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The Horseshoe Crab

Introduction

Spring of 1998 was a time of much suspense and some hope for Ernest Graham. Graham, a staff attorney for the National Audubon Society ("Audubon") in Washington, D.C., had been waging "the horseshoe crab war" for almost two years. In truth, this was not a war against the harmless, ancient horseshoe crab (*Limulus polyphemus*); it was a fight against the unregulated catch of horseshoe crabs by commercial fishermen along the Atlantic seaboard. It was not a war against commercial fishermen (although many of them perceived it that way); it was a battle

Figure 1: Horseshoe crabs on the beach.

Josh Eagle prepared this case study, under the editorial guidance of Professor Barton H. ("Buzz") Thompson, Jr., Robert E. Paradise Professor of Natural Resources Law, Stanford Law School, solely for educational purposes rather than to illustrate either effective or ineffective handling of an environmental matter. Some or all of the characters or events may have been fictionalized for pedagogical purposes.

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against state fishery managers who Graham felt had abdicated their duty to protect a publicly-owned natural resource from a sudden, exponential increase in catch levels.

Spring of 1998 was a time of hope because in less than two years, Audubon, working with other environmental groups, had succeeded in convincing Maryland, Delaware and New Jersey (the three states with the largest historical landings of horseshoe crabs) to adopt some regulations on the catch of horseshoe crabs. Although each state's regulations had weaknesses that might allow excessive catch to continue, Graham felt certain that total 1998 landings from the three states would not exceed 1997 levels.

It was also a time of suspense. If Graham had learned anything from working in the fisheries field, it was that commercial fishermen were among the most ingenious people in the world. He was certain that if there were money in landing horseshoe crabs, commercial fishermen would find a way to land them. Due to the regulations that had been imposed in the three states, it was almost certain – due to the basic economic law of supply and demand – that the dock price of horseshoe crabs would increase. This unintended result of Audubon's work meant that commercial fishermen now had greater incentive to catch horseshoe crabs.

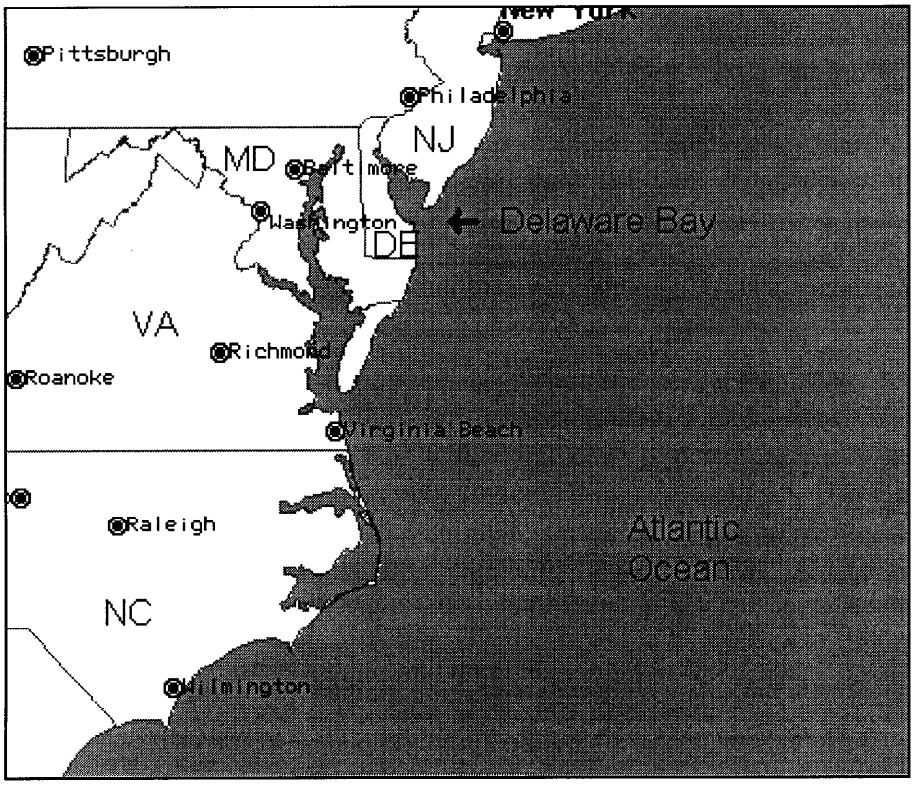

Figure 2: The Mid-Atlantic coast.

What would the fishermen do? Graham and his colleagues considered the possibilities. Maryland had a hard quota in place – there was no legal way for the fishermen to circumvent the newly established cap on landings. Neither Delaware nor New Jersey had a similar cap. Both states had focused in their regulations on limiting some inputs (mandating permits, time and area closures, gear restrictions, etc.) rather than limiting output (landings) as Maryland had. While it was theoretically possible that fishermen in Delaware and New Jersey could attempt to meet market demand for horseshoe crabs by increasing the intensity of their effort, such an increase was for various reasons not likely under the New Jersey regulations. It was a very real possibility in Delaware.

The majority of horseshoe crab landings in Delaware were hand-caught crabs, that is, they were taken off the beaches when they came onto land to spawn. The annual spawning occurred over a two-week period in late May or early June, depending on the lunar cycles. Due to the delay in processing reporting data, no one would know what Delaware's 1998 hand catch was until July. All Graham and the others could do was wait and see. If 1998 numbers turned out to be higher than 1997, Audubon would have to begin lobbying the state for stricter 1999 regulations.

