I. Application for an Individual Incidental Take Permit under the Endangered Species Act of 1973

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III. Species Affected:

The proposed activity may affect the endangered shortnose sturgeon, *Acipenser brevirostrum*, the threatened loggerhead sea turtle, *Caretta caretta*, and endangered Kemp's ridley, *Lepidochelys kempii*, green, *Chelonia mydas*, hawksbill, *Eretmochelys imbricata*, and leatherback, *Dermochelys coriacea*, sea turtles. In addition, Atlantic sturgeon, *A. oxyrinchus*, a candidate species for listing, will be affected.

Shortnose sturgeon, *Acipenser brevirostrum*, occur along the east coast of North America from St. John River, New Brunswick, Canada, to St. John's River, Florida (Grunwald et al., 2002). They were listed as endangered on 11 March 1967 (DOI, 1967). Shortnose sturgeon occur in mainstem rivers, estuaries, and nearshore marine habitats, the degree of marine habitat use depending on latitude (Kynard, 1997). In South Carolina and Georgia, they rarely occur in coastal waters (Collins et al., 1996). Their nearshore marine habitat may be associated with molluscs such as *Mya arenaria* (Dadswell et al., 1984). Juvenile shortnose sturgeon feed on crustaceans and insects, while adults feed primarily on molluscs (Murdy et al., 1997). Spawning occurs from late winter to late spring, depending on latitude, in the freshwater reaches of rivers, while feeding and overwintering may occur in freshwater as well as saline portions (Dadswell et al., 1984). The species may be distributed into 19 distinct population segments (DPS) representing each estuary where they occur, although genetic and tagging studies suggest a single population occurs in Delaware and Chesapeake Bays (Grunwald et al., 2002; Welsh et al., 2002).

The Hudson River and Delaware River population segments are the most likely to be impacted by the proposed activities.

Atlantic sturgeon, *Acipenser oxyrinchus*, occur along the east coast of North America from St. Lawrence River, Quebec, Canada, to St. John's River, Florida (Grunwald et al., 2008). They were listed as a candidate species for protection under the Endangered Species Act on 17 October 2006 (DOC, 2006). Atlantic sturgeon within United States waters have been divided into five DPS (ASSRT, 2007). The New York Bight DPS comprises sturgeon from the Hudson and Delaware Rivers, and is the most likely to be impacted by the proposed activities. Spawning in the mid-Atlantic region occurs in the upper rivers in April and May (ASSRT, 2007). Atlantic sturgeon occur in mainstem rivers, estuaries, and nearshore marine habitats (ASSRT, 2007). Within Delaware Bay, Atlantic sturgeon have been captured primarily from March to May with a small secondary peak from September to November (Brundage and Meadows, 1982a). Atlantic sturgeon have been frequently captured in coastal waters outside Delaware Bay in the fall (Brundage and Meadows, 1982a). Sturgeons in coastal waters undertake extensive migrations, but return to their natal rivers to spawn (ASSRT, 2007). Polychaete worms comprise the primary food group for sturgeons in coastal waters of New Jersey, (Johnson et al., 1997), although they reportedly also feed on mollusks, shrimp, amphipods, oligochaete worms, and fish (ASMFC, 1990).

Loggerhead sea turtles, *Caretta caretta,* are distributed worldwide, and occur from Newfoundland to Argentina in the western Atlantic Ocean (Marquez, 1990; Ernst et al., 1994). In the United States, they occur along the Atlantic and Gulf of Mexico coasts from Maine to Texas (Thompson, 1988). They were listed as threatened throughout their range on 28 July 1978 (DOI, 1978). Loggerhead sea turtles inhabit coastal bays, lagoons, and estuaries as well as the nearshore ocean. Nesting on the Atlantic coast of the United States occurs during summer, primarily on the southern beaches of Florida and Georgia, and as far north as North Carolina. Immature and adult loggerhead sea turtles make seasonal foraging migrations in spring, dispersing throughout the Middle Atlantic Bight (TEWG, 1998). A southward migration occurs in the fall. At least four genetically distinct subpopulations occur in the western North Atlantic. The Northern and South Florida Nesting Subpopulations comprise the majority of sea turtles along the Atlantic coast (TEWG, 2000), and are the most likely to be affected by the proposed activity. Loggerhead sea turtles feed primarily on crustaceans, horseshoe crabs and molluscs, as well as tunicates, sea pens, and fish (Plotkin et al., 1993; Lutcavage and Musick, 1985; Tomas et al., 2001).

Kemp's ridley sea turtles, *Lepidochelys kempii*, occur in the Atlantic ocean, and range from Nova Scotia to Venezuela and the Gulf of Mexico in the western Atlantic (Marquez, 1990; Ernst et al., 1994). They were listed as endangered on 2 December 1970 (DOI, 1970a). Kemp's ridley sea turtles inhabit coastal bays, lagoons, and estuaries as well as the nearshore ocean. Nesting primarily occurs in the western Gulf of Mexico. Adults are believed to be largely restricted to the nearshore waters of the Gulf of Mexico, while occurrences along the Atlantic coast are primarily juveniles (TEWG, 1998). Juveniles inhabit sounds and bays along the Atlantic coast from spring until fall, presumably to forage (Plotkin, 1995). Kemp's ridley sea turtles feed on crabs, shrimp, sea urchins, bivalves, gastropods, and fish (Marquez, 1990).

Green sea turtles, *Chelonia mydas,* occur in tropical and subtropical waters worldwide, and from Massachusetts to Argentina in the western Atlantic (Marquez, 1990; Ernst et al., 1994). Green sea turtles in the Atlantic Ocean may represent a subspecies, *C. m. mydas*. The Florida breeding population was listed as endangered on 28 July 1978, while elsewhere in U.S. waters green sea turtles were listed as threatened (DOI, 1978). Green sea turtles inhabit coastal bays, lagoons, and estuaries as well as the nearshore ocean. In the U.S., nesting occurs on the east coast of Florida, the U.S. Virgin Islands, and Puerto Rico. Critical habitat is designated as the waters around Isla Culebra, Puerto Rico and its associated keys (NMFS, 2002). Primary foraging habitat in the U.S. is in embayments and nearshore coastal waters of the Gulf of Mexico and Atlantic coast of Florida. Green sea turtles originating from the United States, Mexico, and Costa Rica forage in North Carolina (Bass et al., 2006), and sea turtles from these sources may also be affected by the proposed activity. Adult green sea turtles feed largely on vegetation, including algae, seagrasses and mangroves, but juveniles also feed on bivalves, squid, crabs, and fish (Bjorndal, 1980; Mendonca, 1983; Ernst et al., 1994; Limpus and Limpus, 2000).

Hawksbill sea turtles, *Eretmochelys imbricata*, are distributed worldwide, primarily in the tropics (Marquez, 1990; Ernst et al., 1994). A possible subspecies, *E. i. imbricata*, occurs in the western Atlantic from Massachusetts to Brazil. Hawksbill sea turtles are considered uncommon north of Florida (Plotkin, 1995). They were listed as endangered in 1970 (DOI, 1970b). Hawksbill sea turtles inhabit coral reefs and rocky shores, as well as estuaries and lagoons. Nesting occurs on the Yucatan Peninsula, in Central America and in the Caribbean, as well as southeastern Florida (NMFS and USFWS, 1993). Critical habitat is designated as the waters around Mona and Monito Islands, Puerto Rico (NMFS, 2002). Adult and subadult foraging habitat consists mostly of coral reefs, but also other hard-bottom substrate as well as mangrove swamps. Hawksbill sea turtles' diets consist largely of sponges (Meylan, 1988; Leon and Bjorndal, 2002).

