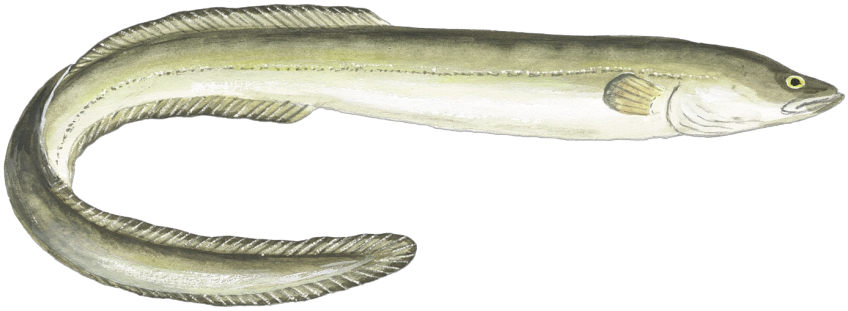
Monterey Bay Aquarium
Seafood Watch

Environmental sustainability assessment of wild-caught American eel from the United States caught using pots, barriers, fences, weirs, corrals, etc.



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Species:	American eel *(Anguilla rostrata)*
Location:	United States, North Carolina: Northwest Atlantic
Gear:	Pots, barriers, fences, weirs, corrals, etc.
Type:	Wild Caught
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Assessed using Seafood Watch Fisheries Standard v4

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About Seafood Watch

Monterey Bay Aquarium's Seafood Watch program evaluates the environmental sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Seafood Watch's science-based ratings are available at www.SeafoodWatch.org. Each rating is supported by a Seafood Watch assessment, in which the fishery or aquaculture operation is evaluated using the Seafood Watch standard.

Seafood Watch standards are built on our guiding principles, which outline the necessary environmental sustainability elements for fisheries and aquaculture operations. The guiding principles differ across standards, reflecting the different impacts of fisheries and aquaculture.

- Seafood rated Best Choice comes from sources that operate in a manner that's consistent with our guiding principles. The seafood is caught or farmed in ways that cause little or no harm to other wildlife or the environment.

- Seafood rated Good Alternative comes from sources that align with most of our guiding principles. However, one issue needs substantial improvement, or there's significant uncertainty about the impacts on wildlife or the environment.

- Seafood rated Avoid comes from sources that don't align with our guiding principles. The seafood is caught or farmed in ways that have a high risk of causing harm to wildlife or the environment. There's a critical conservation concern or many issues need substantial improvement.

Each assessment follows an eight-step process, which prioritizes rigor, impartiality, transparency and accessibility. They are conducted by Seafood Watch scientists, in collaboration with scientific, government, industry and conservation experts and are open for public comment prior to publication. Conditions in wild capture fisheries and aquaculture operations can change over time; as such assessments and ratings are updated regularly to reflect current practice.

More information on Seafood Watch guiding principles, standards, assessments and ratings are available at www.SeafoodWatch.org.

Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished[1] or farmed, that can maintain or increase production in the long term without jeopardizing the structure or function of affected ecosystems.

The following guiding principles illustrate the qualities that fisheries must possess to be considered sustainable by the Seafood Watch program (these are explained further in the Seafood Watch Standard for Fisheries):

- Follow the principles of ecosystem-based fisheries management.
- Ensure all affected stocks are healthy and abundant.
- Fish all affected stocks at sustainable levels.
- Minimize bycatch.
- Have no more than a negligible impact on any threatened, endangered, or protected species.
- Managed to sustain the long-term productivity of all affected species.
- Avoid negative impacts on the structure, function, or associated biota of aquatic habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.

These guiding principles are operationalized in the four criteria in this standard.Each criterion includes:

- Factors to evaluate and score
- Guidelines for integrating these factors to produce a numerical score and rating

Once a rating has been assigned to each criterion, Seafood Watch develops an overall recommendation. Criteria ratings and the overall recommendation are color coded to correspond to the categories on the Seafood Watch pocket guides and online guide:

Best Choice/Green: Buy first; they're well managed and caught or farmed responsibly.

Good Alternative/Yellow: Buy, but be aware there are concerns with how they're caught, farmed or managed.

Avoid/Red: Take a pass on these for now; they're caught or farmed in ways that harm other marine life or the environment.

[1] "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates

Summary

In the United States, the American eel population is managed from Maine to Florida by the Atlantic States Marine Fisheries Commission (ASMFC). ASMFC decides the quota while the states implement and enforce federal and state regulations. Stock assessments were completed in 2012, 2017, and 2023. Reference points for abundance and fishing mortality could not be determined because of data constraints. Even so, the abundance of the stock is "depleted." A number of factors threaten the population: dams are a particular concern as sources of mortality in turbines and barriers to migration. Contaminants and nearshore developments also threaten the population. Models indicate that the stock is likely overfished, but the overall level of fishing mortality is treated as unknown. The rating for the impact on the species under assessment (Criterion 1) is Red.

Bycatch data for the eel fishery are limited. The available catch composition data suggest that the fishery is quite clean. The bycatch mitigation regulations in place suggest that fishing mortality from weirs and fyke nets is low. There is evidence to suggest that diamondback terrapin is caught in eel pots outside of North Carolina. The rating for the impact on other species (Criterion 2) for weirs and fyke nets is Green; for pots in North Carolina, it is Yellow, whereas for pot gear in all other states, it is Red.

All gear types are rated Yellow for management effectiveness (Criterion 3). Management measures are in place to address the declining abundance of the stock, although there are many factors that limit the impact that U.S. management measures can have on the overall abundance of this wide-ranging, panmictic stock. The 2023 benchmark stock assessment suggests that more stringent measures may be necessary. Thus, the management strategy (Factor 3.1) is deemed moderately effective. The bycatch strategy (Factor 3.2) is scored moderately effective for weirs and fyke nets, because bycatch is unknown but it is assumed that the measures in place effectively limit bycatch mortality. The bycatch strategy for pots in North Carolina is scored highly effective, because there are no known main species of bycatch. Pots in all other states score moderately effective because there are some regulations in place to limit bycatch, but their effectiveness is uncertain and more can be done to address diamondback terrapin bycatch. Scientific data collection and analysis (Factor 3.3) is deemed moderately effective because there have been stock assessments, but the nature of the data and the life-history of the species mean that the stock assessments use data-limited and data-poor methods to assess stock health. Enforcement (Factor 3.4) is moderately effective for all gear types. The fyke net fishery had serious issues with poaching, but there have been no reports of systematic noncompliance since 2018. There are no reports of systematic noncompliance for other gear types, but eel species worldwide are at high risk of poaching and the effectiveness of the enforcement systems in place are uncertain. Stakeholder engagement (Factor 3.5) is highly effective, because ASMFC has public comment periods and has made an effort to engage nontraditional stakeholders.

All gear types are rated Yellow for impacts on the habitat and ecosystem (Criterion 4). These gear types come in contact with the substrate, but the impact is low. The fishery management plan (FMP) says that ecosystem considerations are an important part of management; however, there are no specific provisions in the FMP to show that an ecosystem-based fisheries management (EBFM) approach has been adopted. Detrimental food web impacts from the fishery are unlikely, so EBFM (Factor 4.3) scores a moderate concern.