Graham had resigned himself to the fact that there was nothing Audubon could do to further limit Delaware catch in 1998. Delaware's 1998 catch might turn out to be double 1997's, but there was no practical way to prevent it from happening.

On April 16, 1998, Graham got a call from one of his contacts within the Maryland Department of Natural Resources. A New Jersey-registered trawler had just landed a boatload of horseshoe crabs, taken in federal waters off the coast of Delaware, in Chincoteague, Virginia.

The fishermen had easily found the loophole. Maryland, New Jersey and Delaware could only regulate two things: fishing activity within three miles of their coasts and landings at their ports. Fishing for horseshoe crabs was still unregulated in federal waters, that is, waters more than three miles offshore. The horseshoe crabs migrated annually between federal waters and state waters. Some age classes (those individuals too young to spawn) lived in federal waters year round.

Virginia had no real regulations on the landing of horseshoe crabs. Because there were relatively sparse populations of horseshoe crabs in Virginia waters, there had not been any historical need for regulation of the fishery. The rise in dock price had suddenly made it economically feasible for fishermen to sail the extra 30 miles south to Chincoteague, drop off the cargo of horseshoe crabs, and then ship them by truck to markets in New Jersey, Delaware and elsewhere along the Atlantic coast.

Graham typed up a quick letter to the Virginia Marine Resources Commission

("VMRC"), asking them to closely monitor the situation and to prepare emergency regulations. Graham argued that Virginia should respect the other states' efforts to protect their natural resources:

> It would truly be a shame if, after all the work that has gone into protecting the crabs elsewhere, Virginia became "the loophole state." This is especially true considering that the crabs that would be landed in Virginia [in 1998] would be crabs taken from Federal waters off the coasts of Delaware, Maryland, and New Jersey that have migrated from those states' waters.

Graham knew that landing horseshoe crabs in Virginia was perfectly legal, and that Virginia was under no obligation to take any action. He wrote with the slim hope that the state's authorities would take an enlightened, cautious approach to a unique situation.

Jack Travelstead, the chief VMRC fisheries manager, wrote back quickly, assuring Audubon that VMRC would monitor Virginia landings carefully and that it would not hesitate to act if it became clear that Virginia was experiencing a dramatic increase in landings.

In 1997, 37,000 pounds of horseshoe crabs had been landed in Virginia. By July of 1998, 300,000 pounds had been landed in Virginia. Also in July, VMRC estimated total landings for 1998 would be in neighborhood of 1.2 million pounds.

Contrary to its promises, VMRC refused to take any action to regulate the boom. The commission saw the new business as beneficial to coastal communities. It was also not convinced that the data it had obtained from staff of the Atlantic States Marine Fisheries Commission (attached to this case study as Exhibit A, in draft form and with peer review comments) showed that Atlantic horseshoe crab populations were jeopardized by fishing.

Graham and his colleagues saw two years of hard work going down the drain. Given VMRC's refusal to act, what could they do to protect the horseshoe crab?

The Horseshoe Crab: Biology and Ecology

The following information is quoted, in abridged form, from an Atlantic States Marine Fisheries Commission document, Fishery Management Report No. 32 (1998):

Species Life History

Horseshoe crabs are benthic (or bottom-dwelling) arthropods that use both estuarine and continental shelf habitats. Although it is called a "crab," it is neither a decopod or crustacean, rather horseshoe crabs are grouped in their own class (Merostomata), which is

more closely related to the arachnids. Horseshoe crabs, ranging from the Yucatan peninsula to northern Maine, are most abundant between Virginia and New Jersey, with the largest population of spawning horseshoe crabs in the world found in the Delaware Bay.

Studies suggest that each spring, adult horseshoe crabs migrate from deep bay waters and the Atlantic continental shelf to spawn on intertidal sandy beaches. Beaches within estuaries, such as the Delaware and Chesapeake Bay, are preferred because they are low energy environments and are protected from the surf, thus reducing the risks of stranding during spawning events. Spawning generally occurs from March through July, with the peak spawning activity occurring on the evening new and full moon high tides in May and June. In the Delaware Bay and the Chesapeake Bay, spawning activity gradually increases prior to the full and new moon, peaking on the day of the full and new moon, then gradually decreases.

Horseshoe crabs are characterized by high fecundity, high egg and larval mortality, and low adult mortality. Horseshoe crabs spawn multiple times per season, laying approximately 3,650 to 4,000 eggs in a cluster. Adult females lay an estimated 88,000 eggs annually. Egg development is dependent on temperature, moisture, and oxygen content of the nest environment.

Eggs hatch between 14 and 30 days after fertilization. Survival between hatching and sexual maturity remains unknown. Egg and larval mortality is substantial, primarily due to predation. Larvae typically settle in shallow water areas to molt. Juvenile horseshoe crabs generally spend their first and second summer on the intertidal flats, usually near breeding beaches. Older individuals move out of intertidal areas to a few miles offshore, except during breeding migrations.

Larvae feed on a variety of small polychaetes and nematodes. Juvenile and adult horseshoe crabs feed mainly on molluscs including razor clam (*Ensis spp.*), macoma clam (*Macoma spp.*), surf clam (*Spisula solidissima*), blue mussel (*Mytilus edulis*), wedge clam (*Tellina spp.*), and fragile razor clam (*Siliqua costata*). Horseshoe crabs also prey on a wide variety of benthic organisms including arthropods, annelids, and nemertean worms.

