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Fishery Management Plan
for
Atlantic Cownose Rays (October 2025)

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Fishery Management Plan Background

A Fishery Management Plan (FMP) serves as a framework for conserving and wisely using fishery resources. An FMP provides a format for undertaking management measures throughout Maryland state waters, including the Chesapeake Bay, coastal bays, Atlantic Ocean, and all their tidal tributaries. In addition, FMPs allow the Maryland Department of Natural Resources (MD DNR or Department) to specifically address issues that are unique to Maryland resources. The goal of an FMP is to protect the resource while allowing sustainable harvest. For example, the Atlantic States Marine Fisheries Commission (ASMFC) states that the main objective of fisheries management is to "allow enough harvest to sustain and build the fishing and seafood industries while protecting the productivity and sustainability of the marine ecosystems." Therefore, ecological, economic, and sociological factors affecting the resource are considered.

Development of an FMP begins with the Department's Fishing and Boating Services staff preparing a draft document. Guidelines for the contents of a plan have been delineated in Natural Resources Article, §4-215, Annotated Code of Maryland. Staff review previous management measures, current monitoring data and results, stock assessment conclusions, scientific research data, ecosystem and socioeconomic factors, and other relevant data and information. The plan development team defines goals, objectives, strategies, and options/actions for addressing problems/issues. The plan is then reviewed by the Department's advisory commissions such as the Sport Fisheries Advisory Commission (SFAC) and the Tidal Fisheries Advisory Commission (TFAC). After review by the advisory bodies, the plan undergoes a 30-day public comment period. Public comment is incorporated in the final version of the plan when practicable and then the final plan is adopted by the appropriate Maryland authorities.

Upon adoption of an FMP, the appropriate management entities will advance the recommended actions. In some cases, regulatory and statutory actions may be necessary to fully implement a management action and must go through the appropriate process, including scoping and public comment.

In 2017, the Maryland General Assembly directed the Department to prepare a cownose ray fishery management plan and to place a temporary moratorium on cownose ray fishing contests (2017 Md. Laws, Chap. 399). The legislation required the Department to create a fishery management plan for cownose rays, subject to available funding, by Dec. 31, 2018, and to implement a temporary moratorium on a person sponsoring, conducting, or participating in a cownose ray fishing contest in state waters through July 1, 2019. A cownose ray fishing contest is defined as, "any competition, tournament, or derby with the objective of catching or killing cownose rays for prizes or entertainment." In 2019, the Maryland General Assembly extended the moratorium until a fishery management plan is completed, and gave the Department until December 2020 to complete it, subject to funding (2019 Md. Laws, Chap. 343). The Fishery Management Plan for Atlantic Cownose Rays (October 2025) was developed by the Department with the help of the Cownose Ray Workgroup comprised of representatives of interested and impacted parties in the cownose ray fishery.

Table of Contents

Section 1. Goal of Management Plan

The goal of Maryland's Atlantic Cownose Ray Fishery Management Plan is to ensure recreational and commercial harvests that support fishing and seafood industries, while also ensuring the sustainability of cownose ray populations and maintaining the ecological integrity of the Chesapeake Bay and Atlantic coastal bay ecosystems.

Section 2. Purpose of Management Plan

1. Summarize information on the species;
2. Provide management strategies that protect populations;
3. Determine what information we need in the future to manage the species;
4. Create or maintain rules for catch and harvest consistent with the plan;
5. Provide both a general framework and specific guidance for implementing a strategic, coordinated, multipartner management effort (industry, environmental groups, academia, federal agencies, nonprofit organizations, and the general public);
6. Increase understanding of factors affecting Atlantic cownose ray population dynamics and life history through increased research and monitoring.

Section 3. Introduction

The Atlantic cownose ray is a species of eagle ray native to the Chesapeake Bay and Atlantic coastal waters. Cownose rays belong to the family Rhinopteridae, and are also referred to as cowfish or cownose stingray. Cownose rays have a distinctive rhomboid or kite-shaped body with lateral pectoral fins often referred to as wings. The body is dorsolaterally flattened with the width generally longer than the length (measured as disc width). The head extends forward of the body and is square-shaped with an indentation in the center which gives it a distinctive bilobed appearance. The eyes and spiracles, openings behind the eyes that are part of the respiratory system, are located on the sides of the head. Electrosensory pores are found on both sides of the body, with the greatest concentration of pores around the mouth and leading edge of the cephalic fin lobes. The dorsal side of the body is brownish gray to olive colored, with a small dorsal fin at the rear of the body, and a small, barbed, venomous spine located behind the fin and at the base of the whip-like tail. The ventral or underside of the body is whitish with the mouth almost as wide as the head. There are fleshy, cephalic fin lobes in front of a fringed wide lip which aids in manipulating food into the mouth. The mouth has plate-like teeth in rows of 5 to 13 but usually 7, on both the lower and upper jaw. The ventral side also has 5 rows of gill slits on each side of the body. Mature males and females can be differentiated from one another by the presence or absence of claspers, modified pelvic fins used to transfer sperm during internal fertilization.

Atlantic cownose rays have been viewed as a nuisance to commercial harvesters and detrimental to commercial shellfish resources and submerged vegetation. Consequently, there have been calls to develop a directed fishery to cull the population. Reports about the loss of top predators (e.g., sharks) have influenced the perception that rays are overly abundant. Most recently, recreational bowfishing tournaments have come under scrutiny by the media, animal welfare advocates, conservationists, and the public for their methods and associated resource waste. Scientists and conservationists are concerned about cownose rays because their life history characteristics make them vulnerable to overexploitation. These characteristics include a long life span, late maturity, and low fecundity.

Section 3.1 Taxonomy

Collectively, the family of cownose rays comprise a small number of highly similar, benthopelagic stingray species known as Rhinopteridae (Jordan and Evermann 1896), and represented by the single genus *Rhinoptera* (Cuvier 1829). There are eight living species of *Rhinoptera*, forming a circumglobal distribution on the inner continental shelves of tropical and warm temperate latitudes, including the Caribbean, Gulf of Mexico, Mediterranean Sea, Indo-West Pacific, Eastern Central Pacific, and Western Atlantic (Last et al. 2016). Cownose rays are common in the Western Atlantic where they are frequently observed swimming near the surface of the water in large aggregations as they traverse shallow coastal areas along their seasonal migratory routes.

As stingrays, cownose rays belong to the order Myliobatiformes, which is one of four extant orders of "flat sharks" that together with the skates, sawfish, and guitarfish compose the superorder Batoidea. Batoids, together with their close relatives the sharks, constitute the elasmobranchs. Elasmobranchs are cartilaginous fishes (Class Chondrichthyes) that form an evolutionary branch, which diverged from other jawed vertebrates 420 million years ago. During the Jurassic, the modern elasmobranchs (neoselachii) rapidly diversified and adaptively radiated across the world's seas, giving rise independently to the flattened body plan seen in both skates and rays (Aschliman et al. 2012). Worldwide, the highly morphologically diverse Myliobatiform rays comprise approximately 20 percent (210 species) of total living elasmobranch species (Weigmann 2016). The only species of cownose ray to occur in the Chesapeake Bay based on current genetic studies is the Atlantic cownose ray (*Rhinoptera bonasus* Mitchell, 1815). (Carney et al. 2017, McDowell and Fisher 2013, Weber et al. 2021).

Section 3.2 Range and Distribution

The Atlantic cownose ray is endemic to the Western Atlantic ranging from southern New England to the northern coast of Argentina, including the Gulf of Mexico and parts of the Caribbean (Last et al. 2016). Schwartz (1965) first identified separate U.S. East Coast and Gulf of Mexico populations of Atlantic cownose ray based upon differences in long-distance migration routes inferred from extensive tagging studies, and subsequent studies have verified the existence of separate stocks. Neer and Thompson (2005) examined life-history variation among the two stocks, finding that cownose rays from the Gulf of Mexico reach maturity at an earlier age and at a smaller size than cownose rays from the Chesapeake Bay. Stock separation between Gulf of Mexico and U.S. East Coast populations is also supported by independent molecular genetics studies utilizing mitochondrial DNA (Carney et al. 2017) and microsatellite DNA markers (McDowell and Fisher 2013).