Overall, U.S. fisheries for American eel are rated Yellow for weirs, fyke nets, and pots in North Carolina. Pot gear in all other states is rated Red.

Final Seafood Recommendations

SPECIES | FISHERY	C 1 TARGET SPECIES	C 2 OTHER SPECIES	C 3 MANAGEMENT	C 4 HABITAT	OVERALL	VOLUME (MT) YEAR
American eel | Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.	1.732	3.413	3.000	3.000	**Good Alternative (2.701)**	Unknown
American eel | Northwest Atlantic | United States | Maine | South Carolina | Fyke nets	1.732	3.413	3.000	3.000	**Good Alternative (2.701)**	4
American eel | Northwest Atlantic | United States | North Carolina | Pots	1.732	2.236	3.000	3.000	**Good Alternative (2.430)**	2
American eel | Northwest Atlantic | United States | Pots	1.732	1.732	3.000	3.000	**Avoid (2.279)**	191

Preliminary 2021 landings for yellow eel (pots) and glass eel (fyke nets) taken from the 2021 fishing year FMP review (ASMFC 2023a). Silver eels (weirs) are only fished in one river in New York (Thaler et al. 2016) (VanderZwaag et al. 2016) (NYDEC 2023). Landings are not reported in the annual FMP reviews and are assumed to be very small.

Summary

American eel (*Anguilla rostrata*) is a catadromous fish species that spends the majority of its time in freshwater and migrates to the ocean to spawn. This report covers American eel caught on the U.S. Atlantic Coast in pots (for immature eel or yellow eel), weirs (for sexually mature silver eel), and fyke nets (for juvenile glass eel). U.S. fisheries for American eel are rated Yellow for weirs, fyke nets, and pots in North Carolina. Pot gear in all other states is rated Red.

Scoring Guide

Scores range from zero to five where zero indicates very poor performance and five indicates the fishing operations have no significant impact.

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

Best Choice/Green = Final Score >3.2, and no Red Criteria, and no Critical scores

Good Alternative/Yellow = Final score >2.2-3.2, and neither Harvest Strategy (Factor 3.1) nor Bycatch Management Strategy (Factor 3.2) are Very High Concern2, and no more than one Red Criterion, and no Critical scores

Avoid/Red = Final Score ≤2.2, or either Harvest Strategy (Factor 3.1) or Bycatch Management Strategy (Factor 3.2) is Very High Concern or two or more Red Criteria, or one or more Critical scores.

[2] Because effective management is an essential component of sustainable fisheries, Seafood Watch issues an Avoid recommendation for any fishery scored as a Very High Concern for either factor under Management (Criterion 3).

Introduction

Scope of the analysis and ensuing recommendation

This report covers American eel (*Anguilla rostrata*) in U.S. waters (freshwater streams and rivers, as well as coastal marine areas) that are caught by baited pots (for yellow eels) and weirs (mostly for "silver" eels or those out-migrating to marine waters). North Carolina pot fisheries are assessed separately because the bycatch concerns are not as severe as those identified for the Atlantic Coast.

Species Overview

American eel is catadromous, spawning in saltwater and migrating to freshwater to grow and mature. When eel reaches maturity, it migrates from freshwater to the Sargasso Sea to spawn and die. The young-of-the-year eels spawned in the Sargasso Sea drift on ocean currents as leptocephali until they become glass eels. Glass eel is targeted as it returns to rivers from the ocean spawning areas; yellow eel (2 to 3 years old) is targeted while fish are growing (in fresh or brackish water); and silver eel is targeted in the late summer as it returns downriver to spawn (ASMFC 2012). American eel is generally assumed to be panmictic, composed of one genetic population from its northern limit in Greenland to its southern limit in French Guiana (ASMFC 2012)(McCleave et al. 2016). Because all eels return to the Sargasso Sea to spawn, they are all considered to come from a single spawning stock.

The glass eel fishery harvests eel as it returns from ocean spawning areas to freshwater, and uses fyke nets or dip nets to collect glass eel. The yellow eel fishery uses eel pots to capture sexually immature eel of ages 2 to 6 years. Finally, the silver eel fishery targets out-migrating, adult, sexually mature eel with weirs across rivers and streams. Glass eel is used for outgrowing in aquaculture operations in the United States and in Asia.

Small, local-subsistence fisheries for eel were documented as early as the 18th century, with the first commercial fishery activity documented in 1884 (for the fishing period 1877 to 1880) (Goode 1884, cited in (ASMFC 2012)). The market for exporting to Europe expanded in the 1960s and 1970s, and prices for yellow and silver eels rose. Simultaneously, demand from Asian aquaculture operations increased, raising the prices and fishing effort for glass eel. The population was fished down in the 1970s and 1980s because of this increased export demand, in addition to river damming and an increasing number of hydroelectric facilities on dams, which caused additional mortality (ASMFC 2012). American eel faces other stressors including habitat loss from dams, mortality in turbines, parasites, toxic pollutants, and climate change (ASMFC 2023d). There are different exploitation histories for each life stage of eel; for example, silver eel was historically targeted by Native Americans, whereas the earliest commercial records for yellow eel begin in the 18th century.

American eel is managed by the Atlantic States Marine Fisheries Commission (ASMFC) in U.S. territorial waters along the Atlantic Coast from Maine to Florida. The quota is set by ASMFC, and each state is responsible for implementing management rules within state waters.

Production Statistics

American eel is targeted at multiple life stages: glass eel, yellow eel, and silver eel. It is fished in Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, Maryland, the Potomac

River, Virginia, North Carolina, and Florida (ASMFC 2012)(ASMFC 2014a)(ASMFC 2017). The yellow eel fishery is focused around the Mid-Atlantic states, with lower landings in the northern and southern portions of the coast. The glass eel fishery exists only in Maine and South Carolina. The silver eel fishery is found only in New York. The total commercial harvest on the U.S. Atlantic Coast has ranged from 664,000 lb in 1962 to 3.67 million lb in 1979. After catches declined in the 1950s, landings increased in the 1980s and 1990s, continued to decline in the late 1990s, and declined again in the 2000s.

The largest harvest of eel occurs on yellow eel, of which the majority is harvested in the Chesapeake Bay region, with the remaining yellow eel fisheries scattered across other Atlantic coastal states (Figure 1). The coastwide quota for yellow eel was 907,671 lb (Shepard 2015)(ASMFC 2014a).