Factors contributing to natural mortality include age; excessive energy expenditure during spawning, which can result in stranding, desiccation, and predation. The natural mortality rate in adults is probably low. However, horseshoe crab mortality due to predation from sea turtles and other marine animals remains unknown. Shorebirds feed on horseshoe crab eggs in areas of high spawning densities such as the Delaware Bay. Horseshoe crab eggs are considered essential food for several shorebird species in the Delaware Bay, which is the second largest migratory staging area for shorebirds in North America. Despite significant shorebird predation on horseshoe crab eggs, such activity probably has little impact on the horseshoe crab population. Horseshoe crabs place egg clusters at depths greater than 10 centimeters, which is deeper than most short-billed shorebirds can penetrate.

Many eggs are brought to the surface by wave action and burrowing activity by spawning horseshoe crabs. These surface eggs consumed by birds would not survive, due to desiccation. A significant decrease in the number of horseshoe crabs could leave a large portion of migrating shorebirds without necessary food resources to complete migration and successfully reproduce on arctic breeding grounds.

Adult and juvenile horseshoe crabs make up a portion of the loggerhead sea turtle's (*Caretta caretta*) diet in the Chesapeake Bay. Horseshoe crab eggs and larvae are also a seasonally preferred food item of a variety of invertebrates and finfish, including sharks (*Squaliformes*).

Distribution

Horseshoe crabs, ranging from the Yucatan Peninsula to Maine, are most abundant between Virginia and New Jersey. In New Jersey and Delaware, horseshoe crab abundance decreases with distance north and south of the Delaware Bay. Within the Delaware Bay, the largest concentration of horseshoe crabs traditionally was found along the Cape May shore of New Jersey. Spawning densities of over 30 animals per meter occurred on the New Jersey side of the Delaware Bay based on 1986 spawning counts along 15 meter segments. Since 1993, the majority of horseshoe crab spawning activity has occurred on the Delaware shores of the Delaware Bay. Annual variation in spawning concentrations may be the result of weather or habitat changes. In the Chesapeake Bay, spawning densities only exceed one per meter on the most heavily used beaches, based on counts using similar methodology. During peak spawning, densities exceeded three per meter on these preferred beaches.

Sex and Age Ratio

Sex ratios at spawning beaches have been reported in Florida to range from 1 to 14 males per female with a mean of 3.6 males per female. Limuli Laboratories' annual census reports sex ratios in New Jersey and Delaware averaging 2.8 male per female between 1990 and 1995. Shuster and Botton (1985) report sex ratios on spawning beaches in New Jersey and Delaware varying between 5:1 and 3:1 (male : female). Offshore trawl collections indicate a reversed sex ratio, with females outnumbering males from 3:2 to 2:1 or an even sex ratio 1.17 males per female. The New Jersey Division of Fish, Game and Wildlife (1997) identified a female dominated sex ratio of 1:1.4 based on 1996 trawl surveys.

Shuster (1996) suggested that a shift in the normal 1:1 sex ratio toward less than one female per male becomes an important criterion, pointing specifically to overfishing of females. In South Carolina, the 1997 male to female ratio was higher for each estuary sampled than the preceding years (i.e., 1996 and 1995), indicating a population changing due to environmental conditions or overharvesting. Trawling in the Delaware Bay by the Delaware Division of Fish and Wildlife (1997) identified annual sex ratios of approximately

1:1 for 1990 through 1996, except in 1993 and 1994 when 1.6:1 was noted (significant at ($p<0.05$) from 1:1).

ECOLOGICAL IMPORTANCE OF HORSESHOE CRABS

Horseshoe crabs play an important ecological role in the food web for migrating shorebirds, finfish, and Atlantic loggerhead turtles, a federally listed (threatened) species that uses the Chesapeake Bay as a summer nursery area (Keinath et al. 1987).

Shorebirds

The Delaware Estuary is the largest staging area for shorebirds in the Atlantic Flyway and is the second largest staging site in North America. An estimated 425,000 to 1,000,000 migratory shorebirds converge on the Delaware Bay to feed and rebuild energy reserves prior to flying an additional 4,000 kilometers to complete their northward migration. Migratory shorebirds arrive in Delaware Bay and adjacent areas along the Atlantic coast at the peak of horseshoe crab mating in mid-May through early-June, typically spending two weeks in the area. Clark (1996) states that the number of shorebirds coming to the Delaware Bay on spring migrations is between 900,000 and 1.5 million of six species. At least 11 species of migratory birds use horseshoe crab eggs to replenish their fat supply during their trip from South American wintering areas to Arctic breeding grounds. The principle shorebirds observed include ruddy turnstone (*Arenaria interpres*), red knot (*Calidris canutus*), semipalmated sandpiper (*Calidris pusilla*), sanderling (*Calidris alba*), dowitcher (*Limnodromus spp.*), and dunlin (*Calidris alpina*). Other shorebirds frequenting sandy beaches include western sandpiper (*Calidris mauri*), the federally listed (threatened) piping plover (*Charadrius melodus*), black-bellied plover (*Pluvialis squatarola*), semipalmated plover (*Charadrius semipalmatus*), and willet (*Catoptrophorus semipalmatus*). The dominant species of shorebirds that use the Delaware Bay for staging are the red knot, ruddy turnstone, semipalmated sandpiper, and sanderling, representing approximately 88 percent of all shorebirds within the Delaware Bay. The Delaware Bay staging area is unique and of particular importance to shorebirds for the following reasons: shorebirds use few major stopovers during the spring migration; shorebirds arrive at stopover sites with little or no fat reserves; and, shorebirds demonstrate fidelity to staging areas. An estimated 80 percent and 30 percent of the hemispheric population of red knots and sanderlings, respectively, use the Delaware Bay as a staging area.