In response to water temperatures, the U.S. East Coast population of Atlantic cownose ray migrates between southern overwintering grounds off the coast of central Florida and northern bays and estuaries used as nursery and foraging areas. Spring and fall migrations of Atlantic cownose rays have been captured by high resolution digital video aerial surveys conducted over the offshore mid-Atlantic region in 2012 and 2013 as part of baseline studies for offshore wind energy planning. In this survey, Atlantic cownose rays accounted for 44 percent of wildlife observations, and were the most abundant of any bird, marine mammal, sea turtle, pelagic fish, or other wildlife observed in the mid-Atlantic region (Connelly et al. 2015). These aerial surveys were limited by small sample size, incomplete spatial resolution and partial timeframes.

Satellite tagging data from a small sample size of cownose rays captured and tagged in the lower Chesapeake Bay supports the existence of an overwintering area off the central coast of Florida (Grusha 2005, Omori 2015). In the spring, schools of Atlantic cownose rays leave southern overwintering grounds, and migrate northward along the coast, with portions of the adult population segmenting off into different large estuaries (Goodman et al. 2011). Atlantic cownose rays were observed to reach Cape Lookout, North Carolina by April and enter the Chesapeake Bay by May (Smith and Merriner 1987). A recent acoustic telemetry study has provided documentation of the first full annual migration pattern of adult Atlantic cownose rays over multiple years (Ogburn et al. 2018). Tagged adult rays from the Chesapeake Bay (Maryland and Virginia locations) and Georgia repeatedly returned to their same general tagging locations during the summer, after overwintering in a location offshore of Cape Canaveral, Florida. Tag detection ranged from Long Island, New York, to Port St. Lucie, Florida. Although these results provide evidence of philopatry (returning to the same area year after year to give birth and mate), no genetic evidence of geographic population structure has been found among cownose rays sampled from four locations within the Chesapeake Bay (Carney et al. 2017). More research would be needed to fully confirm and validate philopatry.

In addition to tagging data, the seasonal residency and distribution of Atlantic cownose rays in the Chesapeake Bay have been examined through aerial surveys. Blaylock (1993) conducted aerial surveys of the main stem of the lower Chesapeake Bay from 1986-1989. Cownose rays were found from May to October, with numbers increasing from June to September and then declining dramatically in October. They have been found in salinities as low as 8 parts per thousand and water temperatures between 15-29 degrees Celsius (59-84 degrees Fahrenheit). Blaylock (1993) did not survey river systems, thereby neglecting much of the summertime estuarine habitat used by Atlantic cownose rays. However, Smith and Merriner (1987) described rays entering river systems by June and remaining for much of the summer. Parturition occurs from mid-June to early July, closely followed by mating. Shortly thereafter, cownose rays segregate by sex with adult males emigrating from the Chesapeake Bay in late summer (July-August). Satellite tag data from three male cownose rays indicate that after emigrating from the bay, males move to foraging areas in southern New England (Omori 2015). Blaylock

(1989, 1993) observed large pre-migratory congregations numbering in the millions in the higher salinity waters of the eastern, lower bay off Cape Charles, Virginia. As water temperatures cool in September, adult female cownose rays emigrate while young-of-the-year rays remain in the bay until October.

Similar seasonal residency patterns for Atlantic cownose rays were found in aerial surveys of North Carolina's estuarine and coastal waters. Goodman et al. (2011) observed cownose rays entering the region in April, dispersing throughout the estuary from June-August, and emigrating from the region by November. Counts of rays were highest in estuarine habitats during the summer, and highest in coastal habitats during migratory periods in the spring and fall (Goodman et al. 2011).

Section 3.3 Life History Studies in the Chesapeake Bay

In the early 1970s, the apparent devastation of commercial shellfish beds by Atlantic cownose ray predation in the Rappahannock River led to calls for the development of a ray fishery. This motivated a series of studies in the lower Chesapeake Bay by the Virginia Institute of Marine Science (VIMS) researchers Joseph Smith and John Merriner. These investigations, conducted from 1976-1979, and published in the 1980s, produced much of the first detailed information on the life history, diet, foraging behavior, and distribution of the cownose ray population that occurs seasonally in the Chesapeake Bay.

The development of a ray fishery in Virginia was pursued further throughout the 1990s and 2000s by attempting to build domestic and foreign markets for cownose ray products. During the latter part of this period (2006-2009), Robert Fisher and colleagues at VIMS conducted a new series of biological investigations, with broader spatial coverage and larger sample sizes than the original Smith and Merriner studies. Additionally, Fisher and colleagues conducted feeding trials to understand how bivalve shell size and arrangement physically constrain predation by Atlantic cownose rays. The entire findings of these investigations are found in the 2010 report by Fisher, and were later partially published as separate studies in peer-reviewed journal articles as Fisher et al. 2011 and 2013.

Section 3.4 Life Stages and Reproduction (Main references: Fisher 2010, Fisher et al. 2013)

Age-0
Free-swimming age-0 Atlantic cownose rays are first captured in the Chesapeake Bay in late July following parturition. At-term embryos and free-swimming neonates measure a mean disc width of 40-42 centimeters (15.7–16.5 inches), ranging from 30-47 centimeters disc width (11.8–18.5 inches). Age-0 rays remain in the bay until October. Fisher et al. (2013) suggests this delay provides a temporal refuge for age-0 rays from large coastal predators that remain along the coast until September. By October, when age-0 rays emigrate from the Chesapeake Bay, mean disc width has increased to a mean of 51 centimeters disc width (20.1 inches). Sex ratio of embryos and age-0 cownose rays is 1:1.

Juvenile Stages
Juvenile Atlantic cownose rays, ages 1 to 4, and approximately 55 to 75 centimeters disc width (21.7 – 29.5 inches), are rarely captured in the Chesapeake Bay, and little is known about their relative numbers in the overall population, habitat use, or migration patterns. Thirty-two young-of-year rays were tagged with acoustic transmitters in Maryland and Virginia and tracked through collaborative receiver networks that allowed observation of nearly their entire migratory range (Matthew Ogburn, personal communication). The migratory range of juvenile cownose rays was comparable to that of the adults, ranging from Port St. Lucie, Florida to Sandy Hook, New Jersey. Like adults, juvenile rays consistently migrated to the vicinity of Cape Canaveral, Florida during winter. In summer, they generally did not return to the locations in the Bay where they were tagged but ranged across a broad length of the U.S. Mid-Atlantic region during summer from the lower Bay and offshore of the Bay mouth to offshore of New Jersey and Long Island, New York.

Age at Maturity
The estimated size at 50 percent maturity for Atlantic cownose rays occurring in the Chesapeake Bay is 85 centimeters disc width (33.5 inches), which corresponds to ages 6-7 for males and ages 7-8 for females. Mature females are larger on average than mature males, with an observed maximum female size of 110 centimeters disc width (39.4 inches), and observed maximum male size of 98 centimeters disc width (38.6 inches). Maximum observed age is 21 years old in females and 16 years old in males.

Reproduction
The reproductive mode of cownose rays is lecithotrophic viviparity, wherein the embryo is first nourished by a yolk sac, and is then nourished through lipid and protein containing histotroph (uterine milk) that is secreted by specialized structures in the uterus known as trophonemata (Hamlett and Hysell 1998). Gestation is 11 to 12 months. The annual reproductive cycle of the Atlantic cownose ray corresponds to long-distance migrations between southern overwintering areas on the central coast of Florida, and mating grounds in the Chesapeake Bay and other coastal estuaries. Schools of rays, consisting of gravid females carrying three quarter term embryos, and mature males, arrive in the lower Chesapeake Bay when the spring water temperature has reached 16 degrees Celsius (60.8 degrees Fahrenheit). After reaching the Chesapeake Bay, the embryos undergo rapid growth, increasing almost fourfold in weight between May and July. Parturition occurs between mid-June and early July. Mating closely follows parturition, and females are gravid with a new yolk sac embryo by August. Female rays carrying approximately 20 centimeters disc width (7.9 inches) embryos, with yolk sacs near depletion, exit the bay by September.