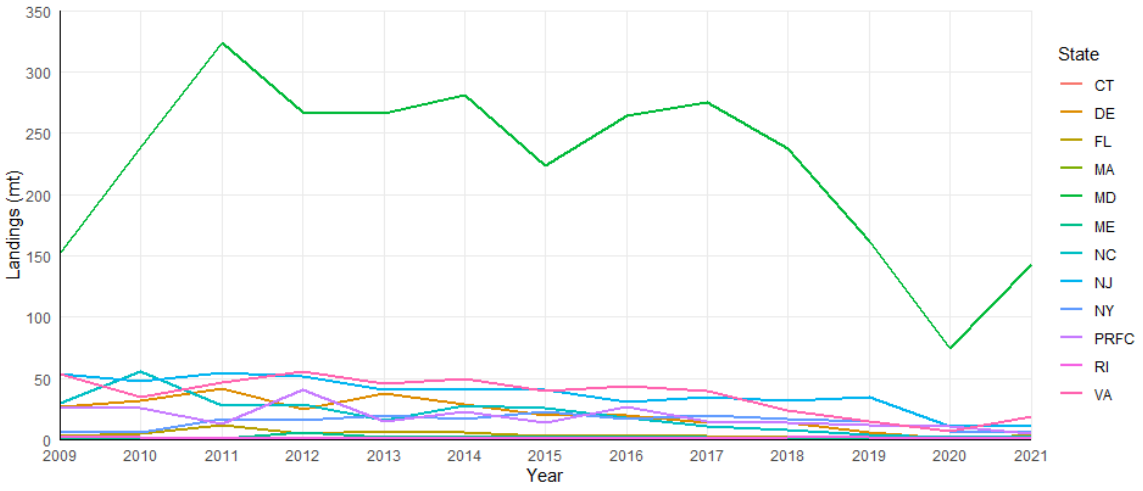

Figure 1: Total harvest of yellow eel by state. PRFC is the Potomac River Fisheries Commission. The majority of landing entries for New Hampshire, South Carolina, and Georgia were either 0 lbs or confidential, so those states were omitted. Data for 2009–16 are from the 2017 benchmark stock assessment (ASMFC 2017). Data for 2017–21 are preliminary landings data presented in the annual FMP reviews.

The recreational harvest of eel has ranged from 353 to 157,155 lb/yr between 1981 and 2009 (ASMFC 2012). Recreational data were collected by the National Marine Fisheries Service's Marine Recreational Information Program (MRIP). The MRIP stopped collecting data on American eel in 2009 because of issues with the study design (ASMFC 2023a).

The value of the fishery varies depending on the life stage: glass eel is the highest-value fishery, with prices often at least $200–300 per pound. Starting in 2010, the price for glass eel rose dramatically following a European Union ban on exporting European eels and a 2011 tsunami that destroyed much of Japan's eel aquaculture infrastructure (Flaherty 2018). Eel aquaculture is not a closed loop; it requires input of wild-caught glass eel (Flaherty 2018). Because of the significantly reduced supply of glass eel worldwide, the 2012 market price for glass eel jumped to $2,000 per lb, and it reached a high of $2,300 per lb in 2018 (Associated Press 2019). Market prices for yellow eel, on the other hand, have declined from $3–4/lb to $1.25–1.75/lb (USFWS). The total value of U.S. commercial landings of American eel ranged from a few hundred thousand dollars (pre-1980s) to a peak of $6.4 million in 1997 (Figure 2).

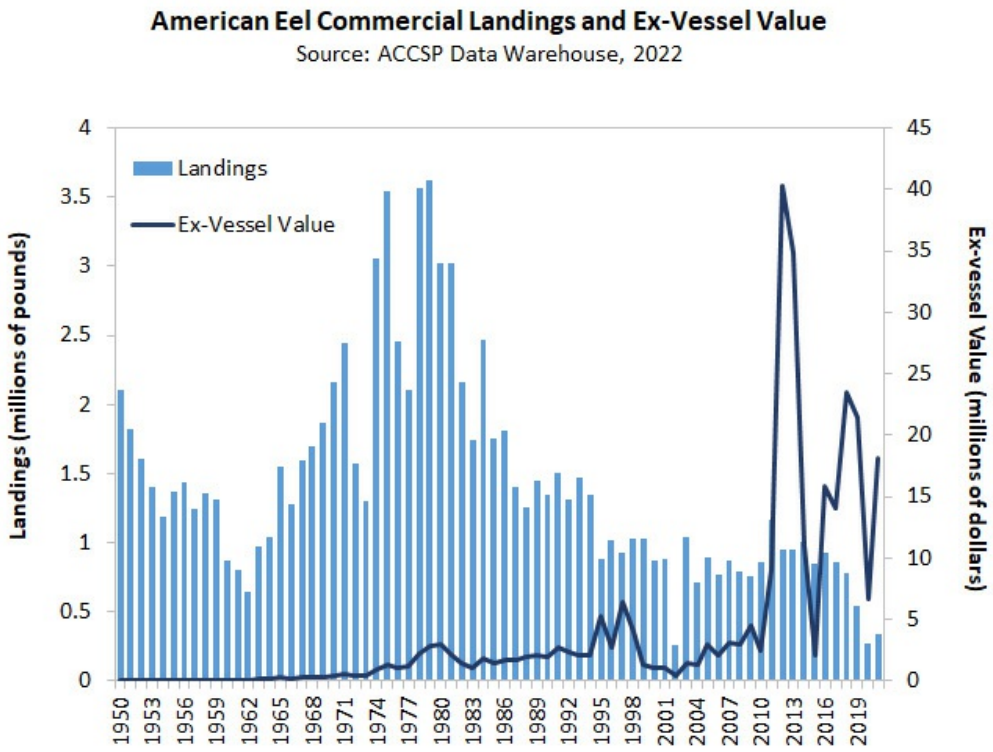

Figure 2: Total commercial landings and ex-vessel value of *A. rostrata* (ASMFC 2023b).

Importance to the US/North American market.

The majority of the capture of *A. rostrata* in North America has been exported to markets in Europe and Asia (Miller and Casselman 2014). Domestic export of *A. rostrata* from the Atlantic Coast has ranged from 229,000 lb to over 6.07 million lb per year from 1981 to 2010; however, eel (live and frozen) is still imported to the U.S. The majority of all eel imports to the United States (including *A. rostrata* as well as *A. japonica*, *A. anguilla*, and *A. australis*) come from China (4,578 mt in 2016), Taiwan (99 mt), and Vietnam (96 mt) (Figure 3). Although import information is not resolved to the species level, global landings are dominated by *A. japonica* (Figure 4).

