping turtle harvest season should be shortened	10.7%	13.8%	43.2%	8.6%	23.7%
The commercial harvest of snapping turtles should be stopped	14.9%	17.8%	32.5%	9.9%	24.9%

According to respondents, the best management regulation would be to limit the number of turtles caught per season. However, there was already a limit in place on the number of turtles collected under a fishing license. The survey also tested angler willingness to accept potential policies limiting number of takes for snapping turtles. Anglers agreed to limiting the number of turtles caught per waterbody (74.4%) and limiting the number of traps and hooks per license holder (66.9%).

6.4.4 Willingness To Pay Analysis

Respondents were asked to state their opinions regarding the current commercial snapping turtle harvest permit cost of $2. They were given the options to state whether the cost is too low, about right, too expensive, or if they had no opinion. Most respondents (60.2%) stated that permit price was too low, 2% believed it was too expensive, and 19% stated permit prices to be about right. 19% of respondents had no opinion on permit price. Respondents were also asked to state the maximum they would be willing to pay to recreationally harvest snapping turtles. The WTP bid option was capped at $100. The cap amount was selected based on the highest available recreational turtle harvesting permit price in the United States. There were a total of 24 outliers where respondents stated to have a WTP above $100. Excluding outliers, the respondents' WTP ranged from $0 to $100 with a mean WTP of $13.31 per year.

<u>6.4.5 Ordinal Logit Model</u>

The results of a chi-square test in the Ordinal Logit Model suggest WTP was significantly influenced by variables including sex and opinion of permit cost ($p < 0.0001$). Additionally, WTP was influenced by whether turtles were caught accidentally, on purpose, or never caught ($p < 0.0001$) (Table 6.4). The independent variables were then evaluated based on their impact on the dependent variable, willingness to pay. The model used the $5 WTP category as the reference level. We found that the independent variables pertaining to the intention of the catch, perceptions about permit costs, gender and income were significant (Table 6.4).

For the independent variable stating if participants had intentionally, accidentally, or had never caught a snapping turtle, the coefficient or WTP associated with respondents who accidentally caught snapping turtles was statistically significant ($p=0.0079$). Respondents who accidentally caught snapping turtles were 0.74 times less likely to have a WTP higher than $5 as compared to those who had never caught a snapping turtle, as indicated by the corresponding proportional odds ratio (Table 6.4). Meanwhile, respondents who actively targeted snapping turtles were more inclined to harvest for consumption, sale, or keeping as a pet, and were willing to pay a higher permit price. WTP is often the measure of demand of a resource. Thus the WTP in this study was driven by the demand and use value of snapping turtles by recreational harvesters (Hussain et al., 2004; Pate and Loomis, 1997). Anglers with no interest in snapping turtles had no need to pay a permit fee for a resource they did not use. As expected, the results showed a tradeoff between the recreational harvesters WTP and interest in taking snapping turtles. A previous study on WTP for a dusky restocking program suggested anglers who fished frequently were willing to pay more than those who fished less frequently (Palmer and Snowball, 2009). Another study found hunters in Alabama to be more likely to pay higher lease fees for land where they were most successful at harvesting their target species (Hussain et al., 2004).

The coefficient associated with the variable capturing respondents' perception about adequacy of permit costs, specifically those who feel that the current \$2 commercial permit fee is too low, was significant ($p<0.0001$) (Table 6.4). The corresponding proportional odds ratio indicates that these respondents were 6.3 times more likely to have a WTP in the higher categories as compared to respondents who felt that the permit price was "about right." This suggests those respondents who believed the permit price was too low also believed the permit price should be above the \$5 reference category. Respondents who stated permit prices to be too expensive were the most successful at catching snapping turtles, catching a mean of 34.9 snapping turtles per person between June 2013- May 2014. Respondents stating the price to be about right and those who had no opinion harvested a mean of 5.51 and 5.38 snapping turtles per person, respectively, between June 2013- May 2014. Lastly, those who believed the commercial permit price was too low were less likely to catch snapping turtles, catching a mean of 3.41 snapping turtles per person between 2013 and 2014. This last group of respondents might be providing a non-use existence value such as the value of the preservation of the species rather than the use (Bateman and Langford, 1997). Similarly, both respondents who stated permit prices to be too expensive as well as those who stated it to be too low might represent a protester respondent rather than their true thought on the cost of the permit (Söderberg and Barton, 2014).

Table 6.4. Summary of ordinal logit regression model odds ratios computed for statistically significant variables (* Indicates significant variables)

Variable	**Estimate**	**Std Error**	**ChiSquare**	**Prob>ChiSq**	**Proportional Odds Ratio**
Intercept [30]	-2.2323	0.4047	30.42	<.0001*	
Intercept [15]	-1.6231	0.4012	16.37	<.0001*	
Intercept [10]	-0.8593	0.3978	4.67	0.0308*	
Intent/Accident [2]	-0.1451	0.1365	1.13	0.2876	
Intent/Accident [1]	-0.3069	0.1156	7.05	0.0079*	0.7357
Permit Cost [1]	1.8411	0.2285	64.93	<.0001*	6.3032
Permit Cost [2]	-0.7565	0.5898	1.65	0.1996	
Permit Cost [3]	-0.2039	0.2673	0.58	0.4454	
Sex [0]	-0.5375	0.1313	16.75	<.0001*	0.5842
Inc [1-0]	0.2452	0.3974	0.38	0.5372	
Inc [2-1]	-0.6676	0.2816	5.62	0.0177*	0.5129
Inc [3-2]	0.5976	0.2073	8.31	0.0039*	1.8177

Our analysis showed that male respondents were 0.58 times less likely than female respondents to have a WTP in the higher categories. Female respondents indicating a higher WTP was in contrast with what has been observed in most other fishing and hunting surveys (Aanesen et al., 2015; Palmer and Snowball, 2009). Survey respondents in this study were mainly males (88.8% male vs. 11.2% female). This distribution discrepancy might be a reason for the difference between male and female WTP. Additionally, males might be representing a protester response while females might be providing a non-use existence value (Bateman and Langford, 1997; Söderberg and Barton, 2014).

Previous studies suggest higher incomes positively affect WTP (Aanesen et al., 2015; Breffle et al., 2015; Palmer and Snowball, 2009). Our model also showed WTP and income to have a significant, though not linear relationship. Respondents in the income bracket between $55,000 to $74,999 had a lower proportional odds ratio of paying a higher permit prices than respondents earning $25,000 to $54,999 (Table 6.4). However, respondents whose incomes exceeded $75,000 were willing to pay 1.82 times more than respondents in the income bracket between $55,000 to $74,999. Respondents in the $25,000 to $54,999 and $75,000 or higher income brackets were more willing to pay higher permit prices than respondents in the $55,000 to $74,999 bracket. Our findings suggest there might be another variable affecting WTP. This might be partially explained by the use of the resource and the ability to pay for that resource. Although there were no significant differences between the salary brackets and the number of snapping turtles caught, the $25,000 to $54,999 and $75,000 or higher income brackets showed a higher mean number of turtles collected during the 2014 harvest season, 1.29 and 0.97, respectively (Table 6.4). The $55,000 to $74,999 income bracket respondents had a mean of 0.71 snapping turtles caught. The mean number of turtles caught from June 2013- May 2014 also showed the same income bracket trend. The $25,000 to $54,999 and $75,000 or higher income brackets caught a higher mean number of turtles (6.29 and 5.60, respectively) than the $55,000 to $74,999 income bracket respondents (mean of 4 turtles per respondent). The lower number of turtles caught by the respondents in the $55,000 to $74,999 income bracket could be a reason for their lower WTP. As suggested by previous research (Hussain et al., 2004; Palmer and Snowball, 2009; Pate and Loomis, 1997), those recreational harvesters who harvested often, or were the most successful at harvesting, also exhibited higher WTP.

6.5 Conclusions

The contingent valuation technique can help us identify the underlying factors that influence Willingness to Pay and enhance our understanding of the perceptions and attitudes of anglers. The results of this study provide insight into the demand and practices of recreational snapping turtle harvesters in New Jersey. Our results suggest most respondents were unaware of, or unlikely to take snapping turtles, yet 1,285 snapping turtles were taken between June 2013 and May 2014. Dissemination of information pertaining to current number of snapping turtles being harvested in New Jersey can provide insight into the immediate and long-term status of the species and assist with oversight and regulatory efforts of the state departments.

The results from the CV survey conducted on a sample of New Jersey fishing license and turtle harvesting permit holders indicated a mean WTP of $13.31 per year to retain the snapping turtle recreational harvest.

Fishing license holders believed the commercial harvesting permit price was too low, which was one of the main factors that positively influenced the potential WTP of survey respondents. Higher WTP for maintaining the recreational harvest might be associated with the perceived value that fishing license holders derive from engaging in such activity and/or having the option to do so. Having such information can help policy makers design user fees or access charges that will help in generating higher revenues from the sale of permits, which can be utilized for the conservation and for monitoring sustainable harvesting of the species. This will not only help mitigate any adverse impacts from biological/ecosystem perspective, but also help in developing and implementing alternate strategies for conservation and management of snapping turtles in New Jersey.

Our model suggests that respondents who actively target snapping turtles and those with salaries between $25,000 to $54,999 and $75,000 or higher were more willing to pay higher permit fees. These respondents were the most successful at collecting snapping turtles. Therefore, our study results suggest that a targeted permit fee increase based on specific socioeconomic profile of respondents can be a viable option for enforcing agencies such as NJDEP and U.S. Fish and Wildlife Service. Survey respondents also demonstrated a preference for sustainable harvesting of snapping turtles and their conservation, with broad agreement on imposing limits on the number, gender and size of turtles harvested, and limits on harvests from specific water bodies. Such insights can be incorporated into the regulation policy compliance and harvest practices, which will be useful in guiding future government policy decision on how to best regulate the snapping turtle harvest. This research was an early attempt to utilize survey-based studies to understand the perceptions of fishing license holders in New Jersey who are key stakeholders and partners for future snapping turtle conservation efforts in the state.

6.6 Literature Cited

Aanesen, M., Armstrong, C., Czajkowski, M., Falk-Petersen, J., Hanley, N., and Navrud, S. (2015) Willingness to pay for unfamiliar public goods: Preserving cold-water coral in Norway. *Ecological Economics*, 112, 53-67.

Agresti, A. (1996) Categorical data analysis (Vol. 996). New York: John Wiley and Sons.

Bateman, I. J., and Langford, I. H. (1997) Non-users' willingness to pay for a National Park: An application and critique of the contingent valuation method. *Regional Studies*, 31(6), 571-582.

Beaudry, F., Demaynadier, P. G., and Hunter, M. L. (2010) Identifying hot moments in road-mortality risk for freshwater turtles. *The Journal of Wildlife Management*, 74, 152–159.

Behler, J. L. (1997) Troubled times for turtles. Proceedings: conservation, restoration, and management of tortoises and turtles. Source:http://nytts.org/proceedings/proceed.htm.

Breffle, W. S., Eiswerth, M. E., Muralidharan, D., and Thornton, J. (2015) Understanding how income influences willingness to pay for joint programs: A more equitable value measure for the less wealthy. *Ecological Economics*, 109, 17-25.

Brooks, R. J., Brown, G. P., and Galbraith, D. A. (1991) Effects of a sudden increase in the natural mortality of adults in a population of the Common Snapping Turtle (*Chelydra serpentina*). *Canadian Journal of Zoology*, 69, 1314-1320.

Ceballos, C. P., and Fitzgerald, L. A. (2004) The trade in native and exotic turtles in Texas. *Wildlife Society Bulletin*, 32(3), 881-891.