Leatherback sea turtles, *Dermochelys coriacea*, occur worldwide, and are distributed from Labrador to Argentina and the Gulf of Mexico in the western Atlantic (Marquez, 1990; Ernst et al., 1994). Leatherback sea turtles were listed as endangered on 2 June 1970 (DOI, 1970b). Leatherback sea turtles are typically found in the open ocean, but occasionally enter shallow coastal waters. In the Atlantic Ocean, nesting occurs on the South and Central American coasts of the Caribbean, as well as on islands throughout the Caribbean including the U.S. Virgin Islands and Puerto Rico. Nesting also occurs on the Atlantic coast of Florida and possibly Georgia (NMFS and USFWS, 1992). Critical habitat is listed as the waters adjacent to Sandy Point, St. Croix, U. S. Virgin Islands (NMFS, 2002). Adults may undertake routine migrations between nesting and foraging areas (Plotkin, 1995). Peak sightings in May off South Carolina and in August and September in Cape Cod Bay off Massachusetts (Plotkin, 1995) suggest a northward dispersal along the coast to forage during summer. Various data sources indicate that leatherback sea turtles migrate to the mid-Atlantic, New England and Canada during the summer to forage, and strandings in the northeast US occur in summer and fall (NMFS, 2001). Leatherback sea turtles feed mostly on jellyfish, but also sea urchins, octopus, squid, snails, bivalves, tunicates, and fish (Ernst et al., 1994).

IV. Proposed activity:

A. Status of the problem

The horseshoe crab, *Limulus polyphemus*, is an ecologically, economically and medically important species on the east coast of the United States (Berkson and Shuster, 1999). Horseshoe crabs occur from Maine to Florida and the eastern Gulf of Mexico, with the center of abundance between New Jersey and Virginia (Shuster, 1982; Botton and Ropes, 1987). In the mid-Atlantic region, horseshoe crabs spawn primarily on intertidal sections of sandy beaches during full and new moon periods in May and June (Shuster and Botton, 1985). Coincident with horseshoe crab spawning, over 50% of the western hemisphere flyway populations of red knots, *Calidris canutus*, ruddy turnstones, *Arenaria interpres*, and semipalmated sandpipers, *C. pusilla*, stop over in the Delaware Bay area to feed (Myers, 1986; Castro and Myers, 1993; Clark et al., 1993; USFWS, 2003). The horseshoe crab spawning event has historically provided the birds with a reliable, abundant food source in the form of crab eggs (Wander and Dunne, 1981; Shuster and Botton, 1985). Shorebirds arrive in the Delaware Bay with little or no fat reserves after flights of up to 12,000 km and must forage intensely, often doubling their body weights during the two to three week stopover, before departing for their Arctic breeding grounds (Myers, 1986; Harrington, 1996). Horseshoe crabs are also commercially harvested as bait for the American eel (*Anguilla rostrata*) and channeled whelk (*Busycotypus canaliculatus*) fisheries (ASMFC, 1998a). Finally, biomedical companies catch horseshoe crabs for their blood, from which they produce Limulus Amebocyte Lysate (LAL) (Novitsky, 1984; ASMFC, 1998a). LAL is used to detect contamination of injectable drugs and implantable devices by Gram-negative bacteria, and is the most sensitive means available for detecting endotoxins (Novitsky, 1984). The horseshoe crab resource, in terms of ecotourism associated with the annual bird migration, the eel and whelk fisheries, and the biomedical industry, contributes a combined $93 to $123 million to regional economies, and at least $175 million to the national economy (Manion et al., 2000).

Despite supporting a fishery for over 100 years, horseshoe crabs have largely been ignored by fisheries managers until recently, when concerns arose regarding the possible overexploitation of the population (Berkson and Shuster, 1999; Walls et al., 2002). Declines in horseshoe crab abundance have been accompanied by declines in the shorebird populations that depend on them (USFWS, 2003). A subspecies of red knot, *C. c. rufa*, was listed as a candidate species for protection under the Endangered Species Act in 2006 (DOI, 2006). The primary threat to the red knots is the loss of food resources due to the reduction in horseshoe crab abundance. As increasing commercial landings raised concerns about the resource's status, the Atlantic States Marine Fisheries Commission (ASMFC) implemented a fishery management plan to regulate the harvest (ASMFC, 1998a).

Proper management of any species requires that specific management goals and objectives be established, and those goals depend on the resource users involved (Quinn and Deriso, 1999). Horseshoe crabs present a distinct resource management challenge because they are important to a diverse set of users (Berkson and Shuster, 1999). The goal of the fishery management plan is to ensure a sustainable population level to support the continued use by all these diverse interests (ASMFC, 1998a). Unfortunately, management policies have been hampered by a lack of scientific data needed to attain that goal (Berkson and Shuster, 1999; Walls et al., 2002). In order to properly manage the horseshoe crab fishery, accurate information on abundance levels and trends is necessary. Fishery-independent monitoring surveys are generally relied upon to provide abundance information (Hilborn and Walters, 1992; Gunderson, 1993). However, most state and federal survey programs are conducted to monitor finfish resources, and the data they provide for horseshoe crabs are of limited use. Because of the lack of adequate information, the ASMFC determined that a trawl survey which specifically targeted horseshoe crabs was the highest priority for the information it would provide for stock assessment. The coastal Delaware Bay area horseshoe crab trawl survey has been conducted since 2001, and is expected to provide the most reliable estimates of horseshoe crab abundance for stock assessment purposes (ASMFC, 2009).

Recent management efforts have recognized the necessity of identifying the horseshoe crab population level necessary to support the energetic needs of migrating shorebirds, rather than that level needed simply for a sustainable horseshoe crab population. The joint ASMFC Horseshoe Crab Technical Committee-US Fish and Wildlife Service (USFWS) Shorebird Technical Committee adaptive resource management model set horseshoe crab abundance levels as management action triggers as well as targets, to attain a sufficient number of eggs on which migrating birds could feed while providing a harvestable surplus. Therefore, absolute abundance estimates in the Delaware Bay area have increased in importance. This study would develop synoptic estimates of abundance in the mid-Atlantic region compatible with ASMFC data needs.

B. The activity

The activity that is the subject of this application is an annual horseshoe crab abundance monitoring trawl survey to be conducted in the coastal mid-Atlantic region and within Delaware Bay. The trawl survey will provide abundance, distribution and demographic information in support of the horseshoe crab Fishery Management Plan of the ASMFC. The proposed sampling gear will consist of flounder trawls, intended to capture horseshoe crabs for examination and enumeration, especially large juveniles and adults. Flounder net turtle excluder devices (TEDs) have been found to reduce the capture of whelks as well as horseshoe crabs (Belcher et al, 2001). This application specifically requests that the sampling gear be operated without modifications such as TEDs which reduce the capture of large objects. It is anticipated that protected fish and sea turtles may be captured by the unmodified gear.

The trawl survey will be conducted from chartered commercial stern trawlers utilizing a flounder trawl with a 18.3-m (60-ft) head rope and 24.4-m (80-ft) footrope equipped with a Texas sweep (Hata and Berkson, 2003). Two versions of this net will be used: one version will consist of 10.2-cm (4-in) stretched mesh Euroline braided polyethylene (4-mm diameter) in the body, and double-yarn 9.5-cm (3.75-in) stretched mesh braided polypropylene in the bag, which will be equipped with chafing gear; the second version will consist of 15.2-cm (6-in) stretched mesh Euroline braided polyethylene (4-mm diameter) in the body, and double-yarn 14.0-cm (5.5-in) stretched mesh braided polypropylene in the bag, which will be equipped with chafing gear. Primary survey trawling will be conducted using the 15.2-cm mesh, while the 10.2-cm mesh will be used occasionally to evaluate size-selectivity of the primary mesh. In the coastal trawl survey the net will be towed at 3.7-5.6 km/h (2-3 knots). In the Delaware Bay, we will attempt to tow the net at 3.7-4.6 km/h (2-2.5 knots). In the coastal trawl survey, the net will be towed for 15 minutes (bottom time). Within Delaware Bay, tow durations may be reduced to 7.5-10 minutes to avoid obstructions such as other vessels or fishing gear, or to reduce targeted catch and bycatch if it is found that catches are too large to handle safely and efficiently. The net mouth will be in the water an estimated 30 minutes for each 15-minute tow. Starting and ending positions for each tow will be recorded using GPS or Loran C. Bottom water temperature and salinity will be recorded for each tow.