Fecundity
Only the left reproductive tract in female cownose rays is functional, and the annual fecundity per female is typically one pup, though minor variations in the number have been reported. Reported maximum fecundity of six offspring per year is found in some authoritative sources, but this has been confirmed to be an error, and based upon one incident of species

misidentification in the field (Jones and Driggers 2015). Smith and Merriner (1986) found only one embryo per gravid female in all 67 specimens examined from the lower Chesapeake Bay. In performing hundreds of necropsies on gravid females from the lower Chesapeake Bay, McDowell and Fisher (2013) discovered six incidents of two embryos.

Due to a combination of late age at maturity (7-8 years) and low annual fecundity, Atlantic cownose rays have one of the lowest lifetime fecundities of any marine vertebrate (Grubbs et al. 2016). Given a reproductive life span of 14 years, based upon first parturition at age-8, and a maximum life span of 21 years, a female Atlantic cownose ray will produce 14 offspring in her lifetime. Because the sex ratio of embryos is 1:1, the estimated lifetime production of female offspring is seven. A low fecundity value indicates that the cownose ray population is not capable of rapid population increases (Grubbs et al. 2016).

Section 3.5 Trophic Dynamics

Feeding Morphology and Foraging Behavior
Cownose rays are benthic feeders and belong to a phylogenetic clade (a grouping that includes a common ancestor and all its descendants) within the Myliobatiformes that have evolved highly engineered jaws with supporting cartilaginous struts, and heavily mineralized tooth plates for crushing prey with hard shells (Summers 2000). Additionally, cownose rays possess depressible sub-rostral fins that are used for prey detection, handling and manipulation (Sasko et al. 2006). The fins and mouth have electrosensory pores that help detect buried prey items (Bedore et al. 2014). Atlantic cownose rays hydraulically excavate deeply buried infaunal bivalves by the repeated jetting of water that is drawn in through the spiracles and out of the mouth, while displacing liquefied sediment through the flapping motion of the pectoral fins (Sasko et al. 2006). Foraging activity by groups of cownose rays over soft sediment habitat leaves behind telltale feeding pits approximately 1 meter in diameter. Within the Chesapeake Bay, Atlantic cownose rays forage in groups, entering subtidal and intertidal flats and shoals during high tide, and retreating when the tide ebbs (Smith and Merriner 1987). Behavioral trials demonstrated that cownose rays improved their prey-searching response when tested in pairs. Results suggest that rays use a cooperative feeding strategy that relies on interactions with other cownose rays (Bedore et al. 2014).

Diet Composition (Main references: Smith and Merriner 1985, Fisher 2010)
Cownose rays are opportunistic predators that consume a wide range of prey. Research findings show their diet composition includes bivalves, crustaceans, polychaete worms, and fish. Dominant prey items vary regionally, reflecting the dietary flexibility of this wide-ranging stingray. Within the Chesapeake Bay, multiple diet composition studies have found that Atlantic cownose ray diets are dominated by thin-shelled bivalves and small benthic crustaceans. A study conducted in the lower Chesapeake Bay that examined the stomach contents of a modest number of rays (n=40) indicated that thin-shelled bivalves, including soft shell clams (*Mya arenaria*), Baltic macoma clams (*Macoma balthica*), and stout razor clams (*Tagelus plebeius*) constituted the bulk of the diet, whereas hard-shelled bivalves, including hard clams (*Mercenaria*

mercenaria), ribbed mussels (*Geukensia demissa*), and oysters (*Crassostrea virginica*), occurred in three or fewer stomachs (Smith and Merriner 1985).

Fisher (2010) examined the stomachs of 781 Atlantic cownose rays captured in the lower Chesapeake Bay by multiple gear types to access stomach samples from different habitats. He found that the cownose ray diet was dominated by thin-shelled bivalves and small benthic crustaceans. The most frequently occurring prey items included clams (*Mya* and *Tagelus*), mud crabs (*Panopeus* spp.), amphipods, and benthic worms. Overall, thin-shelled clams (*Mya* and *Tagelus*) dominated the bivalve portion of the diet, ranging from 85-100 percent of the bivalve portion of the diet in fishery-independent samples. Hard clams occurred in four percent of modified Dutch seine samples and eight percent of longline samples. Eastern oysters occurred in seven percent of longline samples taken adjacent to commercial oyster beds containing spat on shell. Atlantic cownose rays that were sampled adjacent to commercial oyster grounds contained the highest occurrence of crustaceans (43 percent). These crustaceans included mud crabs, amphipods, skeleton shrimp, and barnacles, all of which are associated with oyster beds.

In many instances when conducting a diet study, stomach contents consist of unidentifiable pieces of tissue and partially digested material. This is especially true for cownose ray stomach contents because of their method of crushing prey into small, hard to identify pieces. Diet studies for cownose rays indicate that 20-80 percent of stomach contents are unidentifiable (Collins et al. 2008; Fisher 2010; Ajemian and Powers 2012). Bade et al. (2014) used genetic analysis to identify the presence or absence of seven species of potential bivalve prey items in cownose ray stomachs from the Chesapeake Bay. Samples (n=25) were positive for soft shell clams, stout razor clams, and macoma clams. Samples were not positive for oysters, bay scallops, or Venus clams. The presence or absence of Baltic macoma clams was not determined due to unclear genetic identity.

Predation on planted shellfish (Main reference: Fisher 2010, Fisher et al. 2011)
While not observed in diet composition studies, schools of Atlantic cownose rays are reported to opportunistically depredate seeded oyster and clam beds planted for restoration and for commercial grow-out sites (Smith and Merriner 1979). In a widely reported incident in 2004, cownose rays consumed three quarters of a million individual seed oysters planted in the Great Wicomico River in a restoration test seeding by the U.S. Army Corps of Engineers (USACE). Since then, cultchless oysters are not used for restoration projects or aquaculture unless the oysters are caged and protected. The USACE has developed biosecurity plans that include nets to exclude cownose rays and any other large predators from oyster planting areas.

To understand this exploitative feeding behavior, Fisher conducted a series of feeding trial experiments, and examined the force necessary to crush bivalve prey across a range of shell sizes and shapes. In preference trials, Atlantic cownose rays select softshell and hard shell clams over oysters. Predation on individual oysters was found to be gape limited by shell depth. For adult rays, the probability of predation was highest on intermediate size oysters of shell depths from 3 to 22 millimeters, with corresponding shell heights of 10 to 70 millimeters. The probability of predation fell dramatically for individual oysters greater than 22 millimeters shell depth. Predation on clusters of spat on shell were also examined to potentially constrain predation by cownose rays. They were found to be capable of manipulating clusters of spat on shell to consume oysters, but oyster clusters caused lacerations to the mouth area and loss of tooth plates, indicating a sub-optimal prey of limited energetic value.

Section 3.6 Multispecies Interactions

Predators
Large coastal sharks are natural predators of smaller sharks, skates, and rays, yet the apparent contribution of cownose rays to the diets of large coastal sharks is very modest. In a review of 39 published diet studies of large coastal shark species in the Northwest Atlantic, cownose rays have occurred in six blacktip and in two sandbar shark stomachs (Grubbs et al. 2016). While large coastal sharks are predators of Atlantic cownose rays (Hueter and Manire 1994), quantitative diet studies do not support the existence of predation pressure by large coastal sharks strong enough to control the abundance of Atlantic cownose rays. Cobia are also listed as predators of cownose rays, based on a study conducted in the lower Chesapeake Bay, where cownose ray tooth plates were recovered from eight cobia stomachs, representing nine percent of samples (Arendt et al. 2001).

Trophic Impacts
In 2007, Myers et al. hypothesized that "weakened top-down control by all elasmobranch-consuming sharks could increase abundances of their elasmobranch prey (rays, skates, and small sharks), and that the enhanced predation by these mesopredators might cascade to lower trophic levels." They analyzed and modeled population trends in the abundance of large coastal sharks (10 species), Atlantic cownose rays and other elasmobranch prey (14 species), and commercial landings of shellfish along the Atlantic coast. The data was from a select compilation of surveys and catch data between 1970 and 2005. From their analysis Myers et al. (2007) concluded that there was an 87-99 percent decline in large coastal sharks, and an estimated order-of-magnitude increase in the coastwide population of Atlantic cownose rays. "Given the life history of cownose rays, and the observed rate of increase the population must have an extraordinarily low natural mortality rate, compared to what it would experience under normal levels of predation…..the loss of naturally more intense predation by the great sharks explains why the cownose ray deviates so greatly in mortality rate from what is expected on the basis of life history relationships." (Myers et al. 2007). The increase in cownose rays was then linked to increased predation of bay scallops in North Carolina, and the collapse of commercial bivalve populations along the Atlantic coast.