[Because of the annual spectacle of migrating shorebirds, thousands of birdwatchers and tourists come to Delaware and southern New Jersey every year. These visitations have a significant impact on local economies. A copy of an article estimating this impact is attached to this case study as Exhibit B.]

Despite high shorebird abundance within the Delaware Bay, counts of sanderlings

and semipalmated sandpipers declined significantly over a 7-year period from 1985 to 1992. The decline in shorebirds in the Delaware Bay between 1986 and 1997 is statistically significant ($p<0.05$). The Delaware Division of Fish and Wildlife also reports a 45 percent decline in peak counts of shorebirds from 1990-1996 compared to data from 1986-1989. The International Shorebird Survey also indicated a decline in sanderlings between 1975 and 1983. Declines in shorebird numbers may be the result of several threats, including the potential overharvest of horseshoe crabs.

During the 2-3 week staging period, shorebirds undergo weight gains of 40 percent or more (e.g., increasing body weight from 54 to 79 grams over 3 weeks). Much of this weight gain results from feeding on horseshoe crab eggs. In particular, sanderlings are estimated to consume as much as 30.9 grams of eggs per day per bird (approximately 8,300 eggs/day/bird).

Shorebirds require high daily energy inputs due to their high basal metabolic rates. In addition, shorebirds typically have high daily energy expenditures, and are among the longest-distance migrant animals in the world.

Rather than probing below the surface of the substrate, shorebirds typically forage for horseshoe crab eggs as the eggs are uncovered by successive waves of nesting crabs and erosion from localized storms. Horseshoe crab eggs are the most abundant food item on Delaware Bay beaches during the migratory staging of shorebirds. Botton et al. (1994) found few other available macroinvertebrates and concluded that shorebirds are feeding primarily on horseshoe crab eggs, largely because of their abundance. However, it is likely that shorebirds supplement their diet with ingestion of other food items during the stopover period.

Macroinvertebrate densities on the Delaware Bay beaches rarely exceeded 200/m2 during horseshoe crab spawning season and are several orders of magnitude less than horseshoe crab egg densities. As a result, shorebirds showed a preference for beaches with higher number of horseshoe crab eggs. Access to horseshoe crab eggs by shorebirds may be limited by tidal cycle, human disturbance, and competition among shorebirds and gulls. Burger et al. (1996) concluded that a mosaic of habitat types ranging from mudflats to high marshes is essential to sustain the high population of shorebirds using Delaware Bay during spring migration. In addition, Burger et al. (1996) documented the importance of marshes for foraging in several species of shorebirds. Shorebirds do abandon beaches at night to roost in isolated marshes. This is believed to be related to reducing risk of predation by nocturnal wildlife. Clark et al. (1993) estimated that only 15-20 percent of semipalmated sandpipers and up to 30 percent of dunlins were observed in salt marshes (feeding on prey other than horseshoe crab eggs), as opposed to beaches.

Forage data (stomach contents) collected from sanderlings, ruddy turnstones, least sandpipers, semipalmated sandpipers, dunlins, and red knots on Delaware Bay beaches along

the New Jersey coast (N=70) indicate that horseshoe crab eggs represent the majority of food items taken by shorebirds (15 to 95 percent) in 1996 and 1997, averaging 57.3 percent. As such, horseshoe crab eggs were not taken to the exclusion of other items, such as polychaete worms and arthropods. Based on fat-free weights, red knot, ruddy turnstone, sanderling, and semipalmated sandpiper increased body mass up to 70 to 80 percent while staging on Delaware Bay. This rate of weight gain is the highest recorded for any stopover site in the world and is considered to be the result of feeding on horseshoe crab eggs. Additionally, Tsipoura and Burger (1998) reported that the mass movement of shorebirds (from the New Jersey side to the Delaware side of the Delaware Bay) is correlated with availability of horseshoe crab eggs.

Despite significant shorebird predation on horseshoe crab eggs, such activity probably has little impact on the horseshoe crab population. Horseshoe crabs place egg clusters at depths greater than 10 centimeters, which is deeper than most short-billed shorebirds can reach. Horseshoe crab eggs brought to the surface by wave action and burrowing activity by spawning horseshoe crabs that are available for shorebird predation would probably not survive to hatching due to heat stress or desiccation. Additionally, horseshoe crabs continue to spawn at least one month after the departure of most of the shorebirds. Horseshoe crab larval densities have been observed regularly exceeding 100,000/m2 in July and August. For these reasons, it is unlikely that shorebird predation has a substantial adverse impact on the reproductive success of horseshoe crabs in Delaware Bay.

The food supply provided by horseshoe crab eggs in Delaware has been estimated at 320 tons. Castro and Myers (1993) estimated the total energy requirement of shorebirds and calculated that 539 metric tons of horseshoe crab eggs would be needed to sustain the spring migration of shorebirds through the Delaware Bay (assuming the shorebirds ate only horseshoe crab eggs). Based on this estimate, Castro and Myers (1993) estimated that the total number of females needed to lay the eggs consumed by shorebirds is approximately 1,820,000. Assuming a sex ratio of 1:1, approximately 3,640,000 horseshoe crabs are required to sustain the shorebird migration stopover in Delaware Bay. However, these calculations assume that shorebirds feed exclusively on horseshoe crab eggs. Tsipoura and Burger (1998) indicated that horseshoe crab eggs are a significant part of shorebirds diet, but that diet is supplemented by other food resources. Botton et al. (1994) estimated that an average of 44,000 eggs/m2 would be needed to sustain the entire shorebird population in the Delaware Bay. Their data indicate these densities currently occur within most Delaware Bay beaches. A significant decrease in the number of horseshoe crabs could leave a large portion of migrating shorebirds without either the necessary food resources to complete their trip to the Arctic breeding grounds or the necessary fat reserves upon arrival to initiate egg laying and incubation.