Sampling is expected to be conducted at night, when horseshoe crabs are more susceptible to the gear. Horseshoe crab catches are larger at night than during the day, and catch variances are smaller at night, so sample sizes for a given relative precision are smaller for nighttime sampling than for daytime sampling (Hata and Berkson, 2004). For trawl survey purposes, nighttime is defined as between sunset and sunrise as predicted for the particular location, and there is no preferred subset of that time period for sampling. However, boat traffic and the presence of fishing gear (e.g., crab pots, gill nets, pound nets) may restrict sampling to daylight hours, depending on location. On the basis of prior experience, heavy boat traffic (commercial and recreational) and fishing gear will probably be present within Delaware Bay during the proposed activity period. Therefore, Bay sampling may be conducted during daylight hours by necessity.

Horseshoe crabs will be culled from the catch, and either all, or a subsample, will be examined, depending on catch size. Examined individuals will be measured for prosomal width and identified for sex and maturity. Horseshoe crabs will be classified to maturity stage as immature, those that are newly mature but have not yet spawned, and those that are mature and have spawned previously.

Horseshoe crab catch-per-tow will be calculated for each demographic group assuming a standard 15-minute tow. Alternative crab density will be calculated from estimated net-spread and tow distance, assuming all fishing is done only by the net and no herding by the trawl doors or ground cables occurs (Hata and Berkson, 2003). For each demographic group, the mean and variance of the catch-per-tow or density in each stratum will be calculated using a lognormal delta-distribution model (Pennington, 1983), and these estimates will be combined using formulas for a stratified random design (Cochran, 1977) to obtain an overall stratified mean. Total abundance will be estimated by multiplying the stratified mean density by the study area.

No foreign substances and no non-indigenous organisms will be introduced into the environment. No construction or restoration-related activities will take place.

C. Anticipated dates and durations

The proposed research activity is anticipated to be conducted in the fall, between early September and mid-November. Sampling will target optimum effort allocation among strata to minimize the variance for mature female relative abundance estimates. Planned coastal trawl survey effort will total about 50 stations in the Delaware Bay area (see Section IV.D below) and 60 stations in the New York apex to target a coefficient of variation (CV) of 0.25 for mature females. Given the total survey areas, approximate vessel speeds, and time required to complete sampling at each station (taking water samples, deploying the net, trawling, and retrieving the net), five stations can be completed, on average, each 12-hour day if the vessel returns to port each day. On average, this results in 11.5 kilometers traveled between stations. However, in some instances it will be more economical to remain at sea and complete 10 to 12 stations before returning to port, in which case the actual total days at sea would be reduced. The coastal Delaware Bay area survey is expected to require about 10 days at sea (at five stations per day), while the New York apex survey is expected to require about 12 days at sea. Initial Delaware Bay sampling is expected to consist of 24 tows over 3 or 4 days at sea. Given the Bay survey area, we estimate that six to seven stations can be completed each 12-hour day. This would equate to about 4.5 kilometers traveled between stations. Results from the initial Delaware Bay trawl survey will be evaluated to determine the number of stations and allocation of stations among strata necessary in order to obtain a target CV of 0.25 for mature female horseshoe crabs. Time constraints on completing all coastal and Delaware Bay survey activity will most likely limit Bay sampling to no more than 30 stations and five days at sea regardless of actual CV attained. Specific dates and actual activity duration will depend on vessel availability, weather, and funding. The proposed activity would begin in 2010, and is expected to be conducted annually, although activity in future years will depend on availability of funds.

D. Specific location of activity

The coastal mid-Atlantic trawl survey will consist of two regional surveys; in the Delaware Bay area, where the majority of the coastal horseshoe crab population is centered, and in the New York Bight apex (Figure 1). The coastal Delaware Bay area survey will extend from shore out to 22.2-km (12 nautical miles), and from the Eastern Shore of Virginia (37° 10' N) north to Atlantic City, New Jersey (39° 20' N). The New York apex survey will extend from shore out to 22.2 km (12 nautical miles), and from 39° 20' N north along the New Jersey coast and east along the southern coast of Long Island to Montauk Point, New York (71° 50' W). Horseshoe crab distribution in the Delaware Bay area is affected by distance from shore and bottom topography (Hata and Berkson, 2004). Therefore, the survey there will use a stratified-random sampling design, with stratification by distance from shore and bottom topography. The survey area will be stratified as inshore (0-3 nautical miles: 0-5.6 km) and offshore (3-12 nautical miles: 5.6-22.2 km), and as trough and nontrough, into inshore-trough, inshore-nontrough, offshore-trough, and offshore-nontrough strata. Troughs are components of the prominent ridge and swale topography of the mid-Atlantic coast. For this survey, troughs are defined as depressions in the bottom at least 2.4-m deep from the low point to the "shoulders", no more than 1.8-km wide, and more than 1.8-km long. Ridge and swale topography decreases north of Atlantic City, New Jersey, and does not appear to influence horseshoe crab distribution in the New York apex. Therefore, that survey area will be stratified by distance from shore only, into inshore and offshore strata.

The Delaware Bay trawl survey will be conducted in Delaware and New Jersey state jurisdictional waters deeper than three meters (10 feet) in Delaware Bay west of the territorial sea demarcation line as indicated on NOAA NOS chart 12304, between Cape Henlopen, DE and Cape May, NJ, north to a line between Bombay Hook Point, DE and the mouth of the Cohansey River, NJ (approximately 39º 20' N; river kilometer 61) (Figure 2). Horseshoe crab distribution in the coastal trawl survey is affected by distance from shore and bottom topography (Hata and Berkson, 2004). Within Delaware Bay, spring distributions are apparently depth-dependent (D. Smith, USGS, Personal commun.). Therefore, the study will use a stratified-random sampling design with stratification by depth as shallow (10-30 feet: 3.0-9.1 m) and deep (>30 feet: >9.1 m), and by bottom topography as trough and nontrough, into shallow-trough, shallow-nontrough, deep-trough, and deep-nontrough strata.

Trawl survey areas will be divided into cells of one-minute latitude by one-minute longitude. For the coastal trawl survey, cells in which the majority of the cell area is in water and inside the three-nautical mile line as depicted on NOAA NOS 1:80,000 scale navigation charts will be designated as inshore. Cells in which the majority of the cell area is outside the three-nautical mile line and inside the 12-nautical mile line will be designated as offshore. In addition, cells through which a trough axis passes also will be designated as trough cells, whereas those through which no trough axis passes will be designated as nontrough cells. For the Delaware Bay trawl survey, cells in which the majority of the cell area is in water greater than 3.0 meters and less than 9.1 meters will be designated as shallow. Cells in which the majority of area is in water deeper than 9.1 meters will be designated as deep. Cells will also be designated as trough or nontrough in the same manner as for the coastal trawl survey. Cells in each stratum will be assigned a sequential number. A quantity of random numbers corresponding to the quantity of samples needed from each stratum to obtain a CV of 0.25 with optimum allocation will be drawn prior to survey activity each year. Cells corresponding to those random numbers will be targeted for sampling, although the presence of wrecks or other bottom obstructions, other vessels, or fishing gear such as gill nets, whelk pots, or crab pots, may necessitate moving the tow to another location.

V. Conservation Plan:

A. Anticipated impact on listed species:

Shortnose sturgeon occur all along the Atlantic coast of the United States, and adults occasionally move into nearshore marine waters associated with mollusks (Dadswell et al., 1984). They are not known to make coastal migrations, and their occurrence in nearshore coastal habitats is not well documented (NMFS, 1998). Shortnose sturgeon occur in the Delaware River system primarily above Philadelphia, PA, but on rare occasion have been captured in Delaware Bay, and have been reported from coastal waters south of the bay (Brundage and Meadows, 1982b; Dadswell et al., 1984; O'Herron et al., 1993). Reported occurrences in the fall have usually been at or above Philadelphia, but one record in the coastal Atlantic Ocean occurred in October (Brundage and Meadows, 1982b). Adults in the center of their range (including Delaware River) use saline water the least of all population segments, usually only briefly (Kynard, 1997). The species may be distributed into 19 distinct population segments representing each estuary where they occur, although genetic and tagging studies suggest a single population occurs in Delaware and Chesapeake Bays (Grunwald et al., 2002; Welsh et al., 2002). The Hudson River adult population may be as high as 38,000, whereas that in the Delaware River has been estimated at only 6,000-14,000 individuals (Hastings et al., 1987; O'Herron et al., 1993; NMFS, 1998). Shortnose sturgeons feed on crustaceans, worms, insect larvae, and mollusks (NMFS, 1998). In saline waters, they feed primarily on mollusks, especially *Mya arenaria* and *Macoma balthica* (NMFS, 1998). Shortnose sturgeons are most active at night, presumably to feed (Dadswell et al., 1984). In saline waters, feeding has been described as occurring in all depths over sand, sandy-mud, and mud bottoms (Dadswell et al., 1984).