The Myers study described a top-down trophic cascade: the decline or loss of an apex predator or predators result in the release of intermediate level predators which, in turn, suppresses lower trophic levels. Classic examples of top-down trophic cascades have typically involved terrestrial ecosystems with three-tiered food chain models consisting of carnivores, herbivores, and plants. Large marine ecosystems comprise a complex web of trophic interactions involving many ecologically redundant species. Studying trophic cascades in pelagic ecosystems is challenging (Steneck 2012). Anthropogenic impacts such as fishing have removed predatory fish in large numbers for decades, with uncertain effects and with questionable changes to the ecosystem. Trophic cascade studies typically rely on correlations between predator and prey species. Correlations can be influenced by environmental variation, such as ocean warming, that can change the distribution and abundance of both predator and prey species (Steneck 2012). Detection of trophic cascades is data intensive, and requires abundance or biomass data for many species at multiple trophic levels, over a long time series, and at large spatial scales. Trophic cascade studies should ideally include environmental data (Baum and Worm 2009). “Ecosystem changes cannot be absolutely proven and therefore require robust, transparent, and reproducible studies.” (Baum and Worm 2009).

The Myers et al. (2007) analysis is well known and frequently cited in scientific literature on trophic cascades. The analysis was used as the basis for developing a cownose ray fishery in the Chesapeake Bay to reduce predation on commercial bivalves (Grubbs et al. 2016). However, the effort in Virginia lacked a cost-effective means of processing the fish, and lacked a sustainable market. As a result, a directed commercial fishery did not emerge. Grubbs et al. (2016) critically reviewed the Myers study and conducted a reanalysis with expanded survey data. The review was based on five diagnostic criteria for a trophic cascade (Table 1). To assess the abundance trends of large sharks Grubbs et al. included the time series from the University of North Carolina (UNC) shark monitoring long-line survey, 1972-present (used by Myers at al.) and VIMS shark monitoring long-line survey, 1974-present. Both surveys use fixed stations along the Atlantic coast, located in areas designed to sample migratory sharks: UNC has two nearshore stations and VIMS has five stations stratified by depth. If the UNC survey tracked stock-wide changes, the two surveys should produce similar abundance trends. Both surveys indicate a decline in large sharks during the 1980s, although the decline from the VIMS survey was less severe. Beginning in the 1990s, relative abundance began to increase in the VIMS survey, while the UNC survey did not show any signs of recovery. The VIMS survey trends correlate positively, rather than negatively, with abundance trends for Atlantic cownose rays from the North Carolina survey. Additionally, stock assessments for individual shark species, conducted through the National Marine Fisheries Service Southeast Data Assessment and Review process which included multiple data sources, have concluded that large coastal shark species declined in the 1970s and 1980s by 66-80 percent, less than the Myers et al. estimate, and shark stocks started to recover in the 1990s. The difference between the UNC and VIMS survey result “could be explained by a slight northern shift in the seasonal migration patterns” of sharks (Grubbs et al. 2016).

Myers et al. (2007) reported an increase in cownose rays from survey data taken mainly from the Mid-Atlantic Bight region. Using data from the two surveys with the highest increases in cownose rays, the Delaware Department of Natural Resources and Environmental Control (DNREC) trawl survey and the North Carolina Division of Marine Fisheries (NC DMF) trawl survey, and the VIMS long-line survey of coastal sharks, Grubbs et al. examined the spatiotemporal relationship between rays and sharks. The increasing trend in estimated abundance of cownose rays correlated with an increasing trend in estimated abundance of sharks, not a decreasing trend in sharks as studied by Myers et al. The number of cownose rays was negatively related to shark abundance in the UNC long-line survey, meaning as one went up, the other tended to go down. However, upon examining shark abundance in the VIMS long-line survey related to cownose ray abundance, the relationship was positive, meaning both tended to increase together.

Myers et al. (2007) estimated Atlantic cownose ray abundance trends within the Chesapeake Bay region, using data from the striped bass juvenile seine survey conducted annually by the MD DNR and VIMS. It should be noted that these local trends relied upon a total of 26 Atlantic cownose rays captured between 1976-2005 in the MD DNR survey, and 11 Atlantic cownose rays captured between 1992-2003 in the VIMS survey. These low counts contrast with the apparent high seasonal abundance in the Chesapeake Bay occurring while these surveys are taking place (Myers et al. 2007, Supplement Table S3-S5). Atlantic cownose rays do not appear in the MD DNR seine survey until 1976, despite the survey recording all species in the catch since 1960. From 1976 onwards, the total number of Atlantic cownose rays captured annually in the survey remains stable, between zero and four per year.

In order to fit the trophic cascade theory, the mesopredator population would need to be capable of growing rapidly once the apex predator population is reduced or removed. Atlantic cownose rays have one of the lowest rates of biological productivity among sharks, skates and rays. Grubbs et al. (2016) used a life table analysis to estimate a nearly stable population growth rate from -0.018 per year to 0.032 per year. Myers et al. (2007) reported a "mean meta-analytic population growth rate of 0.087 per year." The high rate of increase for cownose rays reported by Myers et al. can be explained by "high model uncertainty, sampling bias with surveys, or distribution shifts in population (Grubbs et al. 2016)."

Trophic linkages between large coastal sharks, mesopredators, and their prey have been documented. Grubbs et al. (2016) reviewed 39 diet studies of large coastal sharks, and found that cownose rays were found in low frequencies only in blacktip and sandbar sharks along the Atlantic coast. Large coastal sharks in the mid-Atlantic region primarily consume skates. Cownose rays eat a variety of prey items including bivalves, crustaceans, polychaete worms, and fish. Myers et al. (2007) linked the decline of large coastal sharks to an order-of-magnitude increase in cownose rays to the decline/collapse of the commercial bivalve fishery. In North Carolina, experiments on Oscar Shoal showed that predator exclusion devices reduced predation on scallops by cownose rays. In areas without an exclusion device, cownose rays caused "almost complete scallop mortality by early fall." Myers et al. concluded that cownose ray predation had the capacity to decrease and collapse other bivalve fisheries as well. Grubbs et al. (2016) agreed that cownose ray predation could locally deplete areas of high prey densities. However, extrapolating results to coastwide depletions of bivalve populations did not account for other stressors and limitations.

Grubbs et al. examined historic declines in bivalve populations, and did not find a positive correlation between the temporal decrease in bivalves and an increase in cownose rays. Softshell clams are the dominant prey item of Atlantic cownose ray in the Chesapeake Bay (Fisher 2010). Clam populations were substantial and widespread in the 1950s and 1960s, but began experiencing disease impacts resulting in widespread mortality by the early 1970s (Homer et al. 2011). Tropical storm Agnes (1972) caused additional mortality, with a concurrent decrease in soft shell clam habitat. Disease prevalence in both soft shell clams and razor clams ranged at 26-83 percent and 13-100 percent, respectively, during 2000-2009 (Homer et al. 2011). With only remnant populations of softshell clams remaining, Atlantic cownose rays may have modified their foraging behavior by utilizing a wider variety of habitats, and could explain their capture in the MD DNR seine survey from 1976 onward. Estimates of oysters in the Chesapeake Bay are not temporally related to increases in cownose rays. Beginning in the mid-1980s, oysters were already characterized as “severely depleted” (CBP Oyster FMP 1989) before the reported increase in cownose rays. Bivalve stocks along the coast have been impacted not only by predation and disease, but also historic overfishing, loss of habitat, sediment and nutrient pollution, and harmful algal blooms (Grubbs et al. 2016).