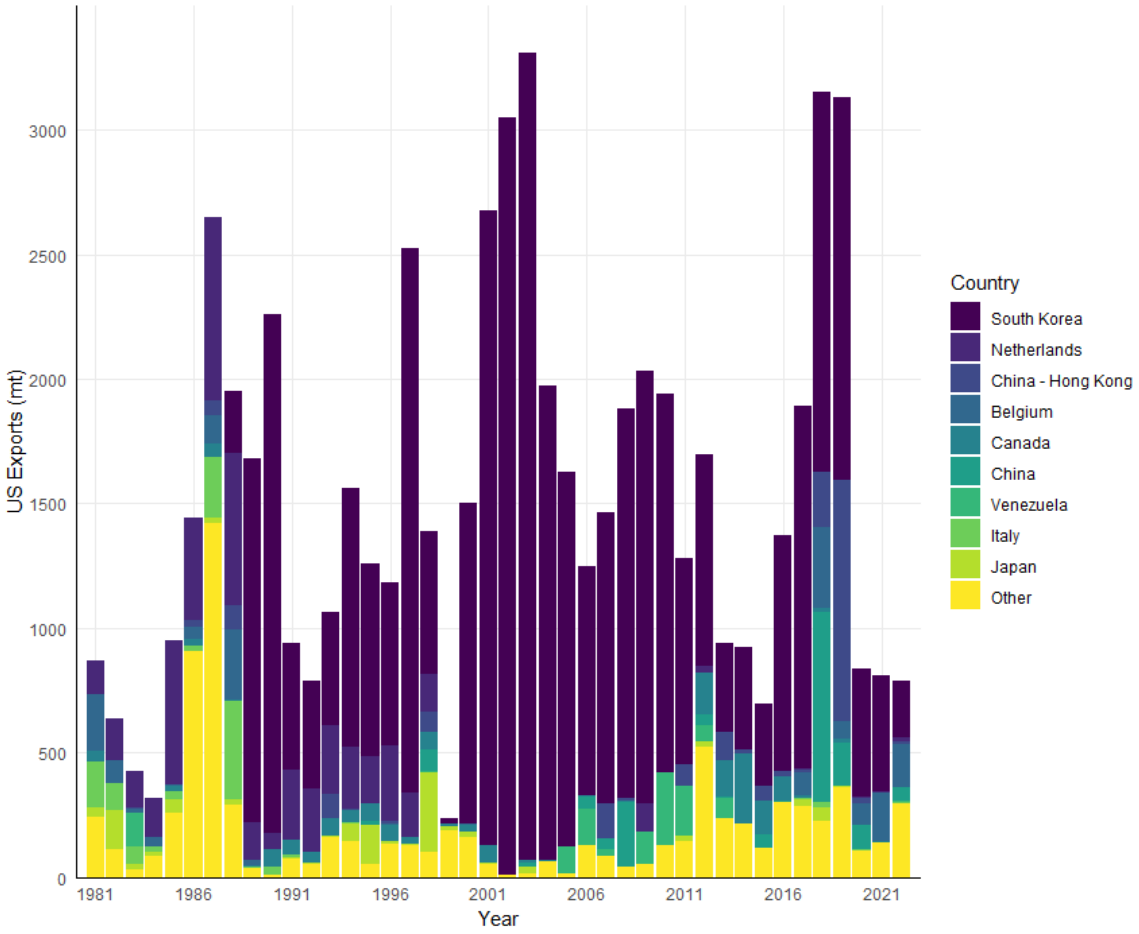

Figure 3: All species and life stages of eel that were exported from the U.S. during 1981–2022. Data from {NOAA FOSS}.

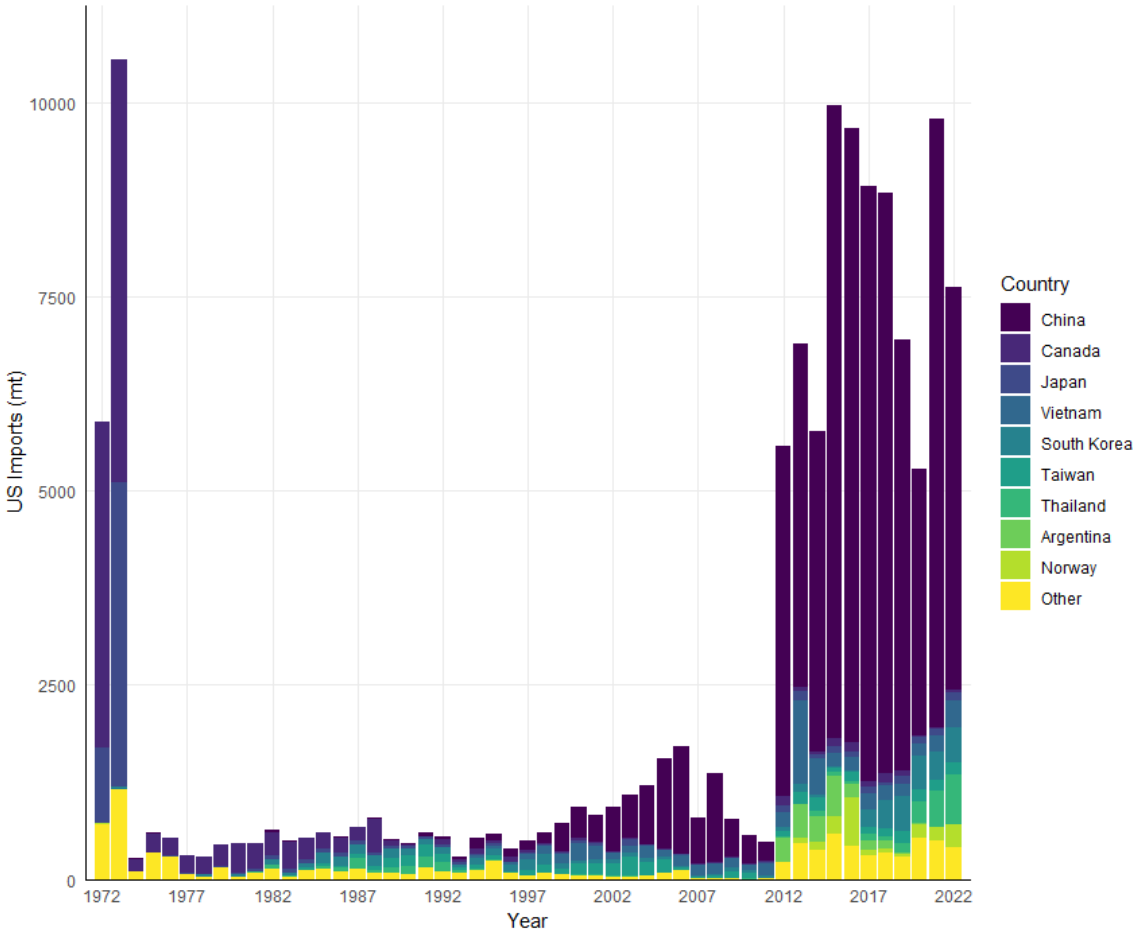

Figure 4: All species and life stages of eel that were imported to the U.S. during 1972–2022. Data from {NOAA FOSS}.

Common and market names.

American eel is sold as freshwater eel, common eel, Atlantic eel, silver eel, or *unagi*. Its acceptable market name according to the FDA is "freshwater eel." Grilled eel is also sold as "kabayaki."

Primary product forms

Eel is sold whole or skinned as steaks or fillets. Smoked, jellied, or cured eel is also available in U.S. markets.

Assessment

This section assesses the sustainability of the fishery(s) relative to the Seafood Watch Standard for Fisheries, available at www.seafoodwatch.org. The specific standard used is referenced on the title page of all Seafood Watch assessments.

Criterion 1: Impacts on the species under assessment

This criterion evaluates the impact of fishing mortality on the species, given its current abundance. When abundance is unknown, abundance is scored based on the species' inherent vulnerability, which is calculated using a Productivity-Susceptibility Analysis. The final Criterion 1 score is determined by taking the geometric mean of the abundance and fishing mortality scores. The Criterion 1 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Factor 1.3 (Fishing Mortality) is Critical.