Atlantic sturgeon also occur all along the east coast of the United States (Grunwald et al., 2008). Atlantic sturgeon occur in mainstem rivers, estuaries, and nearshore marine habitats (ASSRT, 2007). Spawning and early juvenile nursery areas are located in freshwater, whereas older juveniles inhabit lower river and estuarine areas, and move into coastal waters to mature (Smith and Clugston, 1997). Within Delaware Bay, Atlantic sturgeon have been captured from March to November, primarily from March to May with a small secondary peak from September to November (Brundage and Meadows, 1982a). Atlantic sturgeon have been frequently captured in coastal waters outside Delaware Bay in the fall (Brundage and Meadows, 1982a), and have been captured in the coastal horseshoe crab trawl survey in both the New York apex and Delaware Bay areas. Subadult and adult Atlantic sturgeon in coastal waters undertake extensive migrations, but return to their natal rivers to spawn (Greene et al., 2009). Sturgeons from the New York Bight are nearly all of Hudson River origin, while those from the Delaware River may be a mix of South Atlantic and Hudson River origin (Waldman et al., 1996). Hudson River and Delaware River sturgeon have been recaptured from North Carolina to Maine (Waldman et al., 1996; Greene et al., 2009). The 1985-1995 average Hudson River spawning stock was estimated to be 870 adults (ASSRT, 2007). No spawning stock estimates appear to be available for the Delaware River. Juveniles in riverine and estuarine waters feed on worms, amphipods, insect larvae, and mysids (Greene et al., 2009). Polychaete worms comprise the primary food group for sturgeons in coastal waters of New Jersey (Johnson et al., 1997), although they reportedly also feed on mollusks, shrimp, amphipods, oligochaete worms, and fish (ASMFC, 1990).

Shortnose sturgeon are taken incidentally in spring shad gillnet fisheries (NMFS, 1998). Gillnet fishery bycatch and poaching are likely to have significant impacts on populations in the southern portion (south of Chesapeake Bay) of their range, but not on northern populations (Kynard, 1997). Atlantic sturgeons are captured in sink and drift gill nets and otter trawls

(ASMFC, 2007). About 16% of sturgeon caught in gillnets die, and 20% are injured (Collins et al., 1996; 2000). Trawl mortality of Atlantic sturgeons is believed to be low, although subsequent mortality from injuries is unknown (Stein et al., 2004; ASMFC, 2007). Of 551 tagged shortnose sturgeon in the Altamaha River, Georgia, only one (0.2%) was recaptured by a trawl fishery, whereas 2.7% (41 of 1,534) of tagged Atlantic sturgeon were recaptured by trawl fisheries (Collins et al., 1996). Five shortnose sturgeon have been captured within Delaware River and Bay in Delaware Department of Natural Resources and Environmental Control (DNREC) trawl surveys since 1966 (Figure 2): three were caught in the 16-foot juvenile finfish trawl survey in 7,499 tows from 1980 to 2008, and two were caught in the 30-foot adult finfish trawl survey in over 2,000 tows over the periods 1966-1971, 1979-1984, and 1990-2008 (S. Michels, Delaware DNREC, 7 May 2009, Personal commun.). One of those sturgeons was captured in the proposed Delaware Bay study area in May 1991, but none were captured in the proposed study area during the proposed fall activity period. All Atlantic and shortnose sturgeons captured in Delaware DNREC trawl surveys were in good condition when released.

Given the population size and general distribution, shortnose sturgeons are not likely to be caught during the proposed coastal or Delaware Bay survey activities, but the survivability of any caught is likely to be near 100%. Atlantic sturgeon were enumerated in the 2005, 2006, and 2009 coastal horseshoe crab trawl surveys. A total of 25 sturgeons were captured in 258 tows, for an average of 0.1 sturgeons/tow. For an estimated annual coastal trawl survey effort of 110 tows, 11 Atlantic sturgeons would be captured each year. We have no information regarding relative capture probabilities of Atlantic sturgeon within Delaware Bay, but assuming densities are three-times higher within the Bay, the estimated maximum 30 survey tows would capture nine sturgeons. Stein et al. (2004) reported no immediate Atlantic sturgeon mortalities in NMFS observer trawl records, and we observed no immediate mortalities in the coastal trawl survey. We therefore also anticipate survival of Atlantic sturgeons in coastal and Delaware Bay survey activities to be near 100%.

The proposed activity has the potential to impact all five sea turtle species that occur in the western North Atlantic. Interactions with hawksbill sea turtles are unlikely, because they are uncommon in the proposed activity area. Murray (2008) reported no hawksbill sea turtles in NMFS observer records from mid-Atlantic trawl fisheries, and only three hawksbill strandings were reported in the study area (New York to Virginia) from 1986 to 2007 (STSSN[1]; Table 1). However, it is highly likely that loggerhead and Kemp's ridley sea turtles would be affected, because of their habitats and feeding ecologies. Loggerhead sea turtles are the most numerous stranded species reported in study area, followed by leatherbacks and Kemp's ridleys (STSSN[1]; Table 1). Loggerhead sea turtles also are the most commonly observed species in the Delaware Bay, with few Kemp's ridley and leatherback sea turtles also reported (Stetzar, 2002). Green sea turtles have not been reported within the Bay, but have been reported from the Atlantic coast of New Jersey (Stetzar, 2002). Braun-McNeill and Epperly (2002) reported that sea turtle sightings in the Delaware Bay area begin in March-April, and apparently peak in September-October before becoming negligible from November to February. Stetzar (2002) reported a Delaware Bay peak in June and July. Stranding reports in the mid-Atlantic area are highest from June to September, and drop off through October and November (Figure 3). Sea turtles have been

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[1] Sea Turtle Stranding and Salvage Network (STSSN). Accessed 14 Apr 2009. http://www.sefsc.noaa.gov/seaturtleSTSSN.jsp

sighted throughout the Delaware Bay and at all depths from June to October, indicating that they would be present in the Bay sampling area during the proposed activity period (Stetzar, 2002).

The coastal trawl survey will consist of approximately 110 tows over an estimated 22 days at sea. Epperly et al. (1995) reported that the summer flounder 1991-92 winter trawl fishery caught 0.048 sea turtles/standard net-hr (effort adjusted to a 30.5-m headrope following Henwood and Stuntz, 1987). The estimated 33 standard net-hrs in the proposed coastal trawl survey (110 tows × (18.3-m headrope/30.5-m "standard" headrope) × 0.50 "wet" hours/tow) would result in two captures. South Atlantic shrimp fishery catch rates (loggerhead: 0.0456, Kemp's ridley: 0.0018, green: 0.0007 turtles/standard net-hr; Henwood and Stuntz, 1987) also equate to two loggerhead captures in the coastal trawl survey. Catch rates reported in Murray (2008) indicate that one sea turtle would be captured in the Delaware Bay area survey (south of 39° N, depth <50-m, temperature >18° C: 0.0201 turtles/net-hour), and none would be captured in the New York apex survey (north of 39° N, <50-m, <18° C: 0.0004 turtles/net-hour). Catch rates reported in SCDNR (2004) indicated that one Kemp's ridley (0.0352 turtles/standard net-hr) and 24 loggerhead (0.737 turtles/standard net-hr) sea turtles would be captured. Data from the South Atlantic shrimp fishery reported in Epperly et al. (2002) indicate that up to 24 loggerhead (0.4338 turtles/net-hr), 21 Kemp's ridley (0.3732 turtles/net-hr), and four green (0.0741 turtles/net-hr) sea turtles would be captured. Sea turtle mortality rate estimates range from 17 to 29% (Henwood and Stuntz, 1987; Epperly et al., 1995), although true rates may be three-times higher (NRC, 1990). This would indicate that as many as 42 sea turtles will be killed in the coastal trawl survey each year. Poiner et al. (1990) reported no sea turtle mortality for tows less than 90 minutes in the Australian prawn fishery, and Henwood and Stuntz (1987) reported less than 1% mortality for shrimp fishery tows less than 60 minutes. Robins (1995) found that potential mortality in various Australian trawl fisheries was 2.4% for tows of 30-"wet" minutes. Epperly et al. (2002) found that trawl mortality is less than 1% only for tow durations less than 10-minutes. Sasso and Epperly (2006) stated that mortality increased rapidly with tow durations greater than 10 minutes. These mortality rates suggest that up to one sea turtle would be killed in the coastal trawl survey each year.