Atlantic cownose rays can impact invertebrate populations, and may play a significant role in benthic communities. Intense, localized predation by rays temporarily removes dominant bivalve species, and restructures benthic landscapes through bioturbation. The density of cownose ray feeding pits was found to be positively correlated with bivalve functional diversity (Glaspie and Seitz 2017). Successional recolonization of depleted feeding pits begins almost immediately after foraging has commenced. Meiofauna have been found to recolonize cownose ray feeding pits within 48 hours (Curran and Cross 2008).

Atlantic cownose rays may uproot submerged aquatic vegetation (SAV) while foraging for buried clams, which has been observed in isolated incidents to result in fragmentation and losses to existing seagrass beds (Orth 1975, Townsend and Fonseca 1998). Beds of SAV, in a variety of sizes and shoot densities, however, act as important habitats for blue crabs. Hovell and Lipcius (2001) discovered that after Atlantic cownose rays had foraged within and fragmented seagrass beds in midsummer, juvenile crab survival increased in smaller beds, perhaps as a result of reducing the value of the habitat for adult blue crabs, which are a major predator of juvenile blue crabs. Adult blue crabs, meanwhile, preferred larger, continuous beds of SAV.

Section 3.7 Habitat (Main reference: Smith and Merriner 1987)

Similar to many elasmobranch species, Atlantic cownose rays segregate by sex and size, utilizing different habitats at different stages of life. In the spring, schools of Atlantic cownose rays migrate up the coast with segments of the population entering estuaries for reproduction and/or foraging (Goodman et al. 2011). The Chesapeake Bay serves as an important nursery and mating ground for the U.S. East Coast population of Atlantic cownose rays. Upon reaching the Chesapeake Bay in May, a segment of the adult population, representing an unknown proportion of the total adult population, enters the bay. Male and female adult cownose rays then migrate up the bay, entering river systems in June. Parturition occurs from mid-June to early July followed closely by mating. Mating occurs in shallow river areas, with the pectoral wings of female cownose rays frequently observed breaking the surface of the water. Male cownose rays emigrate shortly after mating to southern New England waters (Grusha 2005, Omori 2015). As water temperatures cool in the fall, female adult cownose rays emigrate in September, followed by Age-0 rays in October.

Section 3.8 Stock Status

The International Union for Conservation of Nature listed cownose rays on the Red List of Threatened Species in 2006. In the U.S. they were designated as Least Concern, because there is currently no directed commercial fishery in the Northwestern Atlantic. The Atlantic cownose ray was assessed as "near threatened" globally because of their life history characteristics, lack of population estimates, and fishing pressure in Central and South America. Concern for cownose rays prompted the American Elasmobranch Society to issue a management resolution in 2010. The resolution called for precautionary catch limits, a population assessment, and a science-based management plan. Another resolution was issued in 2013 that encouraged Atlantic states where cownose rays are being landed, particularly Virginia and Maryland, "to immediately impose precautionary state cownose ray catch limits, convene a panel of experts to develop management recommendations through population and/or ecological risk assessments, and to initiate the development of a science-based interstate conservation plan."

The current status of the Atlantic cownose ray is unknown. Available data on the U.S. East Coast population of Atlantic cownose ray is insufficient to conduct a stock assessment. In data-deficient situations, extinction risk can be estimated from a small set of biological parameters to rapidly assess the vulnerability of a species or population (Dulvy et al. 2004). Life history information can provide some insight into how a species will respond to fishing pressure, either directed fishing or incidental bycatch fishing. Life history characteristics of elasmobranch species vary widely, but have a tendency toward slow growth, late age at maturity, and low fecundity (Cortes 2000). This combination of traits leads to low biological productivity.

The biological productivity of a population (i.e. births minus deaths) can be approximated by the intrinsic rate of increase (*r*) from the classic discrete-time Euler-Lotka equation:

$$\sum_{x=\alpha}^{w} l_{\alpha} e^{-rx} m_{x} = 1.0$$

where α is the age of females at 50 percent maturity, w is the maximum reproductive age, l_α is the survival to the age at maturity α, and m_x is the fecundity, defined as the average number of female offspring per female. Various demographic models to determine r have been proposed for elasmobranchs to assist in evaluating the levels of fishing pressure that populations can withstand (Gedamke et al. 2007). The higher the *r* value, the more rapidly a population can reach carrying capacity or recover from a low population size.

Two procedures for estimating *r* were applied to the life-history information determined by Fisher et al. (2013, Table 3). The procedures estimate *r* at different population levels, and use different assumptions and methods to estimate natural mortality. Thus, the resulting *r* estimates are not directly comparable, rather their utility is in making multiple intraspecific comparisons to evaluate the vulnerability of the Atlantic cownose ray population, compared with other elasmobranch and teleost populations.

The first procedure estimates *r* at the maximum sustainable yield (MSY) population size if fishing at MSY were to occur until the population stabilized, and then all fishing ended. This is interpreted as the intrinsic rebound potential of the population when fished down to half of the virgin population size (Au and Smith 1997). Maximum sustainable yield is assumed by Au et al. (2008) to occur for a generalized elasmobranch stock when total mortality (fishing and natural mortality) is equivalent to 1.5 times *M*. Natural mortality (*M*) for this procedure is estimated from the well-known empirical relationship developed by Hoenig (1983) based upon the maximum observed age ($\ln(M)=1.44-0.982\ln(w)$). The assumptions above are applied to cownose rays to facilitate comparisons with other species analyzed with the same set of criteria (Au et al. 2008, Smith et al. 2008). To solve for *r* at this population level ($r_{1.5M}$), the density-dependent survival to maturity under the reduced population size ($l_{\alpha,1.5M}$) is first found by setting total mortality equal to 1.5*M* and setting $r=0$, which is the case when a population reaches equilibrium (equation 4 in Au and Smith 1997). Once $l_{\alpha,1.5M}$ is obtained, $r_{1.5M}$ is determined by solving a simplified form of Lotka's equation (equation 3 in Au and Smith 1997) using the *nlminb* function in the statistical computing language R (version 3.2.3).

The intrinsic rebound potential ($r_{1.5M}$) estimated for the suite of available Atlantic cownose ray life history traits was $r_{1.5M} = 0.029$, or a rebound potential of approximately 3 percent per year. For comparison, Au et al. (2008) found a range of rebound potentials from 1-14 percent per year for sharks, and from 8 to 34 percent for some large pelagic teleosts. Rebound potential of the Atlantic cownose ray is similar to some large-bodied, late maturing, and long-lived species such as the white shark (2.3 percent per year) and mako shark (2.9 percent per year). Highlighting the potential vulnerability of a species with a rebound potential of approximately 3 percent per year, the mako shark is estimated to have declined globally up to 79 percent over the past 72-75 years, owing to its low biological productivity and catch as a target and bycatch species in coastal and pelagic fisheries, leading to a status of globally Endangered (Rigby et al. 2019).

The second procedure estimates the maximum intrinsic rate of increase (r_{max}) for evaluating the level of fishing pressure that would cause species extinction. A core assumption of r_{max} is that population growth is density-independent (i.e., free from the effects of competition and limiting resources) which is a valid assumption when population levels are low or near extinction. It is possible to estimate r_{max} as a function of other biological parameters by numerical solution of the discrete-time Euler-Lotka equation of the form (equation 4 in Pardo et al. 2016):

$$l_\alpha b = e^{r\alpha} - e^{-M}(e^{r})^{\alpha-1}$$

where l_α is the proportion of individuals surviving to maturity, b is the number of female offspring produced by an individual each year, α is the age at maturity, and M is the natural mortality.

Unlike teleost fishes, elasmobranch species typically have low fecundity but large offspring, which are more likely to survive to maturity. Pardo et al. (2016) accounted for increased survival to maturity in elasmobranchs by defining average life span as the midpoint between the age at maturity (α) and maximum age (w). Natural mortality (M) is then estimated as the inverse of average life span as follows:

$$M = \left[\frac{w+\alpha}{2}\right]^{-1}$$

Uncertainty in life history parameters can be incorporated into the estimate of r_{max} through Monte Carlo simulation (Pardo et al. 2018). In the Monte Carlo simulation, life history parameter distributions, instead of fixed parameter values, are resampled with replacement to generate a distribution of r_{max} estimates. Fisher et al. (2013) report a bootstrap-generated age at 50 percent maturity median value of 6.4 with lower and upper 95 percent confidence intervals of 5.91 to 6.90. To generate a distribution based upon this information, it was assumed that age at 50 percent maturity follows a normal distribution with a mean of 6.4 and standard deviation of 0.25 (95 percent confidence intervals: lower=5.91, upper=6.89). The estimated female maximum age used is a point estimate of 21 which was observed by Fisher et al. (2013). Earlier studies by Smith and Merriner (1987) observed a female maximum age 13, but this study had small sample sizes of larger and older individuals.