Finfish

Horseshoe crab eggs and larvae are a seasonal food item of invertebrates and finfish.

In the Delaware River from May through August, striped bass (*Morone saxatilis*) and white perch (*Morone americana*) eat horseshoe crab eggs. American eel (*Anguilla rostrata*), killifish (*Fundulus spp.*), silver perch (*Bairdiella chrysoura*), weakfish (*Cynoscion regalis*), kingfish (*Menticirrhus saxatilis*), silversides (*Menidia menidia*), summer flounder (*Paralichthys dentatus*), and winter flounder (*Pleuronectes americanus*) also eat eggs and larvae. All crab species and several gastropods, including whelks, feed on horseshoe crab eggs and larvae. Shuster (1982) reported a large leopard shark (*Triakis semifasciatum*) preying on adult horseshoe crabs in southern Florida.

Sea Turtles

Lutcavage and Musick (1985) examined the stomach contents or excreta from 527 loggerhead turtles from Chesapeake Bay and nearby coastal waters and found that the most common prey was horseshoe crab. Musick et al. (1983) examined 27 loggerhead turtles and found horseshoe crabs commonly in stomach contents. Similarly, Lutcavage (1981) found that horseshoe crabs represented up to 42 percent of the diet of loggerhead turtles from Chesapeake Bay (N=6), averaging 22 percent. Data collected by the National Marine Fisheries Service ("NMFS") Sea Turtle Stranding and Salvage Network along the Atlantic Coast identified horseshoe crabs in 75 percent of loggerhead stomach contents in 1996 (N=8) and 55 percent in 1997 (N=11). Morreale and Standora (1993) found no evidence of horseshoe crabs in loggerhead turtle diets in New York's Long Island Sound; however, diet largely depends on the relative abundance of prey species. Maintaining abundant stocks of adult horseshoe crabs may be an important component of ensuring the long-term survival of loggerhead sea turtles in the Chesapeake Bay area.

Human Uses of the Horseshoe Crab

The following information is also quoted, in abridged form, from the same document, ASMFC Fishery Management Report No. 32 (1998):

DESCRIPTION OF THE FISHERY

Fishing effort for horseshoe crabs is generally concentrated within the mid-Atlantic area, specifically New Jersey, Delaware, Maryland, Virginia, and adjacent federal waters. Since there is no known recreational fishery for horseshoe crabs, fishing mortality of horseshoe crabs is predominantly from the commercial fisheries including the bait fishery and the biomedical fishery.

Current Fishery Regulations

Current fishing regulations vary dramatically among the Atlantic coastal states. Generally, fishing regulations for horseshoe crabs are minimal or nonexistent in comparison

with other fisheries (Table 1). However, several states have recently initiated or proposed more restrictive harvest regulations. The State of South Carolina has prohibited harvest except for the biomedical industry since 1991.

Commercial Fishery

Between the 1850s and the 1920s, over 1 million horseshoe crabs were harvested annually for fertilizer and livestock feed. Reported harvests in the 1870s were 4 million horseshoe crabs annually, and 1.5 to 1.8 million horseshoe crabs annually between 1880s and 1920s. Shuster (1960) reports that in the late 1920s and early 1930s 4 to 5 million crabs were harvested annually. Shuster (1960) reports over 1 million crabs were harvested during the 1940s and 500,000 to 250,000 horseshoe crabs were harvested in the 1950s. By the 1960s, only 42,000 horseshoe crabs were reported to be harvested annually. Early harvest records are suspect due to under-reporting. The period of time between 1950 and 1960 is considered the nadir of horseshoe crab abundance. The substantial commercial-scale harvesting of horseshoe crabs ceased in the 1960s.

Bait Fishery

Currently, horseshoe crabs are commercially harvested for use as American eel, conch (or whelk), and catfish bait along certain portions of the Atlantic coast. The horseshoe crab fishery is unique in that crabs can be easily harvested during their spawning season and can be caught with a minimal financial expense. The eel fishery is highly dependent on sustained populations of horseshoe crabs and prefers female horseshoe crabs with eggs. The conch fishery also is dependent on horseshoe crabs, but uses both male and female horseshoe crabs.