Guiding principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level*

Criterion 1 Summary

AMERICAN EEL			
REGION / METHOD	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Northwest Atlantic | United States | North Carolina | Pots	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Northwest Atlantic | United States | Pots	1.000: High Concern	3.000: Moderate Concern	Red (1.732)

Criterion 1 Assessments

SCORING GUIDELINES

Factor 1.1 - Abundance

Goal: Stock abundance and size structure of native species is maintained at a level that does not impair recruitment or productivity.

- *5 (Very Low Concern) — Strong evidence exists that the population is above an appropriate target abundance level (given the species' ecological role), or near virgin biomass.*
- *3.67 (Low Concern) — Population may be below target abundance level, but is at least 75% of the target level, OR data-limited assessments suggest population is healthy and species is not highly vulnerable.*
- *2.33 (Moderate Concern) — Population is not overfished but may be below 75% of the target abundance level, OR abundance is unknown and the species is not highly vulnerable.*
- *1 (High Concern) — Population is considered overfished/depleted, a species of concern, threatened or endangered, OR abundance is unknown and species is highly vulnerable.*

Factor 1.2 - Fishing Mortality
Goal: Fishing mortality is appropriate for current state of the stock.

- *5 (Low Concern) — Probable (>50%) that fishing mortality from all sources is at or below a sustainable level, given the species ecological role, OR fishery does not target species and fishing mortality is low enough to not adversely affect its population.*
- *3 (Moderate Concern) — Fishing mortality is fluctuating around sustainable levels, OR fishing mortality relative to a sustainable level is uncertain.*
- *1 (High Concern) — Probable that fishing mortality from all source is above a sustainable level.*

American eel

Factor 1.1 - Abundance

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets
Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

High Concern

The stock status relative to reference points could not be determined because the stock is data-poor and reliable reference points could not be set. This means that a determination cannot be made about whether or not the stock is overfished. But because the abundance of the stock is at or near historically low levels, it was determined to be depleted (ASMFC 2023c)(ASMFC 2023d). This determination was made after exploring numerous statistical models and index-based methods for tracking abundance. Nearly all the methods used to determine stock status indicate that American eel is depleted and is at or near historically low levels (ASMFC 2023d).

Because eel is diadromous and undergoes long-distance migrations between feeding and spawning grounds, it faces different threats throughout its life cycle. Stock status is threatened by human activity on rivers: developments along streams and near estuaries have caused habitat loss, and dams impede upstream and downstream passage (Machut et al. 2007)(Shepard 2015). On continental shelves, where ocean conditions can be affected by oil spills, dredging has also negatively affected eel populations. Finally, temperature is considered one of the triggers for upstream migration and larval transport in the Gulf Stream, so eel is sensitive to temperature changes at multiple spatial scales (Greene et al. 2009). According to a 2015 Biological Report on American eel by the U.S. Fish and Wildlife Service, trends in eel abundance are stable by some metrics and declining by others (Shepard 2015). This report was produced in support of an Endangered Species Act Status Review for the species, which ultimately determined that an ESA listing for the species was not warranted (U.S. Office of the Federal Register 2015). Despite this finding, the 2023 Benchmark Stock Assessment for American eel indicates that abundance has continued to decline (ASMFC 2023c) (ASMFC 2023d).

The abundance of American eel is likely to be depleted and continues to decline. It faces threats from human impacts and changing environmental factors. Therefore, American eel scores a high concern for abundance.

Justification:

During the 2023 benchmark stock assessment, a variety of fisheries-dependent and fisheries-independent data sources were reviewed. A total of 49 surveys were deemed appropriate for use in assessing the stock (ASMFC 2023c)(ASMFC 2023d). Despite the large amount of data available, the stock assessment was still considered data-poor (ASMFC 2023c). This is because of the complex life-history characteristics of the species and the large geographic range that the single, panmictic stock inhabits (ASMFC 2023c). More data are needed to complete a traditional stock assessment.

These issues with data arose in previous stock assessments. The 2012 stock assessment attempted to estimate reference points using DB-SRA and traffic light analysis. The data limitations affected the statistical models, and ultimately, the Peer Review Panel did not approve the reference points for management use (ASMFC 2017). The 2017 stock assessment was an update of the 2012 stock assessment, which meant that the time series data were updated and analyzed using the 2012 methods. Because new analysis methods were not developed for the 2017 update, reference points were not estimated (ASMFC 2017). The latest benchmarks stock assessment explored a variety of statistical models for estimating reference points, including delay-difference models, traffic light analysis, surplus production models, and an egg-per-recruit model (ASMFC 2023c)(ASMFC 2023d). None of the models were fit for management use because of data limitations (ASMFC 2023c). Several index-based methods were explored for tracking abundance of the stock. The I_{TARGET} method was selected to track the abundance trends and inform recommended catch levels (ASMFC 2023c). The I_{TARGET} index shows that the abundance of the stock has continued to decline since the 2017 stock assessment. The abundance is at or near historical lows, which led the assessors to describe the stock as "depleted" (ASMFC 2023c)(ASMFC 2023d).

Other threats faced by American eel populations include contaminant exposure (Shepard 2015), predation by piscivorous fishes (based on studies of silver eels in the St. Lawrence River and estuary (Shepard 2015)(Beguer-Pon et al. 2012)), marine mammals (Lidgard et al. 2014)(Westerberg 2014), and predation on juvenile glass eel by striped bass (Shepard 2015).

Factor 1.2 - Fishing Mortality

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets
Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

Moderate Concern

The 2023 benchmark stock assessment did not succeed in estimating reference points for fishing mortality. As a result, the assessors could not determine whether or not the stock is experiencing overfishing (ASMFC 2023c)(ASMFC 2023d). Because F relative to reference points is unknown, fishing mortality for American eel is considered a moderate concern.

Criterion 2: Impacts on Other Species

All main retained and bycatch species in the fishery are evaluated under Criterion 2. Seafood Watch defines bycatch as all fisheries-related mortality or injury to species other than the retained catch. Examples include discards, endangered or threatened species catch, and ghost fishing. Species are evaluated using the same guidelines as in Criterion 1. When information on other species caught in the fishery is unavailable, the fishery's potential impacts on other species is scored according to the Unknown Bycatch Matrices, which are based on a synthesis of peer-reviewed literature and expert opinion on the bycatch impacts of each gear type. The fishery is also scored for the amount of non-retained catch (discards) and bait use relative to the retained catch. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard/bait score. The Criterion 2 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Factor 2.3 (Fishing Mortality) is Crtitical

Guiding principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level.*
- *Minimize bycatch.*

Criterion 2 Summary

Criterion 2 score(s) overview

This table(s) provides an overview of the Criterion 2 subscore, discards+bait modifier, and final Criterion 2 score for each fishery. A separate table is provided for each species/stock that we want an overall rating for.

AMERICAN EEL			
REGION / METHOD	**SUB SCORE**	**DISCARD RATE/LANDINGS**	**SCORE**
Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.	3.413	1.000: < 100%	Green (3.413)
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets	3.413	1.000: < 100%	Green (3.413)
Northwest Atlantic | United States | North Carolina | Pots	2.236	1.000: < 100%	Yellow (2.236)
Northwest Atlantic | United States | Pots	1.732	1.000: < 100%	Red (1.732)

Criterion 2 main assessed species/stocks table(s)

This table(s) provides a list of all species/stocks included in this assessment for each 'fishery' (as defined by a region/method combination). The text following this table(s) provides an explanation of the reasons the listed species were selected for inclusion in the assessment.