Convention On International Trade In Endangered Species Of Wild Fauna And Flora (2011) Tortoises And Freshwater Turtles (Decision 15.59). Source:https://www.cites.org/eng/com/ac/25/E25-19.pdf.

Congdon, J. D., Dunham, A. E., and van Loben Sels, R. C. (1994) Demographics of Common Snapping Turtles (*Chelydra serpentina*): Implications for conservation and management of long-lived organisms. *American Zoologist*, 34, 397-408.

Committee on the Status of Endangered Wildlife in Canada (2008) Snapping Turtle. Source:http://www.cosewic.gc.ca/eng/sct1/searchdetail_e.cfm?id=1033&StartRow=81&boxStatus=All&boxTaxonomic=All&location=6&change=All&board=All&commonName=&scienceName=&returnFlag=0&Page=9.

Dixon, J. R. (2000) Amphibians and reptiles of Texas. Second edition. Texas A&M University Press, College Station, USA.

Florida Fish and Wildlife Conservation Commission (2012) Three turtle farmers charged and two arrested for illegal turtle trafficking. Source:http://www.justice.gov/usao/fls/PressReleases/120503-02.html.

Gibbons, J. W., Scott, D. E., Ryan, T. J., Buhlmann, K. A., Tuberville, T. D., Metts, B. S., Greene, J. L., Mills, T., Leiden, Y., Poppy, S., and Winne, C. T. (2000) The global decline of reptiles, Déjà Vu amphibians. *Bioscience*, 50, 653-666.

Gibbs, J. P., and Amato, G. D. (2000) Genetics and demography in turtle conservation. In: Klemens, M.W. (Ed.), Turtle Conservation. Smithsonian Institution Press, Washington.

Gibbs, J. P., and Shriver, W. G. (2002) Estimating the effects of road mortality on turtle populations. *Conservation Biology*, 16, 1647-1652.

Giese, C. A. (2012) Alabama Ends Commercial Harvest of Wild Freshwater Turtles Other States, Feds Should Follow Suit to Stop Slaughter of Native Turtles. Center for Biological Diversity. Source:http://www.biologicaldiversity.org/news/press_releases/2012/freshwater-turtles-04-09-2012.html.

Hussain, A., Zhang, D., and Armstrong, J.B. (2004) Willingness to pay for hunting leases in Alabama. *Southern Journal of Applied Forestry*, 28(1), 21-27.

Klemens, M.W., and Thorbjarnarson, J. B. (1995) Reptiles as a food resource. *Biodiversity and Conservation*, 4, 281-298.

Mali, I., Wang, H. H., Grant, W. E., Feldman, M., Forstner, M. R. J. (2015) Modeling Commercial Freshwater Turtle Production on US Farms for Pet and Meat Markets. *PLoS ONE*, 10(9).

National Survey (2011) U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

New Jersey Fish and Wildlife Digest (2011) Licenses information and regulations. http://www.state.nj.us/dep/fgw/pdf/2011/digfsh11-regs.pdf.

Palmer, R. M., and Snowball, J. D. (2009) The willingness to pay for dusky kob (*Argyrosomus japonicus*) restocking: using recreational line fishing license fees to fund stock enhancement in South Africa. *ICES Journal of Marine Science: Journal du Conseil*, 66(5), 839-843.

Pate, J., and Loomis, J. (1997) The effect of distance on willingness to pay values: a case study of wetlands and salmon in California. *Ecological Economics*, 20(3), 199-207.

Roman, J., and Bowen, B. W. (2000) The mock turtle syndrome: genetic identification of turtle meat purchased in the southeastern United State of America. *The Zoological Society of London*, 3, 61-65.

Senneke, D. (2005) Declared Turtle Trade From the United States. The World Chelonian Trust. Source:http://www.chelonia.org/articles/us/USmarket_8.htm.

Söderberg, M., and Barton, D. (2014) Marginal WTP and Distance Decay: The Role of 'Protest' and 'True Zero' Responses in the Economic Valuation of Recreational Water Quality. *Environmental and Resource Economics*, 59(3), 389-405.

U.S. Fish and Wildlife Service (2010) U.S. Turtle Exports and Federal Trade Regulation: A Snapshot. Source:https://www.fws.gov/international/pdf/archive/workshop-terrestrial-turtles-us-turtle-exports-and-federal- trade-regulation.pdf.

Wildlife Conservation Society (2011) Turtles in Trouble: The World's 25+ Most Endangered Tortoises and Freshwater Turtles-2011. Source:http://wwwwcsorg/conservation-challenges/natural-resource-use/hunting-and-wildlife-trade/the-turtle-tradeaspx.

Wood, R. C., and Herlands, R. (1997) Turtles and tires: the impact of roadkills on northern diamondback terrapin, Malaclemys terrapin terrapin, populations on the Cape May Peninsula, Southern New Jersey, USA. In: Van Abbema J. (Ed.), Proceedings of Conservation, Restoration, and Management of Tortoises and Turtles – An International Conference. 11-16 July, 1993, State University of New York, Purchase. New York Turtle and Tortoise Society, New York: 46-53.

Zhou, Z., and Jiang, Z. (2004) International Trade Status and Crisis for Snake Species in China. *Conservation Biology*, 18(5), 1386-1394.

Zimmer-Shaffer, S. A., Briggler, J. T., and Millspaugh, J. J. (2014) Modeling the Effects of Commercial Harvest on Population Growth of River Turtles. *Chelonian Conservation and Biology*, 13(2), 227-236.

Chapter 7. Conservation and Management of Turtle Species In New Jersey

7.1 Introduction

The New Jersey Department of Environmental Protection (NJDEP) Bureau of Freshwater Fisheries has expressed their concern over the harvest of snapping turtles and the lack of understanding of the current practices. This study provides information on the snapping turtle populations in New Jersey, with the goal of helping scientists and policy makers gain a better understanding of the potential risks turtles pose to consumers, the practice of turtle harvesting under the current programs, and the economic impact of the commercial harvesting program. Additionally, this study aims to protect the snapping turtle populations, as well as their consumers, via investigating transport of mercury in aquatic food webs at selected study sites. The results suggest consuming turtle meat might be risky, particularly for sensitive populations, and the implementation of consumption advisories are essential to better inform consumers. Furthermore, with the analysis of the harvest data and the surveys, we have provided suggestions on how to better regulate the harvest. The survey data allows us to examine potential economic impacts of eliminating the current snapping turtle harvest program and also look at other harvesting regulation methods that would be most accepted by harvesters.

Sound policy decisions should be based on scientific discoveries and technological innovations while taking social and economic aspects into consideration. Through this study we have achieved the integration of science, social, and economic components of the snapping turtle harvest to provide evidence-based suggestions for better management and regulation practices, which will be presented to NJDEP.

As previously discussed, turtle populations around the world are imperiled. Approximately 50% of turtles are threatened to some degree, and 80% of these are listed as endangered or critically endangered (Sung et al., 2013; Turtle Conservation Coalition, 2011) warranting a focus on their protection and conservation.

Turtles are a low-visibility species, living sedentary lives, usually within water, under cut bank, shrubs and vegetation, and usually are only spotted on sunny days as they bask on fallen trees and branches over a stream, or when females leave the safety of the stream in search for nesting grounds (often costing them their lives as they encounter roads). This makes estimating the abundance of turtle populations challenging, but declines are believed to be significant, mainly due to the increasing loss of habitat, habitat function, and increased export numbers (ODFW, 2015).

Turtles are especially vulnerable to harvesting due to their delayed sexual maturity, low egg and hatchling survival rate, and habitat needs. Snapping turtle is also a favorite game species due to its large body size. This study recommends methods and techniques for the conservation and safe human consumption of turtles in New Jersey with a special focus on, but not limited to, snapping turtles.

7.2 Overall Turtle Conservation Recommendations

Turtles in New Jersey and around the world continue to experience population declines, making them vulnerable to habitat loss and harvesting among other anthropogenic impacts. The closure of the harvest or overly strict regulations might lead to illegal collection or increased pressure in areas where harvesting is still permitted (Mali et al., 2014; Scheneider et al., 2011). The harvest combined with other anthropogenic stresses may represent an inevitable inclusion to the endangered species list. Therefore we recommend implementing strategies for both habitat improvement and strengthening snapping turtle harvest regulations.

Turtle survival and success depend on available nesting habitat, aquatic habitat, basking structures, aestivation habitat, overwintering habitat, and safe passage while moving between habitats. In New Jersey, much of the state’s turtle habitats have been altered, degraded or permanently lost due to human activities. The current focus should be placed on habitat preservation, creation and enhancement in small to medium size streams and water bodies.

7.2.1 Hydrology Modifications

Nesting, aquatic, and overwintering habitats are impacted by waterway modification and the alteration of hydrology. Nesting sites and overwintering sites may be flooded or be completely eliminated due to damming, channelization, filling, draining, and ditching activities. Avoiding such activities will limit the loss of turtle habitats. For example, during the overwintering months turtles hibernate in streams, muddy bottoms and undercut banks, requiring water to persist throughout the season. Additionally, channelization, impoundments, and draining of wetlands leads to the reduction of food sources, habitat loss, and shifts in species and food web compositions (Bodie, 2001).

Such activities have caused declines of turtle species in the lower Missouri River due to the lost of sandbars and beaches essential to basking and nesting activities (Fitch and Plummer, 1975; Johnson, 1992).

Minimizing impervious surfaces near waterways will help limit flooding and pollution, which contribute to habitat loss, degradation, decreased fecundity, reduced hatchling success, and genetic defects (Bergeron et al., 1994; Bodie, 2011; Lamb et al., 1995; Mascort, 1997). The treatment of stormwater runoff before it is discharged into receiving waterbodies is also crucial, not only for turtles but for all aquatic organisms.

7.2.2 Implement Buffer Zones

The implementation of buffer zones around crucial turtle habitats, such as nesting sites or foraging area, can help protect these sites from human disturbance. Rerouting recreational disturbance or limiting human activities during mating and nesting season will allow people to enjoy the outdoors with less of an impact. This will also decrease nesting predation, as human recreational activities have been associated with an increase of predators (Brooks et al., 1992; Mitchell and Klemens 2000).

7.2.3 Vegetation Management

Vegetation controls, such as eradicating invasive monocultures and planting native species, would benefit turtles (Bodie et al., 2000). The maintenance or reintroduction of native plant species provides turtles with safe summer dormancy sites as well as passageways between habitats (Mali et al., 2014). Turtles need open canopy areas, which are essential for basking and nesting activities. When eradicating invasive species it is important to research the method used, as herbicides have been shown to impact herpetofauna populations (Hayes et al., 2002; Osano et al., 2002). The protection and maintenance of suitable aquatic and adjacent terrestrial habitat are also important, as turtles require both habitat types throughout their live cycles.

7.2.4 Wildlife Crossings

Female turtles are often killed on roads as they travel to and back from nesting sites. The installation of wildlife tunnels or culverts at road mortality hotspots can keep turtles off the road, helping offset the loss of sexually mature females (Aresco, 2005). NJDEP has developed a best management practice for wildlife crossings (NJDEP, unpublished). This can also benefit other species as well as avoid human traffic accidents.

7.2.5 Basking Structures

As ectoderms, basking is an essential turtle behavior for increasing body temperature and metabolism rate. However, basking exposes turtles to predation. To reduce predation, basking structures should be created to include both opening canopy and easy access to the safety of water. Competition for basking areas also occurs, therefore, turtles should have access to multiple basking areas. Natural basking areas, such as fallen trees, should be left in place as potential basking grounds.

7.2.6 Crab Traps

Although diamondback terrapins are no longer harvested, many terrapins drown in crab traps. Crab traps are currently allowed to soak for 72 hours, and turtle excluders are only required in predetermined areas (NJDEP, 2016). We recommend that all crab traps contain turtle excluders, regardless of the site. Shortening the soak times to 24 hours and checking traps more frequently could also result in fewer drowning deaths.