Using these life history parameter estimates (Table 2), r_{max} was estimated 20,000 times using the *nlminb* function in the statistical computing language R (version 3.2.3). Based upon the uncertainty in current life history parameter estimates for Atlantic cownose rays, r_{max} was estimated to have a median of 0.10 (2.5th percentile=0.10, 97.5th percentile=0.11). In comparison with 94 chondrichthyan species with taxonomic breadth covering 12 Orders and 25 Families, and with r_{max} ranging from 0.03 to 1.39, an r_{max} of 0.10 falls within the lower 13th percentile (Pardo et al. 2016 supplemental).

To place r_{max} within the context of sustainable outcomes in elasmobranch fisheries, Simpfendorfer and Dulvy (2017) evaluated the sustainability of 65 elasmobranch fisheries with available stock assessment and catch data. They found that with strong science-based management, some elasmobranch species can support sustainable fishing with an r_{max} as low as 0.10 to 0.20, however, no species with an r_{max} less than 0.10 was sustainable.

With strong science-based management, the Atlantic cownose ray species may be able to support sustainable fishing as the r_{max} of 0.10 and 0.11 falls in the range between 0.10 and 0.20. However, given an estimated r_{max} so close to 0.10, a fishery for Atlantic cownose ray would benefit from science-based management that includes a coast wide stock assessment conducted by a regional or national organization. This conclusion is consistent with the consensus of the scientific community, as the species is inherently vulnerable, and additional protection is advisable due to the low population growth rate (Grubbs et al. 2016, Pardo et al. 2016, Dulvy et al. 2017, Simpfendorfer and Dulvy 2017).

Section 3.9 Description of Fishing

Recreational

Atlantic cownose rays are targeted in the Chesapeake Bay and Maryland's coastal bays by sport fishermen using archery gear, resulting in mortality. They are also incidentally caught by hook-and-line anglers and while trolling. Tournaments, held from May to mid-June, before parturition occurs, were advocated by Smith and Merriner (1979) to achieve a desired reduction in the cownose ray stock. With the implementation of a moratorium on cownose ray contests in Maryland waters, there are currently no contests being held. The previous number of bowfishing tournaments held each year in Maryland and throughout the bay is unknown. Contests, which have typically occurred annually in June, often award participants for the largest rays. Although bowfishing in different locations within the Chesapeake Bay is unlikely to eliminate localized genetic variability, the removal of gravid females could decrease the population by effectively removing two generations at once, the mature female and young of the year (Carney et al. 2017). The moratorium on cownose ray fishing contests in Maryland was originally slated to end on July 1, 2019, though legislation passed during the 2019 legislative session (2019 Md. Laws, Chap. 343) extended the moratorium until a fishery management plan is in place.

In addition to tournaments, cownose ray bowfishing trips are led by charterboat guides/captains, both in the Chesapeake Bay and in Maryland's coastal bays. Operators and customers travel from all parts of Maryland, out-of-state and Canada. Individual anglers also bowfish for rays. While interest in bowfishing has grown, there is a paucity of information on the number of participants, effort and catch. The Marine Recreational Information Program (MRIP) does include cownose rays in their surveys, but the Percent Standard Error is too high to make the data useful. Tournament information from one online source indicated over 100 participants with more than 800 cownose rays killed. Although the sex ratio of the recreational catch is currently unknown, it has the potential to be strongly female-biased due to their larger size, and the emigration of adult males from the Chesapeake Bay early in the season.

Maryland currently has regulations for projectile gear (archery equipment (vertical bow or crossbow), gig, spear, and spear gun) that apply for recreational use and regulations for archery equipment that apply for commercial use. The regulations prohibit use when fishing for certain species, require a retrieval line, and have minimum distance requirements in certain situations. An examination of bowfishing regulations from other states along the Atlantic coast and Gulf of

Mexico revealed that some states have specific gear restrictions that relate to bowfishing, but no state has a minimum size, creel limit, or season for cownose rays. Only Florida has a "wanton waste" regulation for unmanaged species that applies to cownose rays.

Commercial

While there is currently no directed commercial fishery for Atlantic cownose rays in Maryland, a subsidized commercial bycatch fishery occurred in Virginia from 2007 to 2014, but ultimately ended due to the failure of campaigns to develop a viable market. Due to their large size and schooling behavior in shallow coastal waters, cownose rays are vulnerable to incidental capture in large numbers in pound nets and haul seines, where they are frequently culled with gaffs when removed from nets (Fisher 2010). Commercial netters consider cownose rays a potentially dangerous nuisance. They can be numerous in pound nets and their large, flapping wings and barbed dorsal spine make them difficult to handle and discard. Commercial harvesters are required to report their harvest on paper forms or electronically. During the period 2016-2024 commercial harvesters reported harvesting approximately 275 pounds of rays. Of that total, approximately 70 pounds were reported as cownose rays, but it is possible that some of the unclassified rays were cownose rays. No estimate of discard mortality from commercial fisheries currently exists.

The Brazilian cownose ray has been extirpated from its southern range in Brazil due to discard mortality from an intensive summer beach seine fishery that occurred there in the 1980s, and has been assessed by experts as endangered (Vooren and Lamonaca 2004). Data on discard mortality from commercial fisheries and the rapid population decline of this sister species can inform sustainable management practices for the Atlantic cownose rays.

Setting Limits

The life history and population dynamics of rays are different from other commercial species that are typically fished in Maryland. Teleosts or bony fish (such as striped bass) generally exhibit wide fluctuations in recruitment (the number of fish surviving to enter the fishery). These fluctuations are often the result of environmental conditions that affect the survival and growth of early life stages, and can be independent of fishing mortality. Many bony fishes produce millions of eggs, and under optimum environmental conditions produce a dominant year-class that can increase the population and sustain exploitation through years when recruitment is low. Fecundity is one of the most important life history characteristics of reproductive potential, and the ability to rebound from fishing pressure (Frisk et al. 2002).

Cownose rays have one of the lowest intrinsic rates of population increase (Grubbs et al. 2016). Their low fecundity (one per year) and late maturity make them vulnerable to recruitment overfishing, and slow to recover if overfished. The Chesapeake Bay is considered a major area for parturition and mating for Atlantic cownose rays. They are an easy target for recreational fishermen, and are potentially caught by commercial fishing gear because of their tendency to occur in high density aggregates of mature gravid females. However, because cownose rays have not been a research or management priority, data on recreational and commercial catches as well as discard mortality are lacking, and no stock assessments have been conducted. Cownose ray catch limits could be set based on knowledge of reproductive characteristics and ecological risk, but not on traditional population assessment at this time.

Section 3.10 Monitoring

Cownose rays are captured incidentally in fishery independent surveys that primarily target finfish and shellfish species with seine, trawl, and gill nets in shallow coastal and estuarine areas. Table 4 summarizes the available cownose ray datasets from surveys conducted along the Atlantic coast and inner continental shelf.

In composite, these surveys cover the entire range of the U.S. East Coast population of cownose rays from Cape Canaveral, Florida to Cape Cod, Massachusetts. Additionally, existing surveys occur in important seasonal estuarine nursery areas such as the Chesapeake Bay and elsewhere. However, the incidence of non-zero observations per year is extremely low in almost all cases, with the exception of the Southeast Area Monitoring and Assessment Program (SEAMAP) survey, which encounters cownose rays along their seasonal migration route to and from overwintering grounds along the inner continental shelf in the spring and fall. The paucity of positive observations among these surveys highlights the limitations in monitoring a pelagic ray, with existing fisheries independent surveys designed for finfish species. Cownose rays are large-bodied, semi-pelagic and often travel in large congregations near the surface of the water, and therefore, are not vulnerable to typical fishery independent survey gear. However, due to these characteristics, cownose rays can be visually identified and counted over large areas by aerial survey methods that have been developed for monitoring cetacean (whales and dolphins) and sea turtle populations.