Commercial landings data for horseshoe crabs (i.c., metric tons, pounds, and price) are collected by the NMFS by state, year, and gear type. Commercial landings data may include harvest for both the bait and biomedical fisheries. However, the NMFS data are relatively incomplete and disjunct. For example, in several years that NMFS reports no landings in states such as Delaware, state biologists report that landings did occur. In 1994 and 1995, the NMFS reported Maryland's harvest at 232,000 and 117,000 pounds, respectively. Based on State landing records, actual Maryland harvest was approximately 1 million pounds during these years. In many cases, horseshoe crabs are harvested and used directly by eel fishers, whelk fishers, or catfish fishers without going through a dealer (where NMFS gets much of its information) or arrangements are made for harvesters to sell directly to such fisheries without going to dealers. Since such private sales are not reported, NMFS fishery statistics underestimate the catch. Based on NMFS data, commercial harvest from the northeastern Atlantic coast has ranged between 10,000 pounds (in 1969) to over 5.0 million pounds (in 1996). Since 1988, commercial landings have averaged 1,436,808 pounds. Botton and Ropes (1987b) estimated the total number of horseshoe crabs harvested

by comparing the total number of pounds landed with the average weight of an adult horseshoe crab, which is approximately 4 pounds. However, the NMFS used a different conversion factor to estimate the number of pounds landed (e.g., 2.6 pounds per crab). The total average horseshoe crab catch (animals/year) for the Atlantic Coast (assuming an adult horseshoe crab is 4 pounds) has increased from 476,515 in 1993 to 1,288,408 in 1996 (NMFS, 1998). This increase is similar to increases reported by Michels for the Delaware Bay harvest, which ranged from 330,333 in 1993 to 896,540 in 1996. However, Michels did not include the Maryland harvest (which can be substantial). These statistics provide further evidence that the NMFS data represent an underestimate of actual harvest. Regardless of the data set used, all data show a significant increase in harvest between 1990 and 1996.

The SAS [horseshoe crab stock assessment subcommittee of the ASMFC] and the PRP [peer review panel appointed to review the SAS' work] concluded that commercial landings data show a substantial increase in reported harvest during the 1990s. This increase could be, in part, a function of increased harvest reporting efficiency. The states of Delaware, Maryland, New Jersey, and New York represent the largest harvest of horseshoe crabs recently. Estimates in Delaware, Maryland, New Jersey, New York, and Rhode Island indicate a rapid increase in fishery growth, based primarily on use as bait for the American eel and whelk fisheries and the shift in pressure from declining traditional fisheries. However, the States of Connecticut, Massachusetts, North Carolina, and Virginia indicate declines in current harvest compared with harvest in the late 1970s and early 1980s.

Current [as of 1998] fishing regulations for horseshoe crabs by State.

MAINE: No regulations regarding harvest.

NEW HAMPSHIRE: Possession limit of 10 per day per person. License required to sell or distribute and mandatory monthly reporting is required.

RHODE ISLAND: No regulations regarding harvest; however, to sell commercially, a commercial fishing license is required ($200/year). A moratorium on commercial licenses is currently in place.

MASSACHUSETTS: No regulations regarding harvest; however, to sell commercially, a commercial fishing license is required ($65/year-residents, $130/year-nonresidents).

CONNECTICUT: No regulations regarding harvest.

NEW YORK: No regulations regarding harvest; however, to sell commercially, or to take and land more than 50, a license is required ($30/year-residents, $50/year-nonresidents.

NEW JERSEY: Harvest requires a horseshoe crab permit and mandatory monthly reporting. The following persons are exempt from obtaining a permit: (1) property owners removing

dead horseshoe crabs from their property for the purpose of disposal, (2) scientific collection with appropriate scientific collecting permit, and (3) individuals in possession of a miniature fyke, lobster, or fish pot license and written verification that horseshoe crabs were obtained from a legal source. In order to qualify for a horseshoe crab permit, individuals must have had a miniature fyke, lobster, or fish pot license; a horseshoe crab permit; and reported landings for at least 2 years between 1993 and 1997. Harvest by any other means than by hand (i.e., trawling or dredging) is prohibited. Harvest season is April 1 to August 15. No harvest is allowed from the beaches and shoreline and the adjacent waters and uplands within 1,000 feet of mean high water along the Delaware Bay. Hand-harvest is permitted in areas other than the abovementioned areas only two days/week (Tuesday and Thursday).

PENNSYLVANIA: No regulations regarding harvest.

DELAWARE: No collection on State or federal land (horseshoe crab sanctuaries) between May 1 and June 30, except Tuesdays and Thursdays on state owned lands east of State Road Number 89 by persons with valid horseshoe crab collecting permits or American eel licenses. No collection on private land between May 1 and June 30 except permittees on Monday, Wednesday, and Friday. Hand harvest by persons with valid commercial eel fishing licenses requires mandatory reporting and horseshoe crabs must be for personal, non-commercial use. Dredging is prohibited in leased shellfish grounds except on one's own leased shellfish grounds or with permission from the owner of leased shellfish grounds. Harvest by vessels is limited to 1,500 horseshoe crabs/24 hours. Harvest by dredging is prohibited between May 1 and June 30. Trawling is prohibited in State waters. Monthly reporting is required by all permittees. Containment or transport of more than 300 cubic feet of space occupied by horseshoe crabs is prohibited. Permittees must have secured at least 2 valid horseshoe crab collecting permits from previous years. If collecting permits drops to 45 or below, a lottery will be held to increase commercial collecting permits to 50. Permit fees are $100/year-resident and $1,000/year-non- resident.