7.3 Harvest Recommendations

7.3.1 Limit Harvesting Season

A closed season should be maintained for both commercial and recreational harvesting programs to avoid the take of mature nesting females. Prior to 2016, New Jersey imposed a closed harvesting season from May 1 to June 15, which was later extended to July 15 to coincide with the nesting season. Further consideration should be taken to prevent harvesting during mating season (March and April). A longer closed harvesting season will allow turtles to mate and nest prior to being harvested, increasing the rate of nesting success. Extending the closed season should not elicit strong resistance from harvesters, as most turtles were harvested between July and October according to reports submitted by commercial harvesters.

7.3.2 Size Requirement

In 2016 New Jersey implemented a size limit on turtles harvested. Our survey indicated this policy is likely to have little to no effect on the harvest, as many buyers already impose a size limit on the harvests. However, size limits are essential in protecting the sexually mature turtle populations. The 12 inch size requirement in New Jersey is estimated to protect 60% of the sexually mature population (Maryland DNR, 2010).

7.3.3 Bag or Seasonal Take Limit

Regulating daily or seasonal takes can also benefit turtle populations. For example, Alabama allows 10 turtles per day, and North Carolina allows 10 turtles per day and 100 per season. Most states that implement a minimum size requirement do not impose daily or seasonal limits. States that have bag limits often allow unlimited take from private waters (Mali et al., 2014). Future studies estimating wild turtle populations are needed to better guide sound policies on turtle harvest limits in New Jersey.

7.3.4 Proportional Sex Harvest

As discussed in Chapter 5, harvesters receive a higher payment for female turtles than males. If harvesters preferentially target females, it could lead to severe effects on the population (Congdon et al., 1994). Requiring harvesters to report the number of females caught would aid in monitoring skewness in the harvest. It would also benefit biologists by keeping a record of sex ratios and age in populations, assisting with determining if any and when sex and age skewedness occurs. The lack of sexually mature adults and skewed sex ratios are both signs of population decline and excessive pressure on wild turtle populations (Steen and Gibbs, 2004).

7.3.5 Harvest Report

New Jersey currently requires commercial harvesters to submit monthly harvest reports, all of which must be post-marked by October 31 of each year. An online reporting database would be more convenient for harvesters and more efficient in data submission. Additionally, if harvesters are required to submit forms at the end of each month rather than submit all monthly reports by October 31, data can be available more readily and possibly more accurately. The online submission database could also include a map for harvesters to report a more precise harvesting location. Reporting size and sex of the turtles as well as information on the buyers would be beneficial to keep track of population declines. The turtle harvest permit application and renewal process could also be moved online, reducing staff data entry time.

7.3.6 Tagging

New Jersey, as one of the 10 ports participating in the export of turtles, should consider implementing a tagging system to document the origin of the turtles harvested in the state (Mali et al., 2014). A tagging system informs exporting ports and authorities of the state of origin, source (farmed, wild-caught), seller, and destination of the turtles. This can assist in determining the harvesting pressure on wild populations and would further confirm trapping numbers, while also tackling illegal export and trapping activities.

7.4 Consumption Recommendations

Further studies are required to continue assessing mercury concentrations in snapping turtles and waterways. We observed a potential risk of mercury consumption in 4 New Jersey waterbodies (Cape May, Lake Wapalanne, Lake Hopatcong and the Kearny Freshwater Marsh). Therefore, we suggest that turtle consumption advisories and regulations to be developed. We also suggest that children, pregnant women, and women of childbearing age avoid consuming snapping turtles, as a high proportion of samples in this study had mercury concentrations that surpassed the sensitive population threshold.

Although health advisories do little to change behavior, some studies suggest that distributing information on health effects through public media can assist in reaching the general public (Oken et al., 2003; Soumerai et al., 1992). Although most harvesters sell their turtle catch, many also consume turtles. Providing information on turtle parts to be avoided or how to prepare a turtle for consumption should be included on the consumption advisories, for example discarding the highly contaminated liver or the trimming fat from meat. This information could be distributed on the NJDEP website or sent by mail or email when anglers purchase fishing or harvesting permits. A cautious, informed and moderate consumption advisory of fish and turtles from New Jersey waters should be made available.

7.5 Literature Cited

Aresco, M. J. (2005) Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. *Journal of Wildlife Management*, 69(2), 549-560.

Bergeron, J. M., Crews, D., and McLachlan, J. A. (1994) PCBs as environmental estrogens: turtle sex determination as a biomarker of environmental contamination. *Environmental Health Perspectives*, 102(9), 780.

Bodie, J. R., Semlitsch, R. D., and Renken, R. B. (2000) Diversity and structure of turtle assemblages: associations with wetland characters across a floodplain landscape. *Ecography*, 23(4), 444-456.

Bodie, J. R. (2001) Stream and riparian management for freshwater turtles. *Journal of Environmental Management*, 62(4), 443-455.

Brooks, R. J., Shilton, C. M., Brown, G. P., and Quinn, N. W. (1992) Body size, age distribution, and reproduction in a northern population of wood turtles (*Clemmys insculpta*). *Canadian Journal of Zoology*, 70(3), 462-469.

Congdon, J. D., Dunham, A. E., and Van Loben Sels, R. C. (1994) Demographics of Common Snapping Turtles (*Chelydra serpentina*): Implications for conservation and management of long-lived organisms. *American Zoologist*, 34, 397-408.

Fitch, H. S., and Plummer, M. V. (1975) A preliminary ecological study of the soft-shelled turtle *Trionyx muticus* in the Kansas River. *Israel Journal of Zoology*, 24(1-2), 28-42.

Hayes, T., Haston, K., Tsui, M., Hoang, A., Haeffele, C., and Vonk, A. (2002) Herbicides: feminization of male frogs in the wild. *Nature*, 419(6910), 895-896.

Johnson, W. C. (1992) Dams and riparian forests: case study from the upper Missouri River. *Rivers*, 3(4), 229-242.

Lamb, T., Bickham, J. W., Lyne, T. B., and Gibbons, J. W. (1995) The slider turtle as an environmental sentinel: Multiple tissue assays using flow cytometric analysis. *Ecotoxicology*, 4(1), 5-13.

Mali, I., Vandewege, M. W., Davis, S. K., and Forstner, M. R. (2014) Magnitude of the freshwater turtle exports from the US: long term trends and early effects of newly implemented harvest management regimes. *PloS one*, 9(1).

Maryland Department of Natural Resources (2010) Snapping Turtle Management in Maryland. Source: https://www.fws.gov/international/pdf/archive/workshop-terrestrial-turtles-snapping-turtle-management-in-md.pdf.

Mascort, R. (1997) An overview of a threatened population of the European pond turtle, Emys orbicularis. In *Proceedings of the Conservation, Restoration, and Management of Tortoises and Turtles: An International Conference*, 441-443.

Mitchell, J. C., and Klemens M. W. (2000) Primary and secondary effects of habitat alteration. Turtle Conservation, Smithsonian Institution Press, Washington, DC. USA. 5-32.

New Jersey Department of Environmental Protection (2016) Recreational Crab Pot And Trot Line Regulations. Source: http://www.njfishandwildlife.com/pdf/non-comm_crabpot_regs.pdf.

Oken, E., Kleinman, K. P., Berland, W. E., Simon, S. R., Rich-Edwards, J. W., and Gillman, M. W. (2003) Decline in fish consumption among pregnant women after a national mercury advisory. *Obstetrics and Gynecology*, 102(2), 346-351.

Oregon Department of Fish and Wildlife (2015) Guidance for Conserving Oregon's Native Turtles including Best Management Practices. 99.

Osano, O., Admiraal, W., and Otieno, D. (2002) Developmental disorders in embryos of the frog Xenopus laevis induced by chloroacetanilide herbicides and their degradation products. *Environmental toxicology and chemistry*, 21(2), 375-379.

Schneider, L., Ferrara, C. R., Vogt, R. C., and Burger, J. (2011) History of turtle exploitation and management techniques to conserve turtles in the Rio Negro Basin of the Brazilian Amazon. *Chelonian Conservation and Biology*, 10(1), 149-157.

Soumerai, S.B., Ross-Degnan, D., and Kahn, J. S. (1992) Effects of professional and media warnings about the association between aspirin use in children and Reye's syndrome. Milbank Q, 70, 155–82.

Steen, D. A., and Gibbs, J. P. (2004) Effects of roads on the structure of freshwater turtle populations. *Conservation Biology*, 18(4), 1143-1148.

Sung, Y. H., Karraker, N. E., and Hau, B. C. (2013) Demographic evidence of illegal harvesting of an endangered Asian turtle. *Conservation Biology*, 27(6), 1421-1428.

Turtle Conservation Coalition (2011) [Rhodin, A.G.J., Walde, A.D., Horne, B.D., Van Dijk, P.P., Blanck, T., And Hudson, R. (eds.)]. Turtles in Trouble: The World's 25 Most Endangered Tortoises and Freshwater Turtles. Lunenburg, MA: IUCN/SSC Tortoise and

Freshwater Turtle Specialist Group, Turtle Conservation Fund, Turtle Survival Alliance, Turtle Conservancy, Chelonian Research Foundation, Conservation International, Wildlife Conservation Society, and San Diego Zoo Global, 54.

<u>Appendix A. Cape May Diamondback Terrapin Data</u>

ID	**CL (cm)**	**Wt. (kg)**	**Sex**	**Carapace (ppm)**	**Blood (ppm)**	**Muscle (ppm)**	**Collection Method**
1	20.32	NA	F	1.329	NA	0.273	Donated
2	19.05	NA	F	1.023	2.176	0.622	Donated
3	17.145	NA	F	0.873	0.151	0.203	Donated
4	17.78	NA	F	0.835	NA	0.138	Donated
5	18.415	NA	F	1.752	0.366	0.204	Donated
6	15.24	NA	F	1.138	NA	0.725	Donated
7	19.05	NA	F	1.425	0.181	0.11	Donated
8	19.05	NA	F	1.267	NA	NA	Donated
9	19.05	NA	F	0.25	0.019	0.029	Donated
10	20.32	NA	F	0.756	0.081	0.172	Donated
11	20.32	NA	F	0.185	1.511	0.124	Donated
12	16.51	NA	F	13.05	0.049	0.134	Donated
13	17.145	NA	F	0.783	0.143	0.073	Donated
14	21.59	NA	F	3.882	0.104	0.26	Donated
15	17.526	NA	F	3.735	0.195	0.364	Donated
16	19.05	NA	F	5.533	0.408	0.458	Donated
1	12.395	NA	M	3.063	0.084	0.371	Donated
2	12.7	NA	M	4.028	NA	0.583	Donated
3	13.335	NA	M	0.931	NA	0.264	Donated
4	11.43	NA	M	0.43	NA	NA	Donated
5	12.7	NA	M	0.578	NA	0.112	Donated
6	11.43	NA	M	0.728	0.017	0.057	Donated
7	12.065	NA	M	1.189	0.039	0.11	Donated
8	12.065	NA	M	1.244	0.034	0.103	Donated