One loggerhead sea turtle has been captured in the coastal trawl survey in 668 tows conducted in the fall (September-November) from 2001 to 2008, for an overall catch rate of 0.005 turtles/standard net-hr. No sea turtles were captured in an additional 64 tows conducted in the summer (June-August). The sea turtle captured was released in good condition.

The Delaware Bay trawl survey will consist of a maximum of 30 tows over five days. Catch rates in Epperly et al. (1995), Henwood and Stuntz (1987), and Murray (2008) indicate that less than one sea turtle would be caught in the Delaware Bay survey. Sea turtle captures in the Delaware DNREC 10.4-m trawl survey averaged 0.073 turtles/hour (Stetzar, 2002). Assuming the catch rate of the 18.3-m survey net is twice that, the proposed 15 trawl-net-hours would yield two captures. SCDNR (2004) catch rates indicate that seven loggerheads would be caught. Data from the south Atlantic shrimp trawl fishery (Epperly et al., 2002) indicate that as many as seven loggerhead, six Kemp's ridley, and one green sea turtles may be captured. At mortality rates of 87% (Henwood and Stuntz, 1987; NRC, 1990; Epperly et al., 1995), six loggerhead, five Kemp's ridley, and one green sea turtles would be killed in the Delaware Bay survey each year. Tow-duration dependent mortality estimates (Henwood and Stuntz, 1987; Poiner et al., 1990; Robins, 1995) suggest that no sea turtles would be killed in the Delaware Bay trawl survey.

B. Anticipated impact on habitat:

Significant short-term impact on the bottom is anticipated. Horseshoe crabs frequently burrow in the bottom sediment, and the intended sampling gear is designed to dig into the bottom to remove the crabs. The research activity will result in the temporary suspension of fine sediments which will reduce visual foraging. Some benthic fauna will be damaged and exposed even if not captured by the gear, and after examination the catch and bycatch will be returned to the water, so short-term impacts may make food items available to sturgeons and sea turtles that would otherwise not be accessible. Over the long term, trawling and dredging can also reduce habitat structural complexity, epifaunal species diversity, and species richness (NRC, 2002). Such effects may persist for two years or more (Kaiser et al., 2002; NRC, 2002). However, low levels of trawling activity, as proposed, have a similar effect on bottom habitat as natural bioturbation (Kaiser et al., 2002), and the impact of trawling is lessened in areas of naturally high bioturbation, both in the short-and long-term (Hiddink et al., 2006; Simpson and Watling, 2006). Horseshoe crabs, as well as knobbed and channeled whelks (*Busycon carica* and *Busycotypus canaliculatus*), burrow in the sediment and rework the surface, and are abundant in the proposed study area, so we believe their bioturbation would contribute to negating some of the study effects on benthic habitat.

Over 1000 vessels are reported to participate in mid-Atlantic bottom trawl fisheries (DOC, 2009). Murray (2008) reported trawlers fished 26,351 days per year in the mid-Atlantic based on vessel trip reports from 1996 to 2004. Relative to this effort, the impact of the proposed 22 days at sea in the coastal trawl survey would be minimal. Commercial trawling is prohibited within Delaware Bay, but blue crab (C*allinectes sapidus*) and knobbed whelk dredge fisheries exist. The blue crab dredge fishery is conducted predominantly in the winter, while the whelk dredge fishery occurs in the spring. Delaware Bay whelk dredge boats cover 5.0 to 14.2 hectares per trip, using scallop or toothbar dredges (Bruce, 2006). Assuming 16 Delaware whelk dredge licenses (Bruce, 2006) average 4 trips per week and cover 5 hectares per trip, 3,840 hectares would be dredged in 12 weeks from March to June, when most whelk landings occur. Kahn (2003) reported that 114 blue crab dredge licenses were issued for Delaware Bay by Delaware and New Jersey in 2002. Assuming annual effort of 500 boat-days (Kahn, 2003) and coverage of 5 hectares per trip, the blue crab winter dredge fishery would cover 2,500 hectares per year. In comparison, the proposed trawl gear for this study covers an estimated 1.31 hectares per tow, or 39.3 hectares for 30 tows. The estimated 39.3 hectares swept area represents only 0.03% of the 1147.5 km^2 proposed survey area. Although immediate effects on bottom habitat are probable, the total amount of effort expended by the proposed research will be small and diffuse relative to ongoing commercial fishing activities.

Certain habitats such as coral or rock areas and submerged aquatic vegetation, important feeding areas for hawksbill and green sea turtles, will be avoided because of the potentially destructive nature of the proposed sampling gear and possible impacts on sea turtles. The sampling gear was chosen, in part, because other effective gear such as hydraulic clam dredges were considered as damaging or more damaging to the environment.

Critical habitat has been designated for green, hawksbill, and leatherback sea turtles. However, these habitats are all outside the proposed area and would not be impacted by the activities. No critical habitat has been designated for shortnose sturgeons or loggerhead or Kemp's ridley sea turtles.

C. Proposed monitoring and mitigation:

In order to reduce the potential impact of the proposed activity on listed species the amount of effort will be limited to the minimum believed necessary for statistically valid results. Shortnose sturgeon are uncommon in coastal waters, so we believe the potential for impact by the coastal trawl survey is low. Small numbers of Atlantic sturgeons have been captured every year in the coastal survey, and we expect further interactions. The proposed activities within Delaware Bay will be confined to the area below 39º 20' N. We believe this limitation will reduce potential interactions with shortnose sturgeons. However, Atlantic sturgeons utilize estuarine habitats more than shortnose sturgeon, so the Delaware Bay survey area will probably not reduce interactions with Atlantic sturgeons. Horseshoe crabs feed on polychaete worms, and mollusks such as blue mussels (*Mytilus edulis*), surf clams (*Spisula solidissima*), razor clams (*Ensis* spp., *Siliqua costata*), Macoma clams (*Macoma* spp.), and softshell clams (*Mya arenaria*) (Botton, 1984; Botton and Haskin, 1984). These are also prey items of shortnose and Atlantic sturgeons, so both horseshoe crabs and sturgeons may be attracted to areas with high prey abundance. Horseshoe crabs, the survey target species, have been relatively abundant at every coastal trawl survey station in which Atlantic sturgeons have been recorded. Therefore, altering that survey design to avoid Atlantic sturgeons would negatively impact the survey objectives - that is, excluding areas preferred by Atlantic sturgeon would also exclude areas preferred by horseshoe crabs. Trawl survey protocol calls for sampling at night: horseshoe crab catches in the coastal survey are larger at night than during the day, and catch variances are smaller at night, so sample sizes for a given relative precision are smaller for nighttime sampling than for daytime sampling (Hata and Berkson, 2004). However, sampling within Delaware Bay may be restricted to daytime in order to avoid other vessels and fixed fishing gear such as blue crab pots, gill nets and pound nets. Daytime sampling may also reduce interactions with shortnose sturgeon, which are more active at night (Dadswell et al., 1984).

Coral and rock habitats associated with hawksbill sea turtle feeding would be avoided because of the nature of the proposed sampling gear. The proposed activities will avoid areas of submerged aquatic vegetation, due to sampling vessel depth requirements as well as the destructive nature of the sampling gear, so interactions with feeding adult green sea turtles are unlikely. The habitats and diets of loggerhead and Kemp’s ridley, and possibly juvenile green sea turtles, as well as their reported scavenging habits (Shaver, 1991; Tomas et al., 2001), indicate that they are the most likely to be negatively impacted during the research activities. Horseshoe crabs are the principal forage item for loggerhead sea turtles in Delaware Bay, and loggerheads are most often observed in channel areas (Stetzar, 2002), where we also expect horseshoe crabs to be most abundant, so surveys targeting horseshoe crabs are likely to disrupt feeding where loggerhead sea turtles and horseshoe crabs co-occur. Loggerhead, Kemp's ridley, and green sea turtles are the most abundant species in the proposed research area, and are also the most commonly encountered species in east coast trawl fisheries (Henwood and Stuntz, 1987; Epperly et al., 1995; Stetzar, 2002). Therefore, research activities will be tailored to reduce detrimental effects, including using minimal tow durations and avoiding areas of high fishing vessel activity which may attract foraging sea turtles.