MARYLAND: The annual total allowable landings of horseshoe crabs for the commercial fishery is 750,000 pounds. Harvest requires a horseshoe crab catch and landing permit. In order to qualify for a permit, a person must be licensed in accordance with Natural Resources Article S4-701, Annotated Code of Maryland and reported catching and landing horseshoe crabs in Maryland during 1996. A person may not catch or land horseshoe crabs in Maryland between December 1 and March 31. A person may not catch horseshoe crabs within 1 mile of the Atlantic Coast, Chesapeake Bay and coastal bays from April 1 through June 30. A person may catch and land horseshoe crabs on Monday through Friday from outside of 1 mile of the Atlantic Coast between April 1 and June 30 in accordance to the following catch limits: (1) 100 horseshoe crabs for a permittee; and (2) 25 horseshoe crabs for a non-permittee. A person may catch and land horseshoe crabs on Monday through Friday from the tidal waters of the State between July 1 and November 30 in accordance to the following catch limits: (1) the daily catch limit for permittees shall be based on the ratio of landings for 1996 as applied to the annual total allowable landings for the present year; and

(2) 25 horseshoe crabs for a non-permittee. A person who catches and lands horseshoe crabs in Maryland shall report catch and landing information on the forms provided by the Department. A person authorized to catch and release horseshoe crabs for purposes of scientific research shall be exempt from these regulations, but must return the horseshoe crabs live within 48 hours to the waters from which the horseshoe crabs were taken.

VIRGINIA: Harvest by means of trawling or dredging is prohibited. However, special scientific collection permits have been issued to trawler to catch horseshoe crabs for medical purposes. License required to hand-harvest ($15/year) in addition, to obtain a license the applicant must be a registered waterman ($150/year). No limits for hand-harvesting.

NORTH CAROLINA: No regulations regarding harvest.

SOUTH CAROLINA: Special permits required for harvest and/or possession. Harvest of horseshoe crabs is limited to biomedical industry (production of Limulus Amoebocyte Lysate ("LAL")) and to scientific, educational, or commercial display. Harvesting vessels must be properly licensed in addition to being permitted. Permits may be conditioned as to lawful fishing areas; minimum size requirements for horseshoe crabs; mesh size and dimensions of nets and other harvesting devices; bycatch provisions; fishing times or periods; catch reporting requirements; holding facilities, conditions, and periods; and any other conditions the State determines appropriate. Horseshoe crabs harvested for LAL production must be returned unharmed to State waters of comparable salinity and water quality after they are bled. Penalties for violating permit conditions, upon conviction, may include monetary fines, suspension or revocation of the permit(s), and seizure and sale of the permittee's vessel.

GEORGIA: No regulations regarding harvest; however, experimental fishing contract may be required for significant commercial fishery activities.

FLORIDA: No regulations regarding harvest; however, to sell commercially, a salt-water products license is required ($50/year-residents).

FEDERAL WATERS: No regulations regarding harvest.

Based on reported landings in New Jersey alone, horseshoe crab harvests have increased in the last three years from approximately 250,000 in 1993 to over 600,800 in 1996. The Delaware Division of Fish and Wildlife (1997) reports increases in landings between 1990 (under 250,000 pounds) and 1997 (over 1,500,000 pounds). The Delaware Division of Fish and Wildlife (1997) also reports increases in effort as represented by issuance of beach collection permits, which increased from 18 in 1991 to 131 in 1997. However, prior to 1991 little or no reporting occurred within the Delaware Bay. Thus, the increase in horseshoe crab harvest during the 1990s may be partly related to mandatory reporting requirements.

Primary harvest was identified in Rhode Island, New Jersey, Delaware, Maryland, and Virginia. Little to no harvesting of horseshoe crabs was reported in Maine, New Hampshire, or Connecticut. The Chesapeake Bay in Maryland and Virginia likely has a substantial harvest, but without quantitative studies, the catch remains under-reported.

Maryland has been responsible for 23 to 78 percent of the total commercial catch of horseshoe crabs from the northeastern Atlantic coast since 1980. Maryland averaged 357,000 pounds between 1981 and 1991 from a small directed ocean fishery and bycatch from the clam fishery. Since 1992, harvest has increased significantly in Maryland with 2.6 million pounds landed in 1996. Maryland's fishery is primarily an offshore trawl fishery; more than 95 percent of the harvest occurs from July through November. In 1996, 96 percent of Maryland's harvest was from waters outside of 1 mile (52 percent from State waters [1-3 miles] and 44 percent from federal waters [3+ miles]), 3 percent from the coastal bays, and <1 percent from the Chesapeake Bay.

In Virginia, horseshoe crab harvest averaged 190,000 pounds between 1980 and 1988. With a ban on trawling in state waters since 1989 [applicable to all species], horseshoe crab landings have decreased considerably, averaging 22,000 pounds and only increasing to 86,294 pounds in 1996. Demand has increased in Virginia as indicated by whelk landings, which have increased from 75,000 pounds in 1994 to 750,000 pounds in 1995.

Reported dockside value from the northeastern Atlantic coast has ranged between $289 (1967) and $1,541,260 (1996). Fishery statistics for the period 1970 through 1997 indicate a variable fishery. As previously identified, fishery statistics probably underestimate the catch of horseshoe crabs, because the sale of crabs for bait is often arranged between private individuals (i.e., unreported in NMFS landing statistics) rather than through centralized dealers.

In 1997, the majority (85 percent) of horseshoe crabs in Delaware were landed by hand harvest, while dredge harvest made up approximately 15 percent. Between 1991 and 1996 the majority of the horseshoe crabs were landed by hand-harvest (63 percent) compared to dredging (37 percent), except for 1991 when the dredge harvest dominated the catch (56 percent). The increased harvest noted in Delaware mirrored increases in the number of hand-collection permits issued. NMFS data compiled by Delaware Division of Fish and Wildlife (1997) identified that among the northeastern and mid-Atlantic States, Maryland, New Jersey, and Delaware harvest the majority of horseshoe crabs (36, 31, and 14 percent, respectively).