As proof of concept, Table 5 summarizes previous aerial surveys of cownose rays in Atlantic coastal and estuarine areas. Most recently, high resolution digital video from aerial surveys over the mid-Atlantic coast to 75 kilometers offshore has proved to be effective in identifying and counting cownose rays during mass migrations in the summer and fall months (Williams et al. 2015). Aerial surveys were conducted during the 1980s in the lower Chesapeake Bay, and found highly variable cownose ray abundance estimates between years and months (Blaylock 1989, 1993). Due to the complex social behavior and seasonal distribution patterns linked to migration and reproduction, spatial and temporal variability should be considered when designing aerial surveys to estimate trends in relative abundance. Additionally, due to the limitations of aerial survey methodology, prerequisite studies determining the detectability of cownose rays in various turbidity conditions, school sizes and swimming configurations are required to transform aerial transect counts into absolute densities (Goodman et al. 2011).

Stock assessments require both fishery independent and dependent data to simultaneously measure changes in relative abundance and sources of mortality. Estimates of annual relative abundance from standardized aerial surveys over a period of five to 10 or more years would allow for monitoring the relative abundance of the cownose rays in the Chesapeake Bay. In addition to relative abundance, monitoring of the recreational and commercial fishing sectors would be required to estimate total harvest and discard mortality. These data in isolation would be difficult to interpret as indicators of the status of the population as a whole, since it is not known what proportion of the total coastwide population utilizes the bay as a nursery area each year and whether this is stable. A stock assessment could be conducted by a regional or national organization, however, it would require substantial funding and a collaborative effort among the Atlantic states.

Section 4. Management Objectives, Strategies, and Actions

Section 4.1. Management Objectives

1. Utilize the best available data to support science-based management of the Atlantic cownose ray resource.
2. Determine the biologically appropriate levels of harvest and allocation of the resource.
3. Provide public education and raise awareness about Atlantic cownose rays.
4. Promote the effective coordination of state, federal and local agencies, organizations, and stakeholders to meet Atlantic cownose ray outcomes for the ecology, culture, and economy of Maryland.
5. Develop and incorporate an ecosystem-based framework for assessing and managing the Atlantic cownose ray resource throughout Maryland.
6. Implement adaptive management strategies that are compatible with the management objectives of this plan and are periodically reviewed to ensure their effectiveness at achieving the goal of this plan.

Section 4.2. Management Strategies and Actions

Objective 1. Utilize the best available data to support science-based management of the Atlantic cownose ray resource.

Strategy 1.1. Develop scientifically defensible data streams that can be used to assess management strategies for Atlantic cownose rays occurring in Maryland.

Action 1.1.1
Obtain biological and improved fishery related data to increase understanding of fisheries in Maryland waters.

Action 1.1.2
Monitor the status of the resource, including fishery-dependent and independent surveys.

Objective 2. Determine the biologically appropriate levels of harvest and allocation of the resource.

Given the lack of information on the population and low reproductive potential, controls on the harvest are necessary, but there are ways to consider a harvest so that overfishing is prevented and young are protected.

Strategy 2.1. Determine current recreational and commercial harvest levels and methods of catch.

Action 2.1.1
Determine the recreational and commercial harvest using commercial harvest records and the best available recreational data.

Action 2.1.2
Determine the methods used to catch and harvest Atlantic cownose rays recreationally and commercially.

Action 2.1.3
Evaluate gear to maximize survivability. Determine if there are gear adjustments that can be made to maximize survivability for the rays or modifications that would deter the rays from certain gear types.

Strategy 2.2. Include socio-economic considerations when making allocation management decisions.

Action 2.2.1
Work with an economist or partner entity to analyze socio-economic data that will allow the Department to make appropriate management decisions.

Strategy 2.3. Implement and enforce regulations to ensure survivability of the Atlantic cownose ray population while information is being gathered to determine harvest potential.

Action 2.3.1
Continue the moratorium on recreational tournaments. Recreational tournaments have been banned in Maryland since 2017. The ban will continue unless future monitoring provides enough information about the population and harvest methods to set sustainable harvest limits.

Action 2.3.2
Implement recreational and commercial regulations for quotas, catch limits, tags, size limits, and gear based on data obtained under Objectives 1 and 2. For example, there is not a commercial fishery for Atlantic cownose rays; however that could change and parameters should be in place to protect the population if one were to develop. Given low birth rates, regulations are necessary to protect reproducing females while they are on the pupping grounds.

Action 2.3.3
Consider a harvest season based on life cycle history. Data shows that by July 15 each summer, most rays that have come into the Bay to reproduce have birthed pups for the year. One method of controlling harvest for a longer life cycle would be to institute a season.

Action 2.3.4
Implement regulations based on Action 2.1.3.

Action 2.3.5
Consider protections to essential habitat areas such as nurseries and pupping grounds to protect cownose rays during particularly vulnerable stages in their life cycle. The Atlantic cownose ray is a vulnerable species with a strong philopatry to their pupping grounds; therefore, it is necessary to protect reproducing females while they are on the pupping grounds.

Objective 3. Provide public education and raise awareness about Atlantic cownose rays.

Strategy 3.1. Develop educational materials.

Action 3.1.1
Create educational materials to raise awareness about Atlantic cownose rays that include, but are not limited to, the following topics: approved and banned projectile gear; how to remove cownose rays from nets and other gear; non-invasive status; and protection of pupping grounds.

Action 3.1.2
Use educational materials on websites and in printed form to maximize cownose ray survivability.

Objective 4. Promote the effective coordination of state, federal and local agencies, organizations, and stakeholders to meet Atlantic cownose ray outcomes for the ecology, culture, and economy of Maryland.

There are many state, federal and local agencies, organizations, and stakeholders involved with the cownose ray resource. There are an array of objectives, directives, and interests among the groups. The multi-faceted challenge of managing Atlantic cownose rays is bigger than one group can solve alone. It is in the best interest of all partners to utilize a strategic framework that will focus goals and objectives, minimize redundancy, and optimize the use of limited resources.

A coordination process will integrate group effort and ultimately improve outcomes. It is a continuous process that requires effective leadership and communication to facilitate information and exchange ideas. Effective coordination involves an accepted organizational structure and direct interactions through workgroups and meetings.

Strategy 4.1. Engage state, federal and local agencies, academia, non-governmental organizations, industry representatives, and stakeholders in the development and implementation of effective coordination strategies that maximize cooperation to meet cownose ray resource planning objectives and policies.

Action 4.1.1
Coordinate management activities between state and federal waters to promote complementary regulations throughout the species' range.

Objective 5. Develop and incorporate an ecosystem-based framework for assessing and managing the Atlantic cownose ray resource throughout Maryland.

Important ecosystem considerations for cownose rays are land and habitat conservation, multi-species interactions and relationships, and climate change. To safeguard pupping areas and juvenile nursery areas, emphasis should be placed on the conservation and protection of existing high-quality habitat. Conserving agricultural land and natural areas such as forests, wetlands, and stream corridor buffers is a proactive approach and recommended for protecting fish aquatic habitats. These land features have a natural capacity to provide ecological services such as protecting water quality, providing habitat, mitigating stormwater run-off and floodwaters, and filtering pollutants.

Strategy 5.1. Identify habitat requirements and recommend protection and restoration measures.

Strategy 5.2. Ecosystem guidelines will continue to be refined for all phases of Atlantic cownose ray management with habitat and invasive species interactions as the primary ecosystem management focus.

Action 5.2.1
Participate in relevant forums at the state, federal, and regional levels, especially through the Chesapeake Bay Program, ASMFC, and the Mid-Atlantic Fisheries Management Council, to improve the effectiveness of fish habitat conservation and restoration efforts, discuss food web interactions, and implement climate change strategies.

Action 5.2.2
Utilize the environmental review process to prevent the destruction of designated high-quality habitat both in the short-term and the long-term. Emphasis should be placed on preserving habitat in pupping grounds.