NORTHWEST ATLANTIC | UNITED STATES | BARRIERS, FENCES, WEIRS, CORRALS, ETC.			
SUB SCORE: 3.413	DISCARD RATE: 1.000	**SCORE: 3.413**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
American eel	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Finfish	2.330: Moderate Concern	5.000: Low Concern	Green (3.413)

NORTHWEST ATLANTIC | UNITED STATES | MAINE | SOUTH CAROLINA | FYKE NETS			
SUB SCORE: 3.413	DISCARD RATE: 1.000	**SCORE: 3.413**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
American eel	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Finfish	2.330: Moderate Concern	5.000: Low Concern	Green (3.413)

NORTHWEST ATLANTIC | UNITED STATES | NORTH CAROLINA | POTS			
SUB SCORE: 2.236	DISCARD RATE: 1.000	**SCORE: 2.236**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
American eel	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Diamondback terrapins (unspecified)	1.000: High Concern	5.000: Low Concern	Yellow (2.236)

NORTHWEST ATLANTIC | UNITED STATES | POTS			
SUB SCORE: 1.732	DISCARD RATE: 1.000	**SCORE: 1.732**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
American eel	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Diamondback terrapins (unspecified)	1.000: High Concern	3.000: Moderate Concern	Red (1.732)

Landing composition data from eel pots indicate that the fishery does not have major issues with bycatch (I. Braun, Potomac River Fisheries Commission, unpublished data)(A. Bianchi, North Carolina Department of Environmental Quality, unpublished data). American eel was >95% of the catch composition. The only other species caught in sizable numbers in this gear type is blue catfish. Because blue catfish was <5% of the catch composition, it is not included in the analysis of other species.

Capture and drowning in eel pots and traps is one suspected source of mortality for diamondback terrapins in the northwest Atlantic (Radzio and Roosenburg 2005). Diamondback terrapin is listed as "Vulnerable" and has been caught as bycatch in an experimental study on bycatch mitigation for eel pots, so it is included here as a main species (Radzio and Roosenburg 2005). As with other pot and trap fisheries, there are risks that the lines connecting the pots to marker buoys can entangle protected species, including marine mammals and sea turtles. It is unknown whether eel pot locations overlap significantly with either of these two groups.

Bycatch in the fyke net and weir fisheries is unknown. Bycatch is required to be returned to the water alive in both fisheries, but there is no requirement to report bycatch data (Eel Regulations 2023)(NYDEC 2023). For both gear types, the Unknown Bycatch Matrix (UBM) was used to identify the impact that the fishery has on the general category of finfish. In the fyke net fishery, nets must be emptied at least every 16 hours (Eel Regulations 2023). With a limited geographic scope and soak time of the nets, it is unlikely that the fishery is having a major impact on finfish species. The weir fishery occurs in only one river in New York (NYDEC 2023)(Thaler et al. 2016)(VanderZwaag et al. 2016). There is such a low fishing effort with this gear type that mortality on finfish is likely quite limited.

Criterion 2 Assessment

SCORING GUIDELINES

Factor 2.1 - Abundance
(same as Factor 1.1 above)

Factor 2.2 - Fishing Mortality
(same as Factor 1.2 above)

Factor 2.3 - Modifying Factor: Discards and Bait Use
Goal: Fishery optimizes the utilization of marine and freshwater resources by minimizing post-harvest loss. For fisheries that use bait, bait is used efficiently.

Scoring Guidelines: The discard rate is the sum of all dead discards (i.e. non-retained catch) plus bait use divided by the total retained catch.

Ratio of bait + discards/landings	Factor 2.3 score
<100%	1
>=100	0.75

Diamondback terrapins (unspecified)

Factor 2.1 - Abundance

Northwest Atlantic | United States | Pots
Northwest Atlantic | United States | North Carolina | Pots

High Concern
Diamondback terrapins live along the U.S. Atlantic Coast from Cape Cod to Galveston Bay in the Gulf of Mexico (Roosenburg 1991). The population sizes in the states are primarily unknown or declining, and few are considered stable (Roosenburg et al. 2019)(Butler et al. 2006)(Seigel and Gibbons 1995). Seven distinct subspecies are managed as different units. Diamondback terrapins are classified on the International Union for the Conservation of Nature (IUCN) Red List as "Vulnerable" (Roosenburg et al. 2019). For this reason, they are considered a high concern for abundance.

Justification:
Terrapins are long-lived and have low reproductive output. Thus, sources of mortality that affect older individuals can have a large impact on the population.

Factor 2.2 - Fishing Mortality

Northwest Atlantic | United States | North Carolina | Pots

Low Concern
Terrapins are particularly susceptible to bycatch in pot fisheries because they have a high degree of site fidelity and they are gregarious, so individuals can often follow one another into pots (Butler 2000)(Butler 2002). There is little information about bycatch of terrapins in pots targeting eels; however, there are known interactions, and research has demonstrated that interactions can be reduced through the use of excluder devices (Radzio and Roosenburg 2005).

But in North Carolina, the American eel fishery is concentrated in Albemarle Sound (as indicated by the landings data in Table 1), which has a quite low salinity in the range of 0–5 psu (Molina 2002) (Gillum 2014). Diamondback terrapin is an exclusively brackish-water species that is typically found in salinities of 11–35 psu, and it is intolerant of freshwater over an extended period {Williard et al. 2019}(NCGAP 2005). This suggests that interactions between the commercial eel fishery and diamondback terrapins in Albemarle Sound would be low. This is supported by data from fishery-dependent and -independent surveys conducted throughout North Carolina waters by the North Carolina Division of Marine Fisheries Surveys (NCDMF). From 1971 to 2020, a total of 649 diamondback terrapins were encountered across 173 unique locations; from this data, there are only 2 known interactions in Albemarle Sound (Figure 5) (NCDMF 2020)(NCDMF 2023 pers comm). The North Carolina GAP Analysis Project has reviewed the available data on known terrapin occurrence and suitable habitat, and compiled the map shown in Figure 6 (NCGAP 2005). The map shows that, although the presence of diamondback terrapin in Albemarle Sound is possible, it is not predicted—thus further supporting the low likelihood of interaction with the eel fishery.

Considering the available information, which suggests that terrapins are unlikely to be found in the

main area where eel fishing occurs in North Carolina, it is unlikely that the fishery is having a negative impact on the diamondback terrapin population. Therefore, fishing mortality is considered a low concern.

Justification:
North Carolina Division of Marine Fisheries Surveys

As noted above, NCDMF conducts annual fishery-dependent and -independent surveys and records interactions with diamondback terrapins when they occur (NCDMF 2020 pers comm). In Albemarle Sound, there are six different surveys that contributed to this data set.