Appendix B. Hackensack Meadowlands Diamondback Terrapin Data

ID	**CL (cm)**	**Wt. (kg)**	**Sex**	**Carapace (ppm)**	**Blood (ppm)**	**Muscle (ppm)**	**Collection Method**
C	14.5	452	F	0.749	0.154	0.094	Donated
E	11.1	242	F	0.825	0.154	0.111	Donated
G	11.9	252	F	1.753	0.373	0.018	Donated
L	13	364	F	0.799	NA	0.903	Donated
A	12.2	278	M	1.19	0.107	0.307	Donated
B	11.9	256	M	1.193	0.068	0.228	Donated
D	12.5	292	M	0.509	NA	NA	Donated
F	12.5	308	M	0.477	NA	0.305	Donated
H	12.9	338	M	0.778	NA	NA	Donated
I	12.2	256	M	1.388	0.156	0.283	Donated
J	12.2	264	M	1.469	NA	0.3	Donated
K	11.7	238	M	0.443	0.066	0.283	Donated
M	11.6	236	M	0.862	0.244	0.304	Donated

Appendix C. Lake Hopatcong Snapping Turtle Data

ID	**CL (cm)**	**Wt. (kg)**	**Sex**	**Carapace (ppm)**	**Blood (ppm)**	**Muscle (ppm)**	**Collection Method**
H821C	25	10	F	1.246	0.049	0.059	Hoop
H537C	28.7	11.3	F	0.408	0.005	0.034	Hoop
H769C	25.9	8.9	M	0.889	0.014	0.061	Hoop
H634C	33.15	13.2	M	1.329	0.055	0.103	Hoop
H570C	25.1	9.5	M	0.496	0.053	0.016	Hoop
H119C	12.9	4.6	M	0.784	0.025	0.058	Hoop
HJARC1	21.4	8.2	M	2.223	0.053	0.153	Hoop
HJMUSC	11	4.4	F	1.990	0.024	NA	Hoop
H076C	38.75	14.4	F	1.132	0.057	0.072	Hoop
H565C	34.9	13.74	F	0.378	0.026	0.052	Hoop
H886C	24	8.6	M	1.626	0.061	0.129	Hoop
H273C	20.55	7.8	F	1.965	0.158	1.002	Hoop
HS01C	35	13.7	M	3.093	0.059	NA	Hoop
H097C	40.9	15.3	F	2.905	0.142	0.751	Hoop
H005C	37.3	13.7	M	3.942	NA	0.599	Hoop
H052C	16	6.4	M	5.066	0.149	0.789	Hoop
H602C	25	2.7	M	1.493	0.095	0.592	Hoop
H677C	NA	NA	F	4.633	0.193	0.288	Hoop
HJuvDC	NA	NA	J	1.511	0.031	0.103	Hoop
HAdultdDC	NA	NA	F	0.581	0.072	0.058	Hoop

Appendix D. Lake Wapalanne Snapping Turtle Data

ID	**CL (cm)**	**Wt. (kg)**	**Sex**	**Carapace (ppm)**	**Blood (ppm)**	**Muscle (ppm)**	**Collection Method**
S1	26.67	5.22	F	1.102	0.303	NA	Hoop
S2	12.51	0.42	M	2.147	0.099	NA	Hoop
3013833	41.43	14.97	F	2.092	0.341	2.072	Hoop
3004091	32.35	8.62	F	1.981	0.053	NA	Hoop
2895350	39.57	NA	M	1.162	0.583	NA	Hoop
3001011	40.27	16.33	F	1.775	0.074	NA	Hoop
3012607	36.46	8.16	F	3.174	0.085	NA	Hoop
3026069	17.56	1.22	J	1.219	NA	NA	Hoop
3004283	32.73	7.71	M	1.625	0.040	0.414	Hoop
3008091	29.46	4.99	M	1.296	0.205	2.882	Hoop
3010117	38.35	11.34	M	1.214	0.058	NA	Hoop
3029599	31.24	5.44	F	1.806	NA	NA	Hoop
3025611	30.99	6.35	F	1.720	NA	NA	Hoop
3009013	25.4	2.95	M	1.365	0.074	NA	Hoop
3011581	25.63	2.27	F	1.743	0.051	NA	Hoop
3021803	25.65	1.81	M	1.350	NA	NA	Hoop
3029541	25.65	3.18	F	1.879	0.035	NA	Hoop
3008885	25.4	1.81	F	1.154	0.250	NA	Hoop
2895786	26.92	3.18	F	1.516	0.034	NA	Hoop
2891367	26.75	2.72	F	1.160	0.040	NA	Hoop
3004535	37.85	17.7	M	1.210	NA	NA	Hoop
2895039	16	0.45	M	3.843	1.040	NA	Hoop
3008585	9.7	1.36	M	1.473	0.042	NA	Hoop
3029329	18.03	0.68	F	3.089	0.272	NA	Hoop
3013091	24.89	3.18	M	1.163	0.027	NA	Hoop
3001829	30.48	3.63	F	1.314	0.042	NA	Hoop
2889002	21.79	2.36	F	2.469	0.078	0.093	Hoop
3008094	15.62	0.91	F	2.087	0.070	0.098	Hoop
3013091	25.65	3.63	M	1.196	0.368	0.546	Hoop
3013052	31.75	9.1	M	0.756	0.050	0.070	Hoop
3015050	20.83	1.81	F	3.064	0.100	0.157	Hoop
3006086	37.85	16.78	M	1.311	NA	0.286	Hoop
3030293	33.63	6.8	M	1.022	0.116	0.162	Hoop
3025850	25.91	2.72	F	0.927	0.044	0.050	Hoop
1tC13	NA	NA	F	1.651	0.088	0.162	Road kill
2891367	33.02	6.8	F	1.564	NA	NA	Hoop
3004535	35.6	9.1	F	2.543	NA	NA	Hoop

S293C	31.4	6.8	M	0.287	0.005	0.027	Hoop
S013C	34.3	10.4	F	0.770	0.004	0.009	Hoop
S103C	27.6	3.7	F	3.189	0.004	0.104	Hoop
S101C	24.9	2.72	F	0.131	0.005	0.016	Hoop
S513C	24.1	1.81	F	0.517	0.065	0.075	Hoop
S885C	23.75	2.3	F	0.423	0.008	0.072	Hoop
S568C	31.37	7.26	F	0.268	0.007	0.016	Hoop
S786C	25.75	4.5	M	0.712	0.033	0.221	Hoop
S329C	24.65	2.26	F	1.374	0.023	0.291	Hoop
S535C	17.95	0.45	M	1.215	0.026	0.188	Hoop
S094C	38	17.7	M	0.842	0.005	0.076	Hoop
S091C	22.71	4	F	0.336	0.016	0.015	Hoop
S770C	19.95	1.8	F	3.724	0.102	0.693	Hoop
S778C	32.9	10.4	F	0.658	0.011	0.256	Hoop
S329C	18.1	0.9	F	1.167	NA	0.224	Hoop
S278C	25.95	4.5	F	1.212	0.082	0.308	Hoop
S210C	20.9	2.26	F	0.805	0.037	0.340	Hoop
S840C	26.3	3.17	M	1.074	0.074	0.484	Hoop
S548C	34.2	8.16	M	0.786	0.017	0.333	Hoop
S284C	19.7	0.9	M	0.803	0.026	0.585	Hoop
S599C	24.5	3.63	F	0.719	0.018	0.029	Hoop

Appendix E. Kearny Freshwater Marsh Snapping Turtle Data

ID	**CL (cm)**	**Wt. (kg)**	**Sex**	**Carapace (ppm)**	**Blood (ppm)**	**Muscle (ppm)**	**Collection Method**
A landfill	28.45	NA	F	2.184	0.121	0.202	Road kill
B landfill	35.56	NA	F	0.599	0.115	0.501	Road kill
C N. Belleville	33.02	NA	F	0.381	0.142	0.148	Road kill
D Mead	40.64	NA	F	0.241	0.367	0.451	Road kill
E Mead	26.16	NA	F	0.525	NA	0.198	Road kill
F Dissected	NA	NA	F	NA	0.099	0.432	Road kill
Mead Juvenile	11.43	NA	F	0.249	NA	0.270	Road kill
Drown Mead	26.67	NA	F	1.448	NA	0.221	Road kill
Road Mead	30.48	NA	F	0.579	NA	0.247	Road kill
A Mead	NA	NA	F	2.116	0.016	0.198	Road kill
B Mead	NA	NA	F	6.535	NA	1.935	Road kill
K Mead	NA	NA	F	1.902	NA	2.901	Road kill
3020612	19.69	3.6	M	1.354	0.239	NA	Hoop
3004561	29.46	14	M	1.869	0.670	NA	Hoop
2889822	24.51	5.89	F	0.890	0.182	NA	Hoop
2890845	25.48	5	M	1.051	0.856	NA	Hoop
DL 6/20/14	NA	NA	F	0.664	0.026	0.082	Road kill
June2014 C	NA	NA	F	0.693	0.038	0.117	Road kill
2015C	NA	NA	F	2.862	NA	NA	Road kill
KFM Drowning	NA	NA	F	0.547	1.216	0.043	Road kill

Appendix F. Lake Hopatcong Stable Isotope Analysis Data

Species	**$\delta^{13}C$**	**$\delta^{15}N$**	**Hg, ppm**	**TL (cm)**	**TP**
Bluegill	-23.78	13.74	0.044	136	4.25
Bluegill	-27.12	14.81	0.069	146	4.25
Bluegill	-27.81	13.85	0.052	105	4.25
Bluegill	-26.26	13.26	0.030	200	4.25
Bluegill	-27.93	13.17	0.021	140	4.25
Catfish	-26.26	14.66	0.034	220	4.56
Catfish	-28.64	14.76	0.038	320	4.56
Catfish	-28.72	14.48	0.032	310	4.56
Catfish	-29.5	15.08	0.035	330	4.56
Catfish	-29.51	15.12	0.063	340	4.56
Chain Pickerel	-25.97	16.24	0.122	330	4.99
Chain Pickerel	-25.93	16.31	0.137	510	4.99
Chain Pickerel	-25.97	16.26	0.100	440	4.99
Chain Pickerel	-26.05	16.25	0.275	250	4.99
Chironomidae	-25.52	2.02	0.072	NA	0.8
Chironomidae	-25.12	2.01	0.072	NA	0.8
Chironomidae	-25.12	1.98	0.072	NA	0.8
Damselfly	-30.45	4.29	0.237	NA	1.44
Damselfly	-30.65	3.99	0.237	NA	1.44
Damselfly	-30.52	4.27	0.237	NA	1.44
Dragonfly	-29.08	3.39	0.0178	NA	1.29
Dragonfly	-29.03	3.85	0.0178	NA	1.29
Dragonfly	-29.13	3.78	0.0178	NA	1.29
Largemouth Bass	-20.99	9.32	0.046	300	4.53
Largemouth Bass	-26.35	16.37	0.056	300	4.53
Largemouth Bass	-27.04	16.28	0.069	271	4.53
Largemouth Bass	-26.53	15.75	0.037	282	4.53
Largemouth Bass	-27.13	15.81	0.062	220	4.53
Pumpkinseed	-26.7	15.03	0.044	200	4.52
Pumpkinseed	-26.21	15.07	0.044	136	4.52
Pumpkinseed	-26.84	14.19	0.052	140	4.52
Pumpkinseed	-27.19	14.33	0.020	140	4.52
Pumpkinseed	-26.86	14.83	0.032	180	4.52
Snail	-28.27	2.55	0.641	NA	1
Snail	-28.79	2.92	0.641	NA	1
Snail	-28.56	2.64	0.641	NA	1
Snapping Turtle	-27.29	12.63	0.058	12.9	3.70

Snapping Turtle	-27.21	13.92	0.059	25	3.70
Snapping Turtle	-26.59	12.64	0.072	38.75	3.70
Snapping Turtle	-25.64	13.24	0.016	25.1	3.70
Snapping Turtle	-26.86	14.92	0.058	33.2	3.70
Snapping Turtle	-27.36	14.29	0.153	21.4	3.70
Snapping Turtle	-29.34	7.08	0.103	11	3.70
Snapping Turtle	-29.63	6.41	0.058	21	3.70