Action 5.2.3
Consider climate change in cownose ray management planning to the extent that information is available. Base management decisions on changes in climate driven parameters such as migration, reproduction, and nursery areas.

Objective 6. Implement adaptive management strategies that are compatible with the management objectives of this plan and are periodically reviewed to ensure their effectiveness at achieving the goal of this plan.

Adaptive management is a structured, iterative process of decision-making. It generally involves a variety of strategies and techniques that can be refined or modified based on input from monitoring results, new scientific research data, and/or improved understanding from empirical observations. Since adaptive management is based on a learning process, initial objectives and actions will most likely need to change over time and will ultimately improve long-term management outcomes. Adaptive management requires feedback, flexibility, and the ability to adapt and make necessary changes.

Strategy 6.1. Apply an adaptive management approach to modify or adjust objectives, strategies, and/or actions as monitoring results, scientific data, and other relevant information become available to improve outcomes.

Section 5. Research Needs

In 2015, the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team hosted a Cownose Ray Workshop at the National Aquarium in Baltimore, MD. The purpose of the workshop was to bring together managers and scientists to discuss the state of knowledge on cownose rays in the Chesapeake Bay. The following research needs were drawn from the workshop report (2015). The list has not been prioritized.

1. Conduct population surveys in the Chesapeake Bay, other estuaries, and along the Atlantic coast to estimate abundance and to assess stock status and population trends.
2. Determine geographic connectivity between the Western Atlantic cownose ray population, and the size of the (sub) population that annually visits the Chesapeake Bay.
3. Determine if individual cownose rays return to the same tributaries in the Chesapeake Bay to give birth and mate each year.
4. Determine juvenile habitat use and migration patterns.
5. Expand diet studies in the Chesapeake Bay and continue research on the use of genetic techniques to identify stomach contents.
6. Continue to research methods of deterring cownose ray predation on oyster restoration projects and the oyster fishery.
7. Collect cownose ray bycatch and discard data from other directed commercial fisheries by gear type.
8. Collect cownose ray recreational harvest data.
9. Quantify all sources of fishing mortality and determine whether current levels are sustainable.

During discussions with stakeholders, additional research needs were discovered. The list has not been prioritized.

1. What is the ecological role of Atlantic cownose rays?
    a. How does their behavior of actively working the sediment affect the nutrient cycle?
    b. Does their behavior of actively working the sediment contribute to bivalve diversity?
2. Determine if there is a potential to develop a commercial fishery and/or market for cownose rays.

Section 6. Plan Revision

The FMP will be reviewed annually to ensure actions are being taken to implement the plan. Progress toward taking these actions will be reported in annual updates. As information becomes available to sufficiently alter the content of this plan, it will be updated following a similar process as described in the section titled "Fishery Management Plan Background."

Section 7. Tables

Table 1. Critical Examination of the Myers et al. Study Based on Diagnostic Criteria for a Trophic Cascade (Grubbs et al. 2016)

Diagnostic	**Question**
Temporal correlation of abundance trends	How reliable are the relative abundance trends for predators?
Spatiotemporal overlap	Is there spatiotemporal overlap between predators and mesopredators?
Prey growth rapid compared to predator	Are mesopredator population growth rates realistic?
Prey significant part of predator diet	How strong are predator-mesopredator trophic linkages?
Predator primary source of predation mortality	Does the mesopredator negatively affect consumer/resource population?

Table 2. Atlantic Cownose Ray Life History Parameters in the Chesapeake Bay
(Main reference: Fisher et al. 2013)

Parameter	**Sex**	**Value**
Gestation Time		11-12 months
Sex Ratio at Birth		1:1
Size at Birth	Male	40-42 centimeters disc width
	Female	40-42 centimeters disc width
Size at 50 Percent Maturity	Male	85 centimeters disc width
	Female	85 centimeters disc width
Age at 50 Percent Maturity	Male	6-7 years
	Female	7-8 years
Age at First Reproduction	Female	8 years
Maximum Age	Male	16 years
	Female	21 years
Annual Fecundity	Female	0.5 female offspring
Lifetime Fecundity	Female	7 female offspring

Table 3. Atlantic Cownose Ray Life History Values Used to Estimate r_{MSY} and r_{max}

Parameter	**Value**
Age at Maturity (years)	normal distribution (mean=6.4, standard deviation=0.25)
Maximum Age (years)	21
Average Life Span (years)	mean=13.7, 2.5th percentile=13.4, 97.5th percentile=13.9
Litter Size (# of female offspring)	0.51*
Estimated Natural Mortality	Pardo et al. (2016) method: mean=0.073, 2.5th percentile=0.072, 97.5th percentile=0.074 Hoenig (1983) method: 0.21
Estimated Survival to Maturity	Pardo et al. (2016) method: mean=0.63, 2.5th percentile=0.61, 97.5th percentile=0.64 Au and Smith (1997) method: 0.04

*if we assume a litter size of two offspring occurs at a rate of 1.3 percent.

Table 4. Atlantic Cownose Ray Data from Fishery Independent Surveys

Survey	Date Range	Season	Region	Positive Hauls (Total Hauls)
ChesMMAP Bottom Trawl Survey	2002-2015	March-November	Chesapeake Bay	205 (4,733)
NEAMAP Bottom Trawl Survey	2007-2015	Fall	Cape Cod, MA to Cape Hatteras, NC	178 (2,242)
SEAMAP (SC DNR) Paired Trawl Survey	1989-2014	Spring and Fall	Cape Hatteras, NC to Cape Canaveral, FL	1133 (15,391)
NEFSC Bottom Trawl Survey	1969-2008	Spring and Fall	Scotian Shelf to Cape Hatteras, NC	190 (data not acquired)
DNREC Coastal Trawl Survey	1966-2016	March-December	Coastal Delaware	202 (data not acquired)
MD DNR Seine Survey	1976-2016	July-September	Maryland Portion of the Chesapeake Bay	24 (4,880)
VIMS Seine Survey	1992-2016	July-September	Virginia Portion of the Chesapeake Bay	9 (data not acquired)
NC DMF Gillnet Survey	1987-Present	February-December	Pamlico Sound	Data not acquired
SC DNR Trammel Net Survey	1990-2013	April-September	Coastline in estuarine areas	Data not acquired

Table 5. Estimates of Atlantic Cownose Rays from Aerial Surveys

Survey	Date	Season	Region	Abundance Estimates
Mid-Atlantic Baseline Studies (MABS) Aerial Survey	2012-2015	All seasons	Mid-Atlantic coast up to 75 kilometers offshore	Approximately 4.5 per square kilometer
NC Aerial Survey (Goodman 2011)	2004-2006	April-November	North Carolina coastal and estuarine areas	Highly variable; 0-3.47 per square kilometer in estuarine areas and 0-421 per square kilometer on the coast
Blaylock (1993)	1986-1989	May-November	Lower mainstem of the Chesapeake Bay	Extremely high variation between years and months (from 0-37 million in September)
Blaylock (1989)	1988	Two days (July 25 and August 2)	Lower mainstem of the Chesapeake Bay	Single large school (est. 5 million)

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Appendix A. List of Acronyms and Abbreviations

ASMFC - Atlantic States Marine Fisheries Commission
FMP - Fishery Management Plan
Chap. - Chapter
ChesMMAP - Chesapeake Bay Multispecies Monitoring and Assessment Program
Department - Maryland Department of Natural Resources
DNA - Deoxyribonucleic acid
DNREC - Delaware Department of Natural Resources and Environmental Control
MABS - Mid-Atlantic Baseline Studies
MAFMC - Mid-Atlantic Fisheries Management Council
MD and Md. - Maryland
MD DNR - Maryland Department of Natural Resources
NEAMAP - NorthEast Area Monitoring and Assessment Program
NEFSC - Northeast Fisheries Science Center
NC DMF - North Carolina Division of Marine Fisheries
SAV - submerged aquatic vegetation
SC DNR - South Carolina Department of Natural Resources
SEAMAP - Southeast Area Monitoring and Assessment Program
SFAC - Sport Fisheries Advisory Commission
TFAC - Tidal Fisheries Advisory Commission
UNC - University of North Carolina
USACE - U.S. Army Corps of Engineers
VIMS - Virginia Institute of Marine Science