- The juvenile anadromous seine survey in western Albemarle Sound (P100) takes place at 9 stations, with 54 samples taken each year from 1993 to present; there has been 1 interaction with a diamondback terrapin identified in 1993.
- The juvenile anadromous trawl survey in western Albemarle Sound (P100) takes place across 7 stations, with 56 samples per year from 1955 to present; there has been 1 interaction with a diamondback terrapin identified in 2005.
- The juvenile anadromous trawl survey in central Albemarle Sound takes place at 12 stations, with 84 samples per year from 1984 to present; there have been no interactions with diamondback terrapins in this survey.
- The striped bass independent gillnet survey (Fall/Winter) (P135) takes place in Albemarle and Croatan Sounds, with 96 fishing days per year from 1990 to present; there have been no interactions with diamondback terrapins in this survey.
- The striped bass independent gillnet survey (Spring) (P135) takes place in western Albemarle Sound, with 92 fishing days per year from 1990 to present; there have been no interactions with diamondback terrapins in this survey.
- The gillnet observer program is active year-round from 2000 to present, and there have been no recorded interactions with diamondback terrapins in this survey.

Table 1: Pounds, trips, and percent contributions for American eel commercial harvest in the Albemarle Sound area, North Carolina (2009–18). (NCDMF 2019 pers comm)

	Pounds			Trips		
Year	**Albemarle lb.**	**%**	**Total lb.**	**Albemarle Trips**	**%**	**Total Trips**
2009	59,602	91.0	65,481	107	83.6	128
2010	118,813	97.3	122,104	133	81.6	163
2011	59,155	95.5	61,960	130	94.2	138
2012	59,707	93.1	64,110	168	90.3	193
2013	33,030	97.2	33,980	76	92.7	82
2014	59,546	98.0	60,755	147	95.4	151
2015	57,766	>99.9	57,791	127	98.5	129
2016	39,447	98.8	39,911	75	84.3	89
2017	24,421	98.7	24,753	93	93.0	100
2018	18,052	99.9	18,058	67	97.1	69
2009–18	52,945	96.6	54,890	112	91.07	124

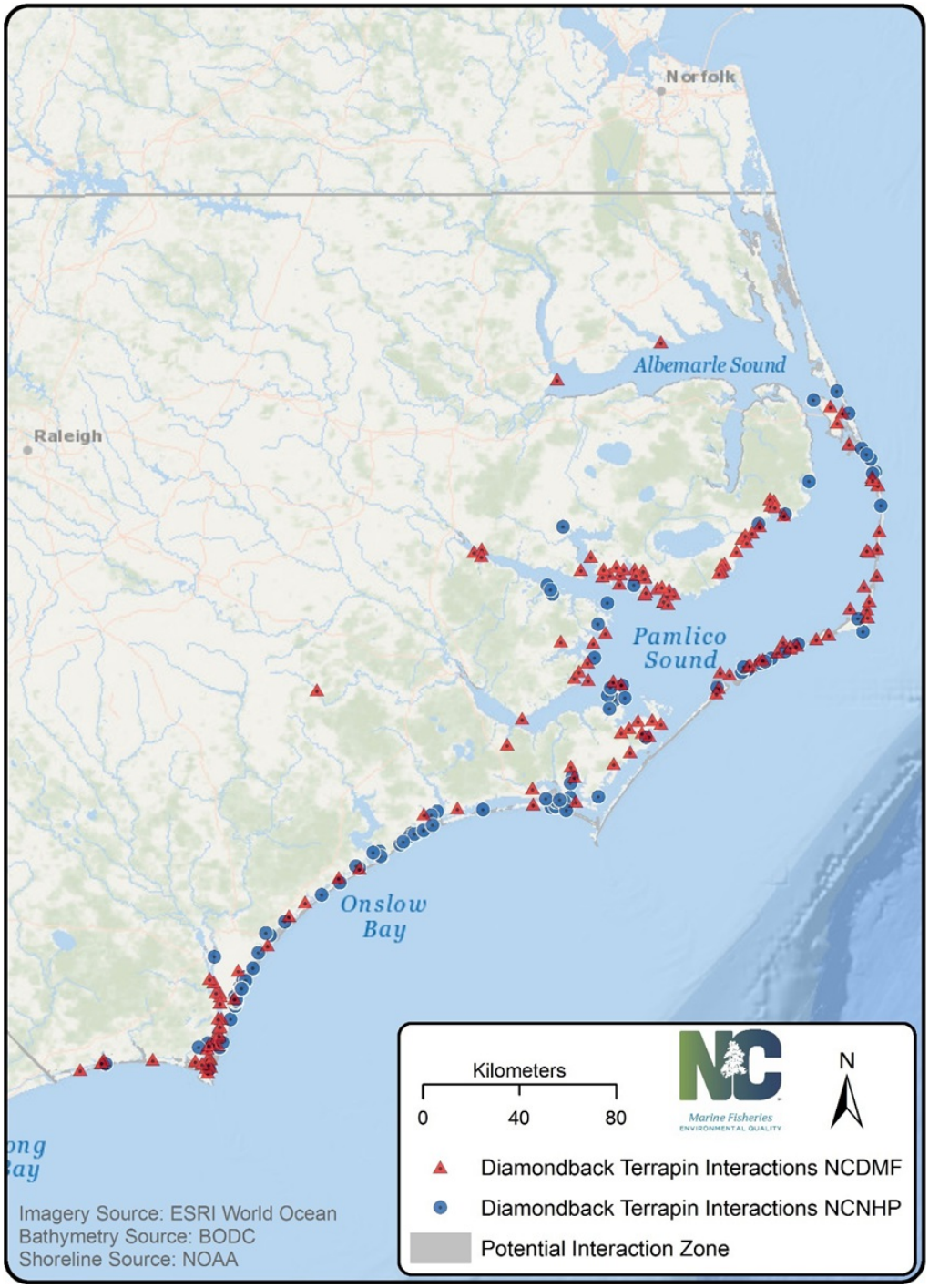

Figure 5: A map of coastal North Carolina showing known interactions with diamondback terrapins from NCDMF (1971–2015) and NCNHP data. From (NCDMF 2019).

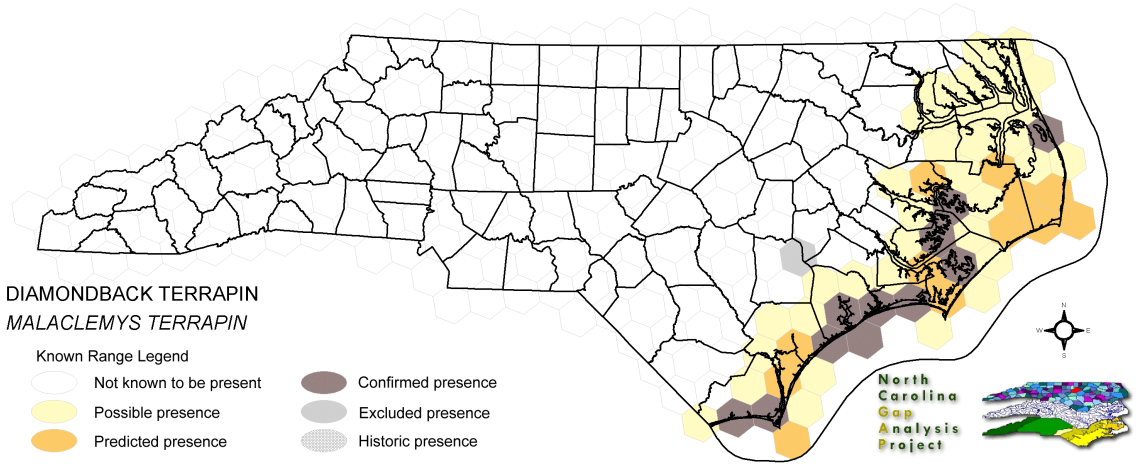

Figure 6: Known range of diamondback terrapin (*Malaclemys terrapin*) in North Carolina. From North Carolina GAP Analysis Project.