Appendix G. Lake Wapalanne Stable Isotope Analysis Data

Species	**$\delta^{13}C$**	**$\delta^{15}N$**	**Hg, ppm**	**TL (cm)**	**TP**
Alder & Damselfly	-22.21	4.54		NA	1.53
Beetle	-15.79	-1.86	0.096	NA	2.63
Beetle	-15.84	-1.74	0.096	NA	2.63
Bluegill	-21.9	8.41	0.096	197	2.63
Bluegill	-21.34	8.14	0.125	192	2.63
Bluegill	-23.29	7.8	0.125	195	2.63
Bluegill	-21.36	7.4	0.131	196	2.63
Bluegill	-22.22	7.42	0.148	187	2.63
Dragonfly	-23.53	2.25	0.152	NA	0.88
Dragonfly	-23.78	2.33	0.152	NA	0.88
Dragonfly	-23.96	2.37	0.152	NA	0.88
Largemouth Bass	-20.58	5.76	0.039	99	2.83
Largemouth Bass	-23.21	10	0.079	304	2.83
Largemouth Bass	-21	9.55	0.061	307	2.83
Largemouth Bass	-20.96	9.55	0.038	96.5	2.83
Largemouth Bass	-23.08	10	0.076	304.8	2.83
Mayfly	-27.02	0.22	0.142	NA	0.26
Pumpkinseed	-21.99	8.54	0.179	NA	2.63
Pumpkinseed	-22.04	8.13	0.178	188	2.63
Pumpkinseed	-22.54	8.23	0.141	188	2.63
Pumpkinseed	-21.48	8.44	0.097	170	2.63
Pumpkinseed	-22.78	8.14	0.316	140	2.63
Scud	-24.62	0.91	0.046	NA	0.27
Scud	-24.42	0.72	0.046	NA	0.27
Scud	-16.73	-0.82	0.046	NA	0.27
Snail	-21.02	2.66	0.271	NA	1.00
Snail	-20.91	2.86	0.271	NA	1.00
Snail	-21.29	2.7	0.271	NA	1.00
Snapping Turtle	-26.2	12.16	0.052	34.9	4.15
Snapping Turtle	-15.9	3.83	0.009	34.3	4.15
Snapping Turtle	-27.42	14.27	0.311	33.15	4.15
Snapping Turtle	-25.46	9.78	0.083	25.9	4.15
Snapping Turtle	-25.4	9.89	0.058	12.9	4.15
Sowbugs	-25.62	0.25	NA	NA	0.31
Sowbugs	-25.43	0.37	NA	NA	0.31
Sowbugs	-25.75	0.52	NA	NA	0.31

Appendix H. Kearny Freshwater Marsh Stable Isotope Analysis Data

Species	**δ13C**	**δ15N**	**Hg, ppm**	**TL (cm)**	**TP**
Pumpkinseed	-24.79	11	0.051	54	1.93
Pumpkinseed	-23.8	10.79	0.057	52	1.93
Pumpkinseed	-24.62	10.9	0.093	55	1.93
Pumpkinseed	-24.91	10.99	0.070	45	1.93
Pumpkinseed	-24.26	10.94	0.073	43	1.93
Shrimp	-21.61	7.81	0.034	NA	0.999
Shrimp	-21.92	7.77	0.034	NA	0.999
Shrimp	-21.45	7.72	0.034	NA	0.999
Snapping Turtle	-20.33	13.59	0.221	26.67	3.05
Snapping Turtle	-21.29	16.62	0.117	23	3.05
Snapping Turtle	-29.49	7.09	0.130	26.4	3.05
Snapping Turtle	-16.24	9.21	NA	NA	3.05
Snapping Turtle	-25.37	9.76	0.489	NA	3.05
Snapping Turtle	-21.56	13.17	0.249	28.45	3.05
Snapping Turtle	-22.29	16.76	NA	NA	3.05
Snapping Turtle	-20.4	13.75	NA	NA	3.05

Appendix I. Commercial Harvest Survey

Survey of the Snapping Turtle Harvest in New Jersey

New Jersey Department of Environmental Protection, Bureau of Freshwater Fisheries would like to better understand the snapping turtle harvest in New Jersey. In collaboration with Montclair State University, the Bureau of Freshwater Fisheries is asking you to please take 20 minutes of your time to fill out this survey.

We anticipate that the result from this study will inform the Bureau of Freshwater Fisheries to better understand your circumstances when they make management plans and policies. You were randomly selected to participate in this voluntary survey. This questionnaire will not take more than 20 minutes. Any response you give will be confidential. If you would like to receive a summary of the results of this study please let us know. Kindly complete this questionnaire at your convenience and drop it in any mailbox; return envelope and postage are provided.

Source: http://www.flickr.com/photos/thesixthland/3957642705/

*If you have any questions concerning this research or survey please feel free to contact:
Natalie Sherwood 1 Normal Ave. Montclair State University, Montclair NJ 07043
Phone: 201-563-2524; Email sherwoodn1@montclair.edu

NEW JERSEY DIVISION OF
Fish and Wildlife

Passaic River Institute
Montclair State University

A brief background on the harvest of snapping turtles is provided here. In New Jersey, the snapping turtle harvest is under the jurisdiction of the New Jersey Division of Fish and Wildlife, Bureau of Freshwater Fisheries. The state currently allows both recreational and commercial harvesters to collect turtles throughout the year with the exception of the nesting season from May 1 to June 15th in freshwater. The New Jersey Division of Fish and Wildlife states “Any person with a valid fishing license or those entitled to fish without a license” may take up to three snapping turtles a day either by traps or with hands, either in water or on land, either adults or juvenile, with no reporting requirement however, these turtles are for personnel consumption only and may not be sold. On the other hand, the commercial snapping turtle harvesters must purchase a $2 permit and turtles caught may be sold.

1. Prior to this survey, were you aware of the snapping turtle harvest in New Jersey?

Yes	☐
No	☐

2. Have you ever applied and obtained any of these permits in New Jersey?

Fishing License	☐
Commercial Snapping Turtle Harvest Permit	☐
Entitled to fish without a fishing license (individuals under the age of 16 and over 70) Limited to 3 per day and cannot be sold.	☐
None	☐

3. Have you ever caught/targeted/trapped Snapping Turtles in New Jersey?

Yes	☐
No	☐

4. For how many years have you caught snapping turtles?

____

5. If you have commercially collected snapping turtles for less than *five years*, what made you interested in becoming a snapping turtle harvester?

____

6. On an average day of trapping, how many snapping turtles do you trap/collect?

____

7. In your opinion, how many turtles would you consider being a successful day of trapping?

____

8. Did you catch any snapping turtles during the open season as per New Jersey Fish and Wildlife regulation (June 2013- April 2014)?

Yes	☐
No	☐

If your response to question 8 was YES please go to question # 9 below.
If your response to question 8 was NO please go to question # 10.

9. How many snapping turtles did you collect during the last open season as per New Jersey Fish and Wildlife regulation (June 2013- April 2014)?

____

Male and female snapping turtles have different physical features that allow you to tell them apart. Males are usually large and have longer tails. Females are usually smaller and have shorter thinner tails.

10. What percent of the snapping turtles that you have caught would you say were adult females?

____

11. If you collected snapping turtles in New Jersey, what types of traps or catching method did you use? Please check all that apply.

Hoop Trap	☐
Box Trap	☐
Hook	☐
Hand	☐

If other, please explain

____

12. If you use hoop or box traps please answer A and B.
    A. If you use a hoop or box trap, how many traps do you set a day?

____

    B. Out of the traps you set, how many traps can you inspect in a day?

____

13. Primary purpose of trips that have resulted in catching snapping turtles. Please check all that apply.

Fishing trip	☐
Hiking/Trail	☐
To catch snapping turtle	☐

14. On average, how many trips do you take each year that have resulted in catching snapping turtles?

____

15. On average, how many hours or days do the trips resulting in catching snapping turtles last?

16. How many miles do you travel to sites that have resulted in catching snapping turtles?

17. In the past three years, the number of miles that you typically travel to sites where you catch snapping turtles have:

Increased	☐
Decreased	☐
No change	☐

18. Do you take trips resulting in catching snapping turtles by:

Yourself	☐
Yourself and a couple friends	☐
A groups larger than 3 including yourself	☐

19. Please name the five most frequented sites that have resulted in catching snapping turtles? Please provide name of the river, pond, lake, etc. (E.g. Clarks Pond, Fairfield, NJ).
    1.
    2.
    3.
    4.
    5.

20. How often do you encounter harvesters, or see their traps when you are setting your own?

Never	☐
Daily	☐
Once a week	☐
Once a month	☐

21. In the last three years, do you feel that the number of snapping turtles in your area has:

Decreased	☐
Increased	☐
Remained stable	☐

22. What do you generally do with the snapping turtles that you catch? Please check all that apply.

Consumed it (food)	☐
Sold it	☐
Kept it as a pet	☐

If you selected "sold it", please continue to question 23 otherwise skip to question 32.

23. Whom did you sell snapping turtles to?

Local restaurant	☐
Seafood vendor	☐
Turtle meat processing factory	☐

If other, please explain

24. What is the average price you got per pound (lb) of snapping turtle sold?

____

25. Does your buyer have a preference for the following? Please check all that apply.

Minimum size	☐
Gender	☐
Live or dead	☐
Other	☐

26. Have you ever been requested by your buyer to catch other turtle species besides snapping turtles?

Yes	☐
No	☐

27. How do you prep/process the turtles for sale/transport?

____

28. On average, how long do you retain the turtles before they are sold?

Less than a week	☐
1 to 2 weeks	☐
3 to 4 weeks	☐
More than a month	☐

29. Where/how do you keep the turtles until they are ready to be sold?

____

30. On average, how much money do you make from selling snapping turtles a year?

____

31. Are you planning to catch snapping turtles in New Jersey during the next open season?

Yes	☐
No	☐

32. Please rank the following statements as they influence your level of enjoyment of the snapping turtle harvest:

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Trapping locations are close to where I live	☐	☐	☐	☐	☐
I am successful at catching snapping turtles at this location.	☐	☐	☐	☐	☐
Catching snapping turtle is a family tradition	☐	☐	☐	☐	☐
I enjoy being outside	☐	☐	☐	☐	☐
Money earned from the harvest is an important source of income	☐	☐	☐	☐	☐

33. The Commercial Harvest of Snapping Turtles requires the submission of a Harvest Report Form. Please rank the following statements concerning harvest report forms:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Harvest Reports Forms are short and easy to complete	☐	☐	☐	☐	☐
I file my Harvest Report Forms immediately and submit at the end of each month	☐	☐	☐	☐	☐
I typically wait until the end of the year before I file my Harvest Report Forms	☐	☐	☐	☐	☐

34. Please provide any suggestions on how to improve the Harvest Report Forms?

____

Studies have cautioned that an increase in unnatural adult mortality could limit the snapping turtle population and its ability to remain in the wild. This section (questions 35-40) deals with policies that can be used for snapping turtle conservation and harvest management.

35. Rank the following statements as they influence your level of compliance with potential snapping turtle regulations.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I catch snapping turtles by spear, hooks, dip net, trap or by hand	☐	☐	☐	☐	☐
I catch and take a maximum of three turtles a day	☐	☐	☐	☐	☐
I catch and take more than three turtles a day	☐	☐	☐	☐	☐
I only catch and take turtles from January 1 to April 30 and June 16 to December 31	☐	☐	☐	☐	☐
My traps have an escape opening for other turtle species	☐	☐	☐	☐	☐
My traps float above the water surface to avoid accidental drowning of turtles	☐	☐	☐	☐	☐
My traps are set at no more than 10 waterways	☐	☐	☐	☐	☐

My traps are identified with the owner's name, address	☐	☐	☐	☐	☐
My traps are checked every 24 hours	☐	☐	☐	☐	☐

36. Do you think the current snapping turtle harvest permit cost is low?

Yes	☐
No	☐

37. What amount would you be willing to pay to keep your snapping turtle harvesting permit?

$5	☐
$10	☐
$15	☐
$30 or more	☐

38. Please state the maximum amount you would be willing to pay to maintain your snapping turtle harvesting privileges.

$ ____

39. Are you satisfied with the current government policies that limits snapping turtle harvesters to 10 waterbodies per commercial harvesting permit?

Yes	☐
No	☐

40. Rank the following statements about governmental regulations from strongly agree to strongly disagree.

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
The number of turtles that can be caught should be limited	☐	☐	☐	☐	☐
Number of female turtles that can be caught should be limited	☐	☐	☐	☐	☐
Number of turtles that can be collected from specific water bodies should be limited	☐	☐	☐	☐	☐
There should be a minimum size of the snapping turtles that can be taken	☐	☐	☐	☐	☐

There should be a permit required for any one catching snapping turtles	☐	☐	☐	☐	☐
The permit prices for a person that is interested in catching snapping turtle should be increased	☐	☐	☐	☐	☐
Permit prices should be increased to deter newcomers and inexperienced persons from targeting snapping turtles	☐	☐	☐	☐	☐
The commercial harvesting of turtles should be stopped	☐	☐	☐	☐	☐
There should be restrictions on the harvest of turtles by fishing license holders	☐	☐	☐	☐	☐
There should be a special permit that allows for recreational harvesting of snapping turtles for personal use	☐	☐	☐	☐	☐
The number of traps, hooks, nets that can be set to catch snapping turtle should be limited	☐	☐	☐	☐	☐
The snapping turtle harvesting season should be shortened.	☐	☐	☐	☐	☐
A snapping turtle dealer permit should be required for anyone who wants to sell turtles	☐	☐	☐	☐	☐

Other comments or suggestions?

Background Information

41. Sex

Female	☐
Male	☐

42. Your age

16 or younger	☐
17 to 25	☐
26 to 40	☐
40 or older	☐

43. Highest level of education attained

Elementary School	☐
High School	☐
Some college	☐
College graduate	☐

44. What was the approximate gross income of your household (before taxes) in 2012?

Less than 25,000	☐
25,000 to 54,999	☐
55,000 to 74,999	☐
Greater than 75,000	☐

45. Please estimate the percentage of your family income that comes from your selling snapping turtles.

None	☐
Less than 10%	☐
Between 10% and 25%	☐
Between 25% to 50%	☐
More than 50%	☐

46. Please check your ethnic group? (*please check one*)

Caucasian	☐
Hispanic	☐
Asian or Pacific Islander	☐
Native American	☐
African-American	☐
Other	☐

****

THANK YOU FOR PARTICIPATING IN THIS STUDY!

Please return the questionnaire in the self-addressed stamped envelope included in this package.

If you have any questions or comments please contact Natalie Sherwood.
Phone: 201-563-2524 Email: sherwoodn1@montclair.edu

Appendix J. Commercial Harvest Survey Data

		#	%
Were you aware of the snapping turtle harvest in New Jersey?			
	No	0	0
	Yes	25	100
Have you over applied and obtained any of these permits?			
	Fishing/Harvester	19	76
	Fishing/Harvester/70+	6	24
Have you ever caught/targeted/trapped snapping turtles?			
	No	0	
	Yes	25	100
For how many years have you caught snapping turtles?			
	Max	56	
	Median	12.5	
	Mean	20.8	
	Min	1	
What made you interested in becoming a harvester?			
	Money	2	18.2
	Always trapped	2	18.2
	Friends/relatives	3	30.3
	Like being outdoors	4	36.4
How many snapping turtles do you trap/collect in a harvest season?			
	Max	500	
	Median	10	
	Mean	39.5	
	Min	1	
How many snapping turtles do you consider being a successful trapping day?			
	Max	100	
	Median	8	
	Mean	13	
	Min	1	
Did you catch during June 2012- April 2013?			
	No	8	32
	Yes	17	68
How many snapping turtles did you collect last open season?			
	Max	409	
	Median	22.5	
	Mean	83	
	Min	0	

How many were females %?		
Max	70	
Median	27.5	
Mean	29	
Min	0	
What catching method do you use?		
Hoop	9	40
Box	6	20
Hand	2	8
Hoop/Box	2	8
Hoop/Hand	2	8
Box/Hand	1	4
Hoop/Box/Hand	2	8
Box/Hook/Hand	1	4
How many traps do you set a day?		
Max	50	
Median	10	
Mean	15.1	
Min	2	
How many traps do you inspect a day?		
All	23	100
What is the primary purpose of trips?		
Catching Turtles	21	87.5
Fishing/Catching Turtles	2	8.3
Fishing/Catching Turtles/Hike	1	4.2
How many trips do you make each year?		
Max	100	
Median	20	
Mean	30	
Min	3	
How many hours do the trips take?		
Max	24	
Median	4	
Mean	6.3	
Min	0.25	
How many miles do you travel?		
Max	500	
Median	20	
Mean	46.5	
Min	2	

The miles you typically travel have:		
Not Changed	15	62.5
Increased	6	25
Decreased	3	12.5
Do you take trips by:		
Yourself	18	72
With friends	6	24
Group of 3+	1	4
How often do you encounter other harvesters?		
Never	17	68
Daily	1	4
Once a week	6	24
Once a month	1	4
Number of snapping turtles in your area has?		
Remained Stable	18	75
Decreased	5	20.8
Increased	1	4.2
What do you with the snapping turtles you catch?		
Consumed	6	24.0
Sold	9	36.0
Consumed/Sold	6	24.0
Consumed/Sold/Kept	2	8.0
Sold/Kept	1	4.0
Released	1	4.0
Whom did you sell snapping turtles to?		
Turtle Factory	9	47.4
Seafood Vendor	3	15.8
Restaurant	2	10.5
Trapper	0	0.0
Turtle Factory/Seafood Vendor	3	15.8
Turtle Factory/Seafood Vendor/Restaurant	2	10.5
What is the average price per lb of snapping turtle sold?		
Max	2.5	
Median	1	
Mean	1.18	
Min	0.65	
Does your buyer have preference a preference for the following?		
Dead	1	5.3
Live	5	26.3

Size Limit	1	5.3
Size Limit/Sex	4	21.1
Size Limit/Live	2	10.5
Size Limit/Live/Sex	6	31.6
Have you been requested to catch other turtle species besides snapping turtles?		
No	18	90
Yes	2	10
How do you prep/process the turtles for sale?		
Live	12	85.7
Clean	1	7.1
Clean/Live	1	7.1
How long do you keep snapping turtles before sale?		
Less than a week	9	47.4
1-2 Weeks	9	47.4
2-3 Weeks	0	0.0
4+ Weeks	1	5.3
Where/how do you keep snapping turtles before sale?		
Live In water	12	57.1
Live dry	6	28.6
Frozen	2	9.5
Frozen or dry	1	4.8
How much do you make a year from the snapping turtle harvest?		
Max	10000	
Median	550	
Mean	1427	
Min	0	
Are you planning to catch snapping turtles next open season?		
No	4	18.2
Yes	18	81.8
Do you believe the harvest permit cost is low?		
No	9	36
Yes	16	64
What is the amount would you be willing to pay for a commercial harvesting permit?		
$5	8	40
$10	7	35
$15	1	5
$30+	4	20
What is the maximum amount you would be willing to pay for a commercial harvesting permit?		
Max	200	

	Median	15	
	Mean	40.76	
	Min	1	
Are you satisfied with the current government policies that limits snapping turtle harvesters to 10 waterbodies?			
	No	9	37.5
	Yes	15	62.5
RANK			
Trapping locations are close to where I live.			
	Strongly Disagree	0	0
	Disagree	3	12
	Neutral	3	12
	Agree	7	28
	Strongly Agree	12	48
I am successful at catching at this location.			
	Strongly Disagree	0	0
	Disagree	1	4
	Neutral	5	20
	Agree	6	24
	Strongly Agree	13	52
Catching snapping turtle is a family tradition.			
	Strongly Disagree	3	12
	Disagree	3	12
	Neutral	3	12
	Agree	5	20
	Strongly Agree	11	44
I enjoy being outside.			
	Strongly Disagree	0	0
	Disagree	0	0
	Neutral	1	4
	Agree	3	12
	Strongly Agree	21	84
Money earned is an important source of income.			
	Strongly Disagree	7	28
	Disagree	2	8
	Neutral	9	36
	Agree	1	4
	Strongly Agree	6	24
RANK Commercial Harvest			
Harvest Reports Forms are short and easy to complete.			

Strongly Disagree	6	26.1
Disagree	5	21.7
Neutral	4	17.4
Agree	4	17.4
Strongly Agree	4	17.4
I file my Harvest Report Forms immediately.		
Strongly Disagree	5	22.7
Disagree	7	31.8
Neutral	3	13.6
Agree	2	9.1
Strongly Agree	5	22.7
I wait until the end of the year before I file harvest reports.		
Strongly Disagree	5	20.8
Disagree	3	12.5
Neutral	5	20.8
Agree	1	4.2
Strongly Agree	8	33.3
RANK compliance		
I catch snapping turtles by spear, hooks, dip net, trap or by hand.		
Strongly Disagree	2	8.7
Disagree	1	4.3
Neutral	1	4.3
Agree	7	30.4
Strongly Agree	12	52.2
I catch and take a maximum of three turtles a day.		
Strongly Disagree	8	32
Disagree	5	20
Neutral	7	28
Agree	3	12
Strongly Agree	2	8
I catch and take more than three turtles a day.		
Strongly Disagree	5	20
Disagree	1	4
Neutral	5	20
Agree	4	16
Strongly Agree	10	40
I only catch and take turtles from January 1 to April 30 and June 16 to December 31.		
Strongly Disagree	0	0
Disagree	1	4
Neutral	1	4
Agree	3	12

Strongly Agree	20	80
My traps have an escape opening for other turtle species.		
Strongly Disagree	1	4
Disagree	2	8
Neutral	3	12
Agree	4	16
Strongly Agree	15	60
My traps float above the water surface to avoid accidental drowning of turtles.		
Strongly Disagree	0	0
Disagree	1	4
Neutral	2	8
Agree	3	12
Strongly Agree	19	76
My traps are set at no more than 10 waterways.		
Strongly Disagree	0	0
Disagree	0	0
Neutral	4	17.4
Agree	4	17.4
Strongly Agree	15	65.2
My traps are identified with the owner’s name, address.		
Strongly Disagree	0	0
Disagree	0	0
Neutral	2	8
Agree	3	12
Strongly Agree	20	80
My traps are checked every 24 hours.		
Strongly Disagree	0	0
Disagree	0	0
Neutral	2	8
Agree	3	12
Strongly Agree	20	80
Regulation Ranks		
The number of turtles that can be caught should be limited.		
Strongly Disagree	9	36
Disagree	6	24
Neutral	8	32
Agree	1	4
Strongly Agree	1	4
Number of female turtles that can be caught should be limited.		
Strongly Disagree	7	28

Disagree	5	20
Neutral	4	16
Agree	5	20
Strongly Agree	4	16
Number of turtles that can be collected from specific water bodies should be limited.		
Strongly Disagree	9	36
Disagree	6	24
Neutral	7	28
Agree	0	0
Strongly Agree	3	12
There should be a minimum size of the snapping turtles that can be taken.		
Strongly Disagree	2	8
Disagree	0	0
Neutral	4	16
Agree	8	32
Strongly Agree	11	44
There should be a permit required for any one catching snapping turtles.		
Strongly Disagree	4	16
Disagree	1	4
Neutral	2	8
Agree	6	24
Strongly Agree	12	48
The permit prices for a person that is interested in catching snapping turtle should be increased.		
Strongly Disagree	5	20
Disagree	2	8
Neutral	9	36
Agree	7	28
Strongly Agree	2	8
Permit price should be increased to deter newcomers and inexperienced persons from targeting snapping turtles.		
Strongly Disagree	5	20.8
Disagree	5	20.8
Neutral	6	25.0
Agree	4	16.7
Strongly Agree	4	16.7
The commercial harvesting of snapping turtles should be stopped.		
Strongly Disagree	20	80
Disagree	3	12
Neutral	2	8
Agree	0	0

	Strongly Agree	0	0
There should be restrictions on the harvest of snapping turtles by fishing license holders.			
	Strongly Disagree	8	33.3
	Disagree	2	8.3
	Neutral	6	25.0
	Agree	3	12.5
	Strongly Agree	5	20.8
There should be a special permit that allows for recreational harvesting of snapping turtles for personal use.			
	Strongly Disagree	10	40
	Disagree	3	12
	Neutral	7	28
	Agree	2	8
	Strongly Agree	3	12
The number of traps, hooks, nets that can be set to catch snapping turtle should be limited.			
	Strongly Disagree	14	56
	Disagree	2	8
	Neutral	3	12
	Agree	2	8
	Strongly Agree	4	16
The snapping turtle harvesting season should be shortened.			
	Strongly Disagree	14	56
	Disagree	5	20
	Neutral	2	8
	Agree	3	12
	Strongly Agree	1	4
A snapping turtle dealer permit should be required for anyone who wants to sell turtles.			
	Strongly Disagree	11	46
	Disagree	3	13
	Neutral	4	17
	Agree	1	4
	Strongly Agree	5	21
Sex			
	Male	25	100
	Female	0	0
Age			
	17-25	3	12
	26-40	6	24
	40+	16	64
Highest level of education attained			

Elementary	1	4
High School	13	52
Some College	2	8
College	9	36
What was the approximate gross income of your household (before taxes) in 2012?		
Less than 25	4	17
25-54,000	8	33
55-74,000	4	17
75,000+	8	33
What was the approximate income from the snapping turtle harvest?		
None	11	44
Less than 10%	8	32
10-25%	5	20
25-50%	1	4
50%+		
Please check your ethnic group? (please check one)		
Caucasian	24	96
Native American	1	4

Appendix K. Commercial Harvesting Sites

Site Name
Abrams pond
Allow Creek
Alloway River
Black Creek
Butterfly Bogs
Carnegle Lake
Cohansey Creek
Cohansey River
Conte Farm
Crosswick Creek
Daretown Lake
Dave Pond
Delaware River
Delaware River & Canal
Delaware River and Trib
DOD ponds carneys pnt
Dornal Lake
Fenwick River
Game Creek
Indian Mills
Larksboro Lake
Manalapan River
Manasquan River
Mannington Meadow
Manumskin
Maurice River
Metedeconk
Mill Pond
Millstone River
Minantico
Mullica River
Muskconetcong River
Muskee Creek
Muster Mill Lake
New Fragdon Pond
Oldmans Creek
Pauliskill River

Pequest Rivers
Racoon Creek
Raritan River
Repopo Creek
Rockaway River
Salem River
Silver Lake
Slabston Lake
South River
Sturbridge Vorhees
Thundergut pond
Timber creek
Toms River
Union Lake
Wallkill River
Whippany River

Appendix L. Recreational Harvest Survey

A Survey of the Snapping Turtle Harvest in New Jersey

Montclair State University and the New Jersey Division of Fish and Wildlife, Bureau of Freshwater Fisheries have developed this survey to gain a better understanding of the snapping turtle harvest in the state. We anticipate the results from this study will allow the Bureau of Freshwater Fisheries to further understand your circumstances and opinions when it comes to making regulations and policies.

You were randomly selected to participate in this voluntary survey. This questionnaire will not take more than 15 minutes. Any response you give will be strictly confidential. If you would like to receive a summary of the results of this study please let us know.

Source: http://www.flickr.com/photos/thesixthland/3957642705/

*If you have any questions concerning this research or survey please feel free to contact:
Natalie Sherwood, 1 Normal Ave. Montclair State University, Montclair NJ 07043;
Phone: 201-563-2524; Email sherwoodn1@montclair.edu

NEW JERSEY DIVISION OF
Fish and Wildlife

Passaic River Institute
Montclair State University

A brief background on the harvest of snapping turtles is provided here. In New Jersey, the snapping turtle harvest is under the jurisdiction of the New Jersey Division of Fish and Wildlife, Bureau of Freshwater Fisheries. The state currently allows both recreational and commercial harvesters to collect turtles throughout the year with the exception of the nesting season from May 1 to June 15th in freshwater of the state. The New Jersey Division of Fish and Wildlife states "Any person with a valid fishing license or those entitled to fish without a license" may take up to three snapping turtles a day either by traps or by hand, either in water or on land, adults or juvenile, with no reporting requirement however, these turtles are for personal consumption only and may not be sold. On the other hand, commercial snapping turtle harvesters pay $2 for a permits that allows the unlimited harvest of snapping turtles from 10 freshwater bodies. In recent years, both the number of commercial harvesting permits issued and reported harvested turtles have increased dramatically.

47. Prior to this survey, were you aware of the commercial harvest of snapping turtles in New Jersey?

Yes	☐
No	☐

48. Prior to this survey, were you aware that fishing permit holders can take up to three snapping turtles a day during the open season as per New Jersey Fish and Wildlife regulation (June 16-April 30)?

Yes	☐
No	☐

49. Now knowing the regulations, will you be collecting snapping turtles in the future?

Yes	☐
No	☐

50. Have you ever intentionally or accidentally caught snapping turtles in New Jersey?

Yes	☐
No	☐

If **YES**, please continue to question number **5.** If **NO**, please go to question number **17.**

51. What do you generally do with the snapping turtles that you catch? Please check all that apply.

Consumed it (food)	☐
Sold it	☐
Kept it as a pet	☐
Released it	☐

52. How many turtles have you intentionally or accidentally caught in the past three years?

____

53. Did you catch any snapping turtles during the preceding open season (June 2013- May 2014) as per New Jersey Fish and Wildlife regulation?

Yes	☐
No	☐

54. How many snapping turtles did you collect during this preceding open season (June 2013- May 2014)?

____

55. What trapping method did you use? Please check all that apply.

Spear	☐
Hook	☐
Dip Net	☐
Trap	☐
Hand	☐

56. What is the primary purpose of trips that have resulted in catching snapping turtles?

Fishing trip	☐
Hiking/Trail	☐
To catch snapping turtle	☐

57. How many trips in the past three years have you undertaken to catch snapping turtles?

____

58. Typically how many miles do you travel to sites that result in catching snapping turtles?

____

59. The number miles that you typically travel to sites where you can catch snapping turtles has __________ the past three years?

Increased	☐
Decreased	☐
No change	☐

60. In the last three years, do you feel that the number of snapping turtles in your area has:

Decreased	☐
Increased	☐
Remained stable	☐

61. Please name the five most frequented sites that have resulted in catching snapping turtles? Please provide name of the river, pond, lake, etc. (E.g. E.g. Clarks Pond, Fairfield, NJ).
    1.
    2.
    3.
    4.
    5.

62. Rank the following statements from the most important (5) to the least important (1) as they influence your level of enjoyment of the snapping turtle harvest:

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Trapping locations are close to where I live.	☐	☐	☐	☐	☐
I am successful at catching snapping turtles at this location.	☐	☐	☐	☐	☐
Catching snapping turtle is a family tradition.	☐	☐	☐	☐	☐
I enjoy being outside.	☐	☐	☐	☐	☐

63. Are you planning to catch snapping turtles in New Jersey during the next open (January 1 to May 15 and June 16 to December 31, 2015) season?

Yes	☐
No	☐

This section (questions 18-21) deals with policies and programs that can be used for snapping turtle conservation and harvest management.

64. A commercial permit to harvest snapping turtles currently cost $2.00 per year. What is your opinion about the cost of this permit?

Too much	☐
Not enough	☐
About right	☐
No opinion	☐

65. What amount would you be willing to pay to keep your snapping turtle harvesting privileges of taking 3 snapping turtles a day during the open season?

$5	☐
$10	☐
$15	☐
$30 or more	☐

66. Please state the maximum amount you would be willing to pay to maintain your snapping turtle harvesting privileges.

$ ____

67. Rank the following statements from the strongly agree (5) to the strongly disagree (1) as they influence your level of compliance with potential snapping turtle regulations.

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
The number of turtles that can be caught should be limited	☐	☐	☐	☐	☐
Number of female turtles that can be caught should be limited	☐	☐	☐	☐	☐
Number of turtles that can be collected from specific water bodies should be limited	☐	☐	☐	☐	☐
There should be a minimum size of the snapping turtles that can be taken	☐	☐	☐	☐	☐
There should be a permit required for anyone catching snapping turtles	☐	☐	☐	☐	☐
The permit price for catching snapping turtles should be increased	☐	☐	☐	☐	☐
Permit prices should be increased to deter newcomers and inexperienced persons from targeting snapping turtles	☐	☐	☐	☐	☐
The commercial harvesting of snapping turtles should be stopped	☐	☐	☐	☐	☐
The recreational harvesting of snapping turtles should be stopped	☐	☐	☐	☐	☐
There should be a special permit that allows for recreational harvesting of snapping turtles	☐	☐	☐	☐	☐
The number of traps, hooks, and nets that can be set to catch snapping turtles should be limited	☐	☐	☐	☐	☐
The snapping turtle harvesting season should be shortened	☐	☐	☐	☐	☐
There should be restrictions on the harvest of turtles by fishing license holders	☐	☐	☐	☐	☐

Other comments or suggestions?

Background Information

68. Sex

Female	☐
Male	☐

69. Your age

16 or younger	☐
17 to 25	☐
26 to 40	☐
40 or older	☐

70. County of residence ______________________________

71. Highest level of education attained

Elementary School	☐
High School	☐
Some college	☐
College graduate	☐

72. What was the approximate gross income of your household (before taxes) in 2012?

Less than 25,000	☐
25,000 to 54,999	☐
55,000 to 74,999	☐
Greater than 75,000	☐

73. Please check your ethnic group? (*please check one*)

Caucasian	☐
Hispanic	☐
Asian or Pacific Islander	☐
Native American	☐
African-American	☐
Other	☐

****

THANK YOU FOR PARTICIPATING!

If you have any questions or comments please contact Natalie Sherwood.
Phone: 201-563-2524 Email: sherwoodn1@montclair.edu

Appendix M. Recreational Harvest Survey Data

		#	%
Prior to this survey, were you aware that snapping turtles can be legally harvested for commercial purposes in New Jersey?			
	No	436	58.4
	Yes	311	41.6
Prior to this survey, were you aware that with a regular resident or non-resident fishing license up to three snapping turtles a day can be taken?			
	No	508	68.0
	Yes	239	32.0
Now knowing the regulations, will you be recreationally be collecting snapping turtles in the future?			
	No	511	68.5
	Yes	66	8.8
	Not sure	169	22.7
Have you ever intentionally or accidentally caught snapping turtles in New Jersey?			
	No	283	37.9
	Yes, accidentally	309	41.4
	Yes, purposefully	155	20.7
What do you generally do with the snapping turtles that you catch? Please check all that apply.			
	Released	347	75.6
	Consumed	53	11.5
	Pet	6	1.3
	Sold	7	1.5
	Consumed/Released	18	3.9
	Released/Pet	13	2.8
	Consumed/Sold	6	1.3
	Sold/Released	2	0.4
	Consumed/Sold/Released	2	0.4
	Consumed/Pet/Released	3	0.7
	Sold/Pet/ Released	1	0.2
	Consumed/Sold/Pet/Released	1	0.2
How many turtles have you intentionally or accidentally caught in the past three years?			
	Max	32	
	Median	2	
	Mean	3.37	

Min	0	
Did you catch any snapping turtles during the last open season (June 2013- April 2014)?		
No	355	76.5
Yes	109	23.5
How many snapping turtles did you collect during this last open season (June 2013- April 2014)?		
Max	15	
Median	0	
Mean	0.56	
Min	0	
What trapping method did you use? Please check all that apply.		
Hook	173	51.8
Hand	86	25.7
Trap	21	6.3
Net	12	3.6
Net/Trap	12	3.6
Spear/Hand	1	0.3
Hook/Hand	17	5.1
Net/Hand	2	0.6
Trap/Hand	3	0.9
Hook/Net	1	0.3
Trap/Hand/Hook	2	0.6
Net/Hand/Hook	2	0.6
Trap/Net/Hook	1	0.3
All	1	0.3
What is the primary purpose of trips that have resulted in catching snapping turtles? Please check all that apply.		
Fishing	319	74.0
Catching Turtles	44	10.2
Hiking	27	6.3
Fishing/Hiking	21	4.9
Fishing/Catching Turtles	14	3.2
Fishing/Catching Turtles/Hiking	6	1.4
How many trips in the past three years have you taken to catch snapping turtles?		
Max	20	
Median	0	
Mean	0.72	

Min	0	

Typically how many miles do you travel to sites that result in catching snapping turtles?

Max	50	
Median	2	
Mean	6.34	
Min	0	

In the last 3 years, the number miles that you typically travel to sites where you catch snapping turtles has:

Not Changed	373	91.2
Decreased	27	6.6
Increased	9	2.2

In the last 3 years, do you feel that the number of snapping turtles in your area has:

Remained Stable	259	59.7
Decreased	86	19.8
Increased	89	20.5

Are you planning to catch snapping turtles in New Jersey during the next open (January 1 to April 30 and June 16 to December 31, 2015) season?

No	67	42.7
Yes, recreational	84	53.5
Yes, commercial	6	3.8

A commercial permit to harvest snapping turtles currently cost $2.00 per year. What is your opinion about the cost of this permit?

Not Enough	450	60.2
About Right	142	19.0
No Opinion	140	18.7
Too Much	15	2.0

What amount would you be willing to pay to keep your recreational snapping turtle harvesting privileges of taking 3 snapping turtles a day during the open season?

$5	409	54.8
$10	96	12.9
$15	72	9.6
$30	170	22.8

Please state the maximum amount you would be willing to pay to maintain your ability to recreationally take snapping turtles.

Max	250	
Median	5	
Mean	15	
Min	0	

Rank the following statements from Strongly Agree to Strongly Disagree as they influence your level of enjoyment of the snapping turtle harvest:

Trapping locations are close to where I live.			
	Strongly Disagree	22	5.2
	Disagree	20	4.7
	Neutral	169	40.0
	Agree	96	22.7
	Strongly Agree	115	27.3
I am successful at catching snapping turtles at this location.			
	Strongly Disagree	48	11.6
	Disagree	21	5.1
	Neutral	202	48.8
	Agree	69	16.7
	Strongly Agree	74	17.9
Catching snapping turtle is a family tradition.			
	Strongly Disagree	176	41.8
	Disagree	78	18.5
	Neutral	104	24.7
	Agree	38	9.0
	Strongly Agree	25	5.9
I enjoy being outside.			
	Strongly Disagree	6	1.3
	Disagree	36	7.6
	Neutral	19	4.0
	Agree	36	7.6
	Strongly Agree	374	79.4
Rank the following statements from strongly agree (5) to strongly disagree (1) as they influence your level of compliance with potential snapping turtle regulations.			
Number of turtles that can be caught per season should be limited			
	Strongly Disagree	29	3.9
	Disagree	30	4.0
	Neutral	85	11.4
	Agree	205	27.4
	Strongly Agree	398	53.3
Number of female turtles that can be caught per season should be limited			
	Strongly Disagree	18	2.4
	Disagree	28	3.7
	Neutral	96	12.9
	Agree	176	23.6

Strongly Agree	429	57.4
Number of turtles that can be collected per season from specific water bodies should be limited		
Strongly Disagree	27	3.6
Disagree	44	5.9
Neutral	120	16.1
Agree	196	26.2
Strongly Agree	360	48.2
There should be a minimum size limit on snapping turtles that can be taken under a recreational fishing license		
Strongly Disagree	30	4.0
Disagree	37	5.0
Neutral	87	11.6
Agree	197	26.4
Strongly Agree	396	53.0
There should be a special permit (in addition to a regular fishing license) required for anyone catching snapping turtles whether for recreational or commercial purposes		
Strongly Disagree	139	19.0
Disagree	93	12.7
Neutral	123	16.8
Agree	93	12.7
Strongly Agree	284	38.8
The permit price for taking snapping turtles should be increased		
Strongly Disagree	94	13.7
Disagree	76	11.1
Neutral	142	20.7
Agree	76	11.1
Strongly Agree	297	43.4
Permit prices should be increased to deter newcomers and inexperienced persons from targeting snapping turtles		
Strongly Disagree	162	21.9
Disagree	134	18.1
Neutral	166	22.4
Agree	75	10.1
Strongly Agree	204	27.5
The commercial harvest of snapping turtles should be stopped		
Strongly Disagree	111	14.9
Disagree	132	17.7
Neutral	244	32.7

	Agree	74	9.9
	Strongly Agree	186	24.9
There should be a special permit that allows for recreational harvesting of snapping turtles			
	Strongly Disagree	134	19.6
	Disagree	96	14.1
	Neutral	152	22.3
	Agree	96	14.1
	Strongly Agree	205	30.0
The number of traps, hooks, and nets that each licensee/permittee can set to catch snapping turtles should be limited			
	Strongly Disagree	42	7.2
	Disagree	54	9.3
	Neutral	97	16.6
	Agree	54	9.3
	Strongly Agree	336	57.6
The snapping turtle harvest season should be shortened			
	Strongly Disagree	80	10.7
	Disagree	103	13.8
	Neutral	325	43.5
	Agree	64	8.6
	Strongly Agree	177	23.7
There should be restrictions on the harvest of turtles by fishing license holders			
	Strongly Disagree	84	12.1
	Disagree	86	12.4
	Neutral	178	25.7
	Agree	86	12.4
	Strongly Agree	259	37.4
Sex			
	Male	657	88.8
	Female	83	11.2
Age			
	18	9	1.2
	18-25	21	2.8
	26-40	107	14.5
	41+	603	81.5
County of residence			
	Atlantic	27	3.8

	Bergen	34	4.8
	Burlington	39	5.5
	Camden	34	4.8
	Cape May	11	1.6
	Cumberland	10	1.4
	Essex	21	3.0
	Gloucester	30	4.2
	Hudson	16	2.3
	Hunterdon	36	5.1
	Mercer	20	2.8
	Middlesex	47	6.6
	Monmouth	40	5.7
	Morris	71	10.0
	New Castle	1	0.1
	Ocean	58	8.2
	Passaic	36	5.1
	Salem	13	1.8
	Somerset	48	6.8
	Sussex	51	7.2
	Union	20	2.8
	Warren	25	3.5
	PA	9	1.3
	North Carolina	1	0.1
	USA	6	0.8
	NY	3	0.4
Highest level of education attained			
	Elementary	6	0.8
	High School	121	16.4
	Some College	191	25.8
	College	421	57.0
What was the approximate gross income of your household (before taxes) in 2012?			
	Less than 25,000	42	6.1
	25-54,000	107	15.5
	55-74,000	149	21.6
	75,000+	391	56.7
Please check your ethnic group? (please check one)			
	Caucasian	673	92.7

Native American	7	1.0
Asian Pacific Islander	14	1.9
African American	4	0.6
Hispanic	6	0.8
Other	22	3.0

Appendix N. Recreational Harvesting Sites

Site Name
17 River
20 County NJ
8 Township, NJ
Alexauken Creek
Amp Lake Fort Dix Browns Mill
Assunpink Lake
Bailey Park Pond
Beaver Dam Creek
Bicennetial Park
Big Flatbrook
Birch Grove Park
Black Creek
Bogue Pond
Boonton Reservoir
Boyd Pond
Branch Brook Park
Carnegie Lake
Carp Pond
Cedar Brook Spillway
Clay Pits
Clove River
Colliers Mills Main Lake
Columbia Lake
Cranberry Lake
Cub Lake
Davidsons Mill Park
Dear Head Lake
Deer Park Pond
Delaware Canal
Delaware Lake
Delaware Raritan Canal
Delaware River
Dod Ponds
Donaldson Park Pond
Double Creek
Duck Pond
Duhearnal Pond

Echo Lake
Egg Harbor River
Farm Pond In 22 County
Farrington Lake
Fin, Fur And Feather Pond
Forked River, Middle Branch
Garveys Pond Earle Navy Base
Gerald Farms In Madison
Glendola Reservoir
Green Brook
Green Turtle Pond
Hackensack River
Haddon Lake
Hamilton Fire Pond
Hammonton Lake
Hockhockson Brook
Holmdel Park Pond
Hopkins Pond
Husky Brook
Iles Lake
Jefferson Lake
Jumping Brook Pond
Kearny Freshwater Marsh
Kearny Marsh
Kearny Meadows
Kettle Creek
Kettle Creek
Lake Barnegat
Lake Glenlock
Lake Musconetcong
Lake Renee
Lake Solitude
Lake Stockholm
Lake Topanemus
Lake Valhalla
Laurel Acres Pond
Laurel Pond
Little Ponds
Mac's Pond
Malaga Lake

Manasquan Reservoir
Manasquan River
Matawan Creek
Maurice River
Meisel Ave Pond
Menantico Wma
Metedeconk River
Middle Creek
Monarch Lake
Morris Canal
Mullica River
Musconetcong River
Nevius St Bridge
New Egypt Lake
Nomahegan Pond
North Branch
North Branch Millstone River
Old Mill Pond
Oxford Furnace Lake
Packanack Lake
Panther Lake
Papakating Brook
Park Pond 19 County
Patcong Creek
Paulinskill River
Pembroke/Flagg Pond
Piscataway Raritan River
Plainsboro Pond
Pohatcong Creek
Pompton Lake
Pond On Gully Road
Pond Side
Prospertown Lake
Quicks Pond
Raccoon Creek
Railroad Pond
Ramapo Lake
Rancocas Creek
Raritan Canal
Raritan River

Reminissen Brook
Rockaway Creek
Rockaway River
Round Valley Swimming Area
Saddle River
Sawmill Lake
Shadow Lake
Shark River
Shark River Park Pond
Shark River Pond
Silver Bay
South Bound Brook
South Branch Raritan River
South Plainfield Spring Lake
Spooky Brook
Spring Lake
Spruce Run Recreation Area
Spruce Run Reservoir
Swayze Mill Pond
Sylvan Lake
Timber Creek
Toms River
Tuckahoe River
Turtle Pond
Vernon Valley Lake
Verona Park
Walkill River
Wanaque Reservoir Swamp Area
Wanaque River
Watchung Reservation
Wawayanda Lake
West Hudson Park Pond
Westons Mill
Whippany River
White City Lake
White Meadow Lake
Whites Pond
Woodcliff Lake
Wreck Pond

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