Loggerhead sea turtles submerge for an average of 16.1 minutes, but averages range from 4.2 minutes in summer to 171.7 minutes in winter (Lutcavage and Lutz, 1991; Renaud and Carpenter, 1994). Reported average submergence durations for Kemp's ridley sea turtles range from 18.1 to 63.2 minutes (Byles, 1989; Gitschlag, 1996). In captivity, average submergence times for Kemp's ridley and large loggerhead turtles averaged less than 5 minutes (Lutz and

Bentley, 1985). Submergence times are generally greater at night when resting, so the probability of encounter may be higher than indicated in the studies above. Sea turtles are physiologically stressed during involuntary submergence, as when caught in trawls, and the stress is exacerbated by repeated involuntary submergence (Lutcavage and Lutz, 1991). Substantial acidosis occurs in involuntary submergences less than 30 minutes, and repeated captures may cause mortality when sea turtles are unable to compensate for the stress (Lutcavage et al., 1997).

Research tows will be limited to no more than 15 minutes bottom time to minimize adverse impacts on sea turtles while maintaining a viable sampling protocol. At tow durations less than 15 minutes variability in the time the gear starts and stops fishing may become significant relative to tow duration, affecting the accuracy of the resulting information (Pennington and Volstad, 1991). However, within Delaware Bay, tow durations may be reduced to 7.5-10 minutes to reduce bycatch and help avoid interactions with other vessels and obstructions such as fixed fishing gear. The typically shallower depths of Delaware Bay should reduce gear set and retrieval time and resultant errors in actual tow duration. In the Gulf of Mexico and south Atlantic shrimp trawl fisheries sea turtle mortality rates were less than 1% in tows less than 60 minutes, and no sea turtle mortality was observed in tows less than 90 minutes in the Australian prawn fishery (Henwood and Stuntz, 1987; Poiner et al., 1990). The National Research Council recommended limiting tow durations to 40 minutes in the summer and 60 minutes in the winter (NRC, 1990), although Sasso and Epperly (2006) stated that mortality increased rapidly with tow durations greater than 10 minutes. While reducing the impacts on captured sea turtles, reduced tow durations within Delaware Bay also may reduce the likelihood of encountering shortnose or Atlantic sturgeons, and reduce stress or injury to any that may be captured.

Under the coastal horseshoe crab trawl survey protocol, trawling is conducted at speeds of 3.7-5.6 km/hr (2-3 knots). The magnitude of horseshoe crab catches is correlated with vessel speed, which influences tow distance, net spread, and bottom contact. Murray (2008) reported no effect of tow speed on sea turtle bycatch in mid-Atlantic trawl fisheries. However, the rate of sea turtle encounter may decrease at tow speeds less than 4.6 km/hr (2.5 knots) to about half that at higher speeds (SCDNR, 2004). Small green sea turtles can swim at burst speeds of 3.6-7.2 km/hr, while adults can swim at around 10-12 km/hr (Prange, 1976; Heithaus et al., 2002). Loggerhead sea turtles flee from simulated shark attacks at average speeds of about 4-6 km/hr (Heithaus et al., 2002; Wirsing et al., 2008). Green sea turtles are much more likely to flee from a boat approaching them at 4 km/hr (2 knots) than at 11 or 19 km/hr (6 or 10 knots), and they flee while the boat is at a greater distance (Hazel et al., 2007). Shortnose sturgeon swim at about 0.6 body lengths per second (BL/s) in estuaries (NMFS, 1998). Burst speeds are apparently unreported, although lake sturgeon (*A. fulvescens*) can swim for two minutes at 2.45 BL/s (Webb, 1986). For a 50-cm sturgeon, these speeds equate to 1.1-4.4 km/hr. Atlantic sturgeons were captured in coastal trawl survey tows made at 4.4-5.6 km/hr, with an average tow speed of 5.1 km/hr (average speed for all tows 5.0 km/hr). Within Delaware Bay, where sea turtle and sturgeon densities are probably higher, we will attempt to tow at speeds around 3.7-4.6 km/hr (2-2.5 knots) in order to reduce the probability of capturing a sea turtle while maintaining an acceptable catchability of horseshoe crabs. Tow speeds of 3.7-4.6 km/hr will provide adequate horseshoe crab catchability while providing sea turtles opportunity to avoid the gear, although these speeds probably would not allow sturgeons to escape. However, river and tidal currents, as well as wind speed and direction, may necessitate higher speeds in order to maintain steerage.

Both loggerhead and Kemp's ridley sea turtles feed on fishing vessel discards (Shaver, 1991; Tomas et al., 2001), which may make them especially susceptible to capture or recapture in areas of heavy trawling activity. To avoid capturing sea turtles that may be feeding on fishing vessel discards, and to avoid capturing sea turtles that may have been recently caught and stressed, the proposed research activities will avoid known areas of active or recent high fishing effort and no trawling will be conducted if a sea turtle is observed in the area. Standard horseshoe crab trawl survey protocol requires only one tow at each station. If more than one tow is required at a location, as in gear comparison or mesh selectivity studies, protocol dictates that the second tow is conducted at least 24 hours after the first tow, to allow the swept area to re-populate. If a species of concern is captured in the first tow, no other tows would be conducted in that location. This protocol should reduce the likelihood of recapture of sea turtles or sturgeons.

All activities will be conducted under the direct supervision of scientific parties from Virginia Tech. If a sturgeon or sea turtle is captured, all efforts will be made to release the animal as quickly as possible with minimal trauma. The recommended short-term handling protocol for sturgeons is to hold them in a live car or net pen (Moser et al., 2000). On a research vessel they may be held in a live-well with constant water flow or complete water replacement every 15-20 minutes (Moser et al., 2000). Use of a net pen or live car will require cessation of survey activities, as it will restrict vessel speed and maneuverability, and readily accessible areas of the boats for suspending pens or live cars - sides aft of the wheelhouse, and stern - are in the operating zone of the trawl doors, cables, and net. The side areas of vessels previously used are also subject to bilge discharge, and are therefore probably not suitable for holding. Fishing vessels previously chartered to conduct the trawl survey routinely carry on board or have readily available large tubs normally used to hold the catch during commercial fishing operations. Such tubs are about 1.5-m on each axis. Sturgeons could be held in those tubs with running water from the deck hose until they have recovered from capture stress. Tubs could also be covered with the tub lid or a tarp to protect the fish from the sun. If necessary, swim bladders can be deflated by gently rubbing the ventral surface in a back-to-front direction (Moser et al., 2000). Sea turtles that are actively moving will be released off the stern of the vessel, away from boat traffic and fishing activity, with the engine out of gear (DOC, 2001). If necessary, resuscitation of sea turtles will be attempted following published guidelines (DOC, 2001; NMFS SEFSC, 2008). Scientific parties will be familiarized with resuscitation techniques prior to surveys, and a copy of the resuscitation guidelines will be carried aboard the vessel during survey activities. In the event resuscitation is unsuccessful, the sea turtle will be transferred to the sea turtle stranding network of the appropriate jurisdiction (see Appendix). Other monitoring or mitigation actions will be undertaken as requested or required.

The proposed research activity is funded through contracts from the Northeast Regional Office of the National Marine Fisheries Service to The Virginia Polytechnic Institute and State University to conduct horseshoe crab research. Remediation funds would derive from those sources.