Northwest Atlantic | United States | Pots

Moderate Concern

Terrapins are particularly susceptible to bycatch in pot fisheries because these turtles have a high degree of site fidelity and are gregarious, so individuals can often follow one another into pots (Butler 2000)(Butler 2002). There is little information about bycatch of terrapins in pots targeting eels, but there is some information about bycatch in the blue crab pot fishery. This information is included with the caveat that crab and eel pot designs are different, so bycatch rates are not expected to be the same for both types of pots.

For crab fisheries that use pots and traps, diamondback terrapin is considered a "high concern" bycatch species. Estimates of terrapin mortality in crab pots range from 1,759 terrapins per year in South Carolina (Butler and Heinrich 2007) to 17,749 to 88,740 per year in New Jersey (Wood and Herlands 1997). In Chesapeake Bay, mortality rates from the crab fishery are estimated at 15–78% of the population per year (Butler and Heinrich 2007).

Eel pots do capture diamondback terrapins, especially pots with large funnel entrances (Radzio and Roosenburg 2005). A study evaluating the effectiveness of bycatch reduction devices in eel pots in Maryland estimated a bycatch rate that was about 3% of the local terrapin population when bycatch reduction devices were not used. Thus, there is some evidence that eel pots contribute to terrapin mortality, but there is also a high degree of uncertainty about the contribution of eel pots specifically, relative to other pots. Because of this uncertainty, mortality of terrapins is scored a moderate concern.

Justification:

A review of derelict gear in Chesapeake Bay found that the majority of derelict gear was crab pots (relative to eel pots; (Bilkovich et al. 2016)), suggesting that eel pots are not the primary source of bycatch mortality for terrapins in that area. Bycatch reduction devices have been found to decrease bycatch rates in blue crab pots by up to 73.2% (Butler and Heinrich 2007), but there is no information available about the use of BRDs in eel pots.

Finfish

Factor 2.1 - Abundance

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets

Moderate Concern
The Unknown Bycatch Matrix (UBM) was used to identify that bycatch of this category of species is likely. Following the scoring guidelines of the UBM, finfish score a moderate concern for abundance.

Factor 2.2 - Fishing Mortality

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.

Low Concern
The weir fishery is only conducted in the Delaware River in New York (NYDEC 2023)(Thaler et al. 2016)(VanderZwaag et al. 2016). Given the limited geographic scope and effort, fishing mortality from this gear type is unlikely to have a significant impact on any species. Therefore, fishing mortality scores a low concern.

Northwest Atlantic | United States | Maine | South Carolina | Fyke nets

Low Concern
The fyke net fishery occurs in South Carolina and Maine. South Carolina's landings and effort are extremely low (ASMFC 2023a). Any fishing mortality impacts would be driven by activity in the Maine fishery. Maine regulations require fishers to empty their nets at least every 16 hours and return all bycatch to the water alive (Eel Regulations 2023). This is a highly lucrative fishery, and it is likely that fishers are checking their nets much more frequently than at 16-hour intervals (Associated Press 2019). Thus, most bycatch is probably still alive when the fishers check their nets. Therefore, fishing mortality from this gear type is likely not a substantial contributor to mortality of any finfish species, and fishing mortality scores a low concern.

Factor 2.3 - Discard Rate/Landings

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.

< 100%
All bycatch in weirs must be released alive, so discards are assumed to be low (NYDEC 2023). In addition, bait is not used with this gear type. Therefore, weirs are scored as having bait use and discards of <100%.

Northwest Atlantic | United States | Maine | South Carolina | Fyke nets

< 100%

Bycatch and discard data are not available for this gear type. There are regulations requiring that fyke nets be emptied at least every 16 hours and that all bycatch be released alive (Eel Regulations 2023). Based on these regulations, it is probable that discards from fyke nets are quite low, so they are scored as <100%.

Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

< 100%

Based on catch composition data for eel pots, bycatch is extremely low (I. Braun, Potomac River Fisheries Commission, unpublished data)(A. Bianchi, North Carolina Department of Environmental Quality, unpublished data). Even if all bycatch were treated as discards, the overall discard rate would be well below 100%. Bait is used in pots; however, there is no evidence that bait use is substantial relative to landings. Therefore, bait use and discards are scored as <100%.

Criterion 3: Management Effectiveness

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

- *5 (Very Low Concern) — Meets the standards of 'highly effective' for all five factors considered.*
- *4 (Low Concern) — Meets the standards of 'highly effective' for 'management strategy and implementation' and at least 'moderately effective' for all other factors.*
- *3 (Moderate Concern) — Meets the standards for at least 'moderately effective' for all five factors.*
- *2 (High Concern) — At a minimum, meets standards for 'moderately effective' for Management Strategy and Implementation and Bycatch Strategy, but at least one other factor is rated 'ineffective.'*
- *1 (Very High Concern) — Management Strategy and Implementation and/or Bycatch Management are 'ineffective.'*
- *0 (Critical) — Management Strategy and Implementation is 'critical'.*

The Criterion 3 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Management Strategy and Implementation is Critical.

Guiding principle

- The fishery is managed to sustain the long-term productivity of all impacted species.

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

Criterion 3 Summary

FISHERY	MANAGEMENT STRATEGY	BYCATCH STRATEGY	DATA COLLECTION AND ANALYSIS	ENFORCEMENT	INCLUSION	SCORE
Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.	Moderately Effective	Moderately Effective	Moderately Effective	Moderately Effective	Highly effective	**Yellow (3.000)**
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets	Moderately Effective	Moderately Effective	Moderately Effective	Moderately Effective	Highly effective	**Yellow (3.000)**
Northwest Atlantic | United States | North Carolina | Pots	Moderately Effective	Highly effective	Moderately Effective	Moderately Effective	Highly effective	**Yellow (3.000)**

Northwest Atlantic | United States | Pots	Moderately Effective	Moderately Effective	Moderately Effective	Moderately Effective	Highly effective	**Yellow (3.000)**

Criterion 3 Assessment

SCORING GUIDELINES

Factor 3.1 - Management Strategy and Implementation

Considerations: What type of management measures are in place? Are there appropriate management goals, and is there evidence that management goals are being met? Do manages follow scientific advice? To achieve a highly effective rating, there must be appropriately defined management goals, precautionary policies that are based on scientific advice, and evidence that the measures in place have been successful at maintaining/rebuilding species.

Factor 3.2 - Bycatch Strategy

Considerations: What type of management strategy/measures