Biomedical Fishery

Scientists have used horseshoe crabs in eye research, surgical sutures wound dressing development, and detection of bacterial endotoxins in drugs and intravenous devices. LAL, a clotting agent in horseshoe crab blood, has made it possible to detect human pathogens

such as spinal meningitis and gonorrhea in patients, drugs, and all intravenous devices. In 1964, researchers discovered that horseshoe crab blood coagulates in the presence of minute quantities of gram-negative bacterial endotoxin and the LAL industry was initiated. By 1979, the U.S. Food and Drug Administration ("FDA") issued draft guidelines for the use of LAL as an end-product pyrogen test for endotoxin in medical devices and injectable drugs. The LAL test is currently the worldwide standard for screening medical equipment for bacterial contamination; any drug produced by a pharmaceutical company must pass an LAL screening. No other known procedure has the same accuracy as the LAL test. If LAL became unavailable, it could take years to find a universally accepted replacement. To obtain LAL, manufacturing companies catch primarily adult horseshoe crabs, collect a portion of their blood, and then release them alive.

In 1989, the FDA reported that 130,000 horseshoe crabs were used in the biomedical industry. The current estimate of medical usage is between 200,000 and 250,000 horseshoe crabs per year on the Atlantic Coast. The FDA mandates conservation by requiring the return of horseshoe crabs to the environment. Most labs return bled crabs to their habitat within 72 hours of capture, but may or may not release crabs at the collection site. Approximately 10 percent of the crabs do not survive the bleeding procedure, which comprises a source of mortality that is not included in the commercial catch statistics. This mortality is minimal compared to that from the commercial bait fishery.

Horseshoe crabs are used also to make chitin filament for suturing (Hall, 1992). Since the mid-1950s medical researchers have known that chitin-coated suture material enhanced healing time by 35-50 percent. Currently, horseshoe crabs are harvested on a limited basis to manufacture chitin-coated suture material and chitin wound dressings (Hall, 1992). Horseshoe crab blood is also beneficial in cancer research; the LAL could lead to controlled cancer therapy. Endotoxins and other substances in horseshoe crab blood may have the potential for diagnosing leukemia.

The ASMFC

The ASMFC and its regulatory power are the product of two federal laws. The first, passed by Congress in 1940, granted "the consent and approval of Congress to an interstate compact [the Atlantic States Marine Fisheries Compact ("Compact")] relating to the better utilization of the fisheries (marine, shell and anadromous) of the Atlantic seaboard and creat[ed] the Atlantic States Marine Fisheries Commission." Pub. L. No. 539, ch. 283, 56 Stat. 267, as amended by Pub. L. No. 81-721 (1950). In its original form, the ASMFC was purely a deliberative and advisory body (made up of representatives of 15 Atlantic coastal states and the District of Columbia). It had no ability

> to limit the powers of any signatory state or to repeal or prevent the enactment of any legislation or the enforcement of any requirement by any signatory state imposing additional conditions and restrictions to conserve its

fisheries.

Compact, Article IX. The ASMFC was limited to studying Atlantic coastal fisheries and making recommendations to the various member states regarding conservation measures.

The Atlantic Coastal Fisheries Cooperative Management Act ("Coastal Act"), 16 U.S.C. §5101 *et seq.*, passed in 1993, gave the ASMFC significant additional responsibilities and powers. Under the Coastal Act, the ASMFC "shall prepare and adopt coastal fishery management plans [("FMP")] to provide for the conservation of coastal fishery resources." 16 U.S.C. §5104(a)(1). A "coastal fishery resource" is defined as "any fishery, any species of fish, or any stock of fish that moves among, or is broadly distributed across, waters under the jurisdiction of two or more States or waters under the jurisdiction of one or more States and the exclusive economic zone." 16 U.S.C. §5102(2). A complete copy of the Coastal Act is attached to this case study as Exhibit C.

The Coastal Act gave the ASMFC the ability to impose its FMPs on its member states. By law, the plans must specify what each state must do to be in compliance with the FMP. Each state is responsible for implementing and enforcing the FMP in its own waters. If a state fails to comply with an ASMFC plan, the Secretary of Commerce "shall declare a moratorium on fishing in the fishery in question within the waters of the noncomplying State." 16 U.S.C. §5106(c)(1).

In the mid-1990's, the ASMFC began development of a joint FMP for the American eel and the Crab. The rationale for the joint plan was that the species were best managed together, because Crabs were used as bait in the fishery directed at adult eels. In October of 1997, the ASMFC voted to split the plans and develop two separate plans, one for the American eel and one for the Crab. In splitting the plans, the ASMFC vowed that it would adhere to its original schedule by issuing final plans for both species by October of 1998.

The "Loophole" State

In July of 1998, when it began to be clear that Virginia would – in the absence of dramatic action – become "the loophole state," there were no limiting Virginia, ASMFC or federal regulations in place. What strategy or strategies do you think Ernest Graham should follow in seeking to ensure the sustainability of the Crab fishery? What strategy should be used with respect to the Virginia state government? What arguments could be made to convince Virginia to take action? To which other authorities should Audubon appeal? Aside from lobbying various agencies and officials for action, are there other possible ways to close the loophole?

Case Study Exhibits

Exhibit A:	Status of the Horseshoe Crab Population of the Atlantic Coast, ASMFC, 1998
Exhibit B: "	Bird business soaring, boosts Cape economy," The Press of Atlantic City (NJ), July 28, 1997
Exhibit C:	Atlantic Coastal Fisheries Cooperative Management Act