D. Alternatives to the proposed activity:

As an alternative to conducting the proposed research, no action could be taken, and horseshoe crab management would rely on existing sources of relative abundance information. Alternative approaches include using current state and federal finfish monitoring programs, analysis of commercial harvest, and on-shore counts of spawning horseshoe crabs. Existing finfish monitoring programs are inefficient for sampling horseshoe crabs and are insensitive to population changes. A decline in the horseshoe crab population of 70% or more over five years would be required for those programs to detect any decline (ASMFC, 2004). Commercial harvesting within the proposed study site is primarily done by hand. Hand-harvesting targets adults as they move onto beaches to spawn, and could not enumerate juveniles. Furthermore, commercial harvest caps would inhibit detection of any population increase: Delaware restricts harvesting to only males, and New Jersey prohibits all harvesting. As with commercial hand-harvesting, on-shore surveys enumerate only mature, spawning individuals, and are not indicative of all segments of the population.

Another alternative to the proposed research is to conduct the activities elsewhere. horseshoe crabs occur along the Atlantic coast from Maine to Florida, along the Florida coast of the Gulf of Mexico, and on the Yucatan Peninsula. The Delaware Bay area is the center of horseshoe crab abundance and is the primary feeding ground for some migrating shorebirds (Shuster, 1982; Botton and Ropes, 1987; USFWS, 2003). Landings data suggest that restrictions in the Delaware Bay area have shifted harvest effort to the New York area, indicating these areas should be managed, and monitored, together. Conducting the proposed activities in other locations would impose similar impacts on other species, protected species, and the environment as the proposed locations, although different species may be affected or the affects could be of different magnitudes. However, sampling in other locations would not provide the critical management information for the largest and most significant segment of the horseshoe crab population, possibly leading to greater impacts on the population than it currently endures. Conducting the proposed activities in other areas would have the same effective impact on management of the Delaware Bay horseshoe crab population segment and survival of migrating shorebirds as the no-action alternative.

Further, the proposed activities could be conducted with alternative sampling methods. Hydraulic clam dredges, blue crab (toothbar) dredges, and scallop dredges (e.g., New Bedford type) may be effective for sampling horseshoe crabs, but impose similar bycatch, bycatch mortality, protected resource, and habitat concerns as the proposed gear (DuPaul et al., 1995; NRC, 2002). For example, a majority of sea turtles captured in scallop dredges suffer injuries (Haas et al., 2008). Clam and scallop dredges impart substantial damage and mortality on target species, so we would expect similar impacts on horseshoe crabs and bycatch (McLoughlin et al., 1991; Moschino et al., 2003; Morello et al., 2005). Toothbar blue crab dredges are used to harvest horseshoe crabs, especially in Virginia. We have examined toothbar dredge-harvested horseshoe crabs previously for genetic studies, and the proportion of injury and mortality was much higher than we have observed from the proposed trawl gear. Hydroacoustic survey techniques rely on density differences between air bladders in fishes and the surrounding water for detection. They would not be effective for horseshoe crabs, which lack air bladders. They would also not be able to reliably detect horseshoe crabs on or within the substrate. Diving and remotely-operated vehicles would be prohibitively time consuming and expensive and diving would introduce additional hazards regarding diver safety. Horseshoe crabs generally burrow in the bottom and may not be easily or positively detectable by divers or remotely-operated vehicles. Furthermore, hydroacoustic techniques and remotely-operated vehicles would not distinguish sex or maturity, characteristics critical for management. Horseshoe crabs have not been shown to be effectively captured by traps or other passive sampling gear, and the amount of survey area to be covered, and the labor and time required to sample that area would make such research activities impractical. The set times required to collect a relatively sedentary species such as horseshoe crabs would increase the hazard of entanglement, which represents a source of mortality for sea turtles (NRC, 1990) and marine mammals (Waring et al., 2009). In addition, passive gears such as gillnets would also likely impose a much greater mortality on bycatch and protected species such as shortnose sturgeon (Collins et al., 2000).

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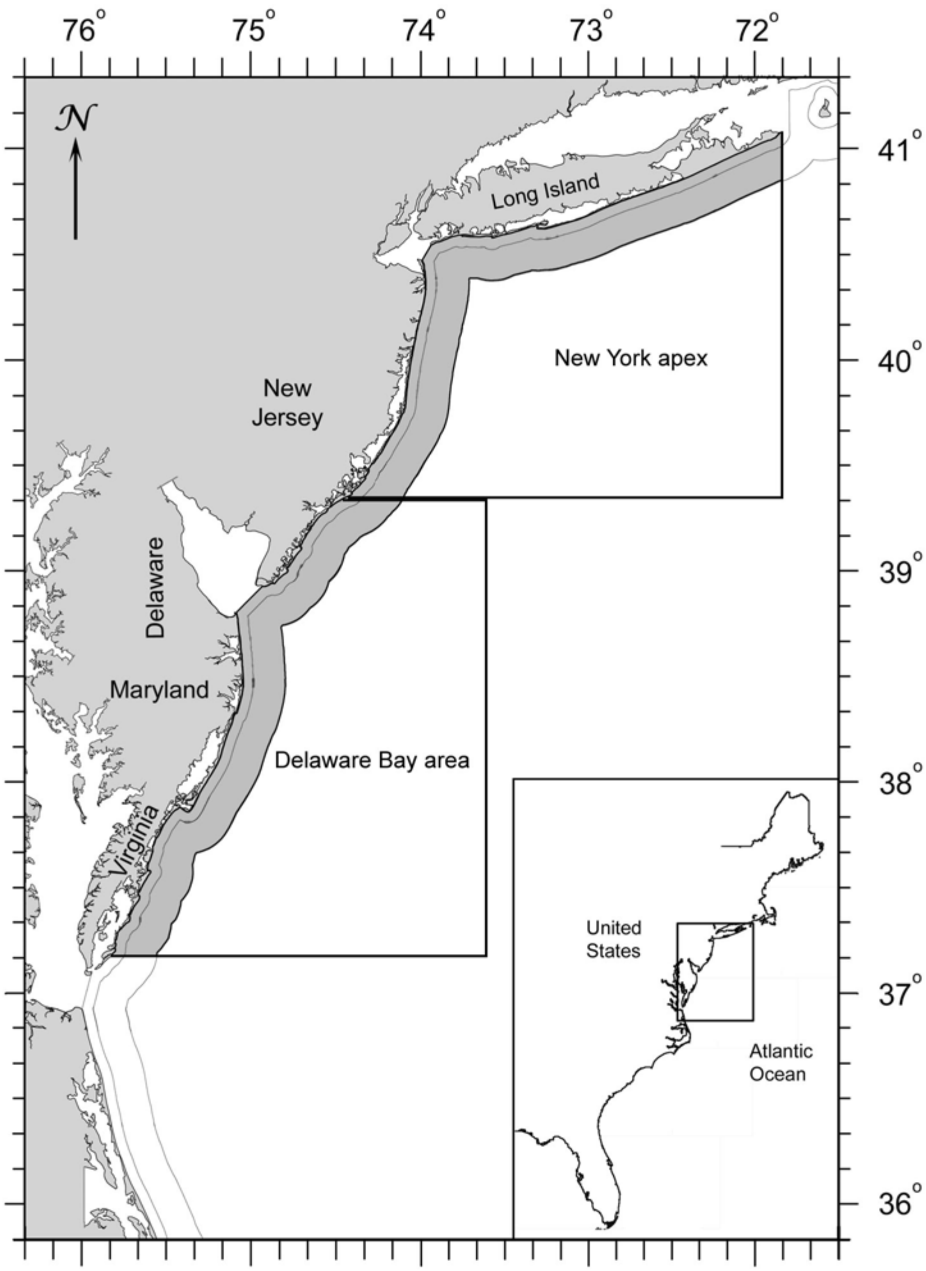

Figure 1. Proposed coastal horseshoe crab trawl survey sampling area (shaded).

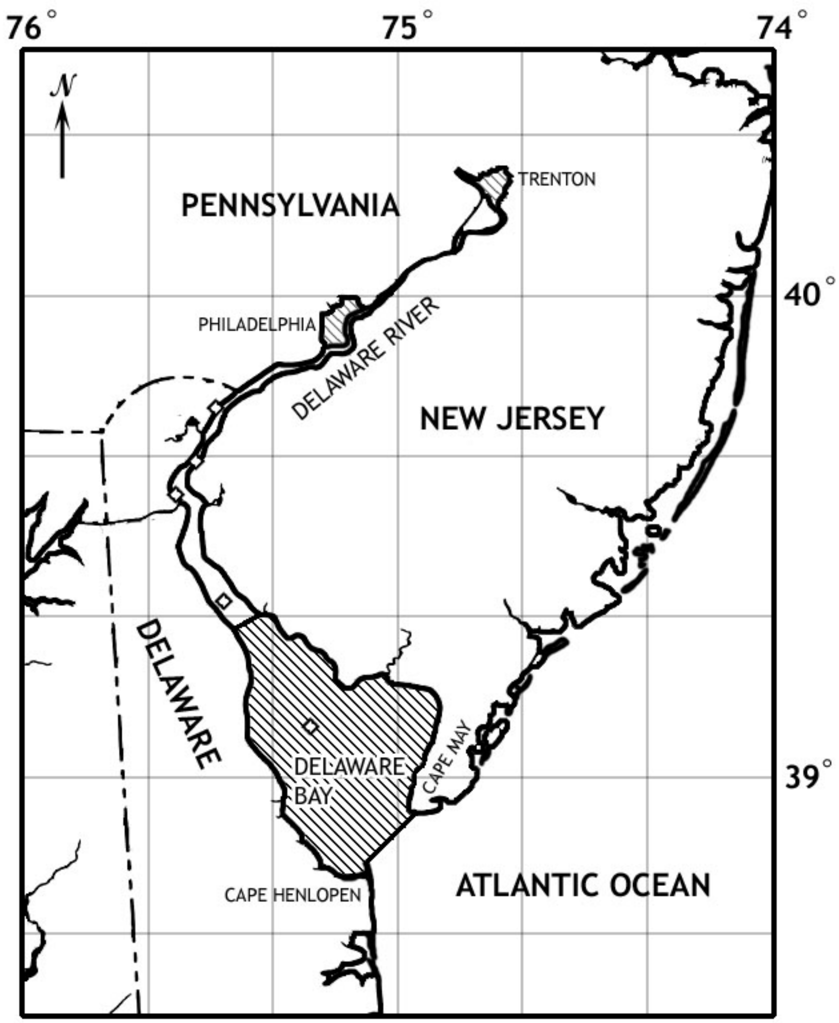

Figure 2. Proposed Delaware Bay sampling area (shaded). The sampling area extends from the Delaware Bay mouth to about 39º 20' N and in water deeper than 10-ft. Diamonds indicate captures of shortnose sturgeon in Delaware DNREC trawl surveys.

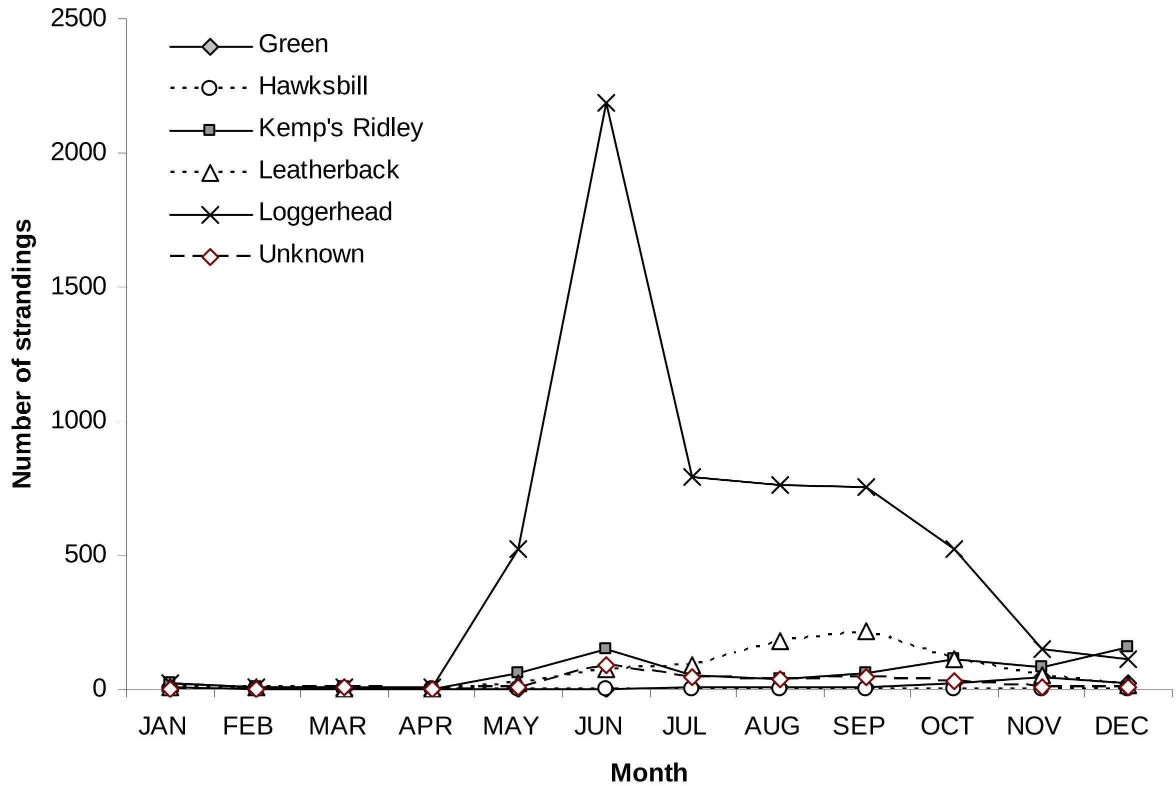

Figure 3. Monthly sea turtle strandings reported in the mid-Atlantic to the Sea Turtle Stranding and Salvage Network, 1986-2007.

Table 1. Yearly sea turtle strandings by species reported in the mid-Atlantic to the Sea Turtle Stranding and Salvage Network, 1986-2007.

STATE	Green	Hawksbill	Kemp's Ridley	Leatherback	Loggerhead	Unknown	Total
Delaware	2		27	42	372	53	496
Maryland	1		14	48	356	17	436
New Jersey	9	1	42	293	756	50	1151
New York	54		255	250	421	12	992
Virginia	69	2	403	137	3946	138	4695
Total	135	3	741	770	5851	270	7770

Appendix

Sea Turtle Stranding and Salvage Network contacts in proposed study area.

Virginia:
The Virginia Marine Science Museum
717 General Booth Blvd.
Virginia Beach, VA. 23451
(757) 437-6159

Maryland:
Maryland Department of Natural Resources / Cooperative Oxford Lab
904 South Morris Street
Oxford, MD 21654
(410)226-5901

Delaware:
Marine Education, Research and Rehabilitation Institute
P.O. Box 411
Nassau, DE 19969
(302) 228-5029

New Jersey:
Marine Mammal Stranding Center
PO Box 773
3625 Brigantine Blvd.
Brigantine, NJ 08203
(609) 266-0538

New York:
The Riverhead Foundation for Marine Research and Preservation
467 East Main Street
Riverhead, NY 11901
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EDUCATION:
1993 Ph.D.: College of William and Mary-School of Marine Science
Major: Marine Science
1985 M.S.: Texas A&M University
Major: Wildlife and Fisheries Science
1982 B.S.: Rutgers, the State University of New Jersey
Major: Environmental Science

PROFESSIONAL EXPERIENCE:
2001-Present:
Research Associate/Research Scientist
Department of Fisheries and Wildlife Sciences/ Virginia Tech
Developing Horseshoe Crab Stock Assessment Information/Benthic Trawl Survey Design
1998-2001:
Senior Marine Scientist
Department of Fisheries Science/Virginia Institute of Marine Science
Fish monitoring program for Virginia Department of Health human cohort study on *Pfiesteria*
1994-1998:
Marine Scientist
Department of Fisheries Science/Virginia Institute of Marine Science
Juvenile finfish and blue crab stock assessment program bottom trawl survey

RECENT PUBLICATIONS:
Graham, L. J., B. R. Murphy, and D. Hata. 2009. Using species composition data from a trawl survey to determine potential bycatch of the commercial trawl fishery for horseshoe crab *Limulus polyphemus* in the Middle Atlantic Bight. North American Journal of Fisheries Management 29:478-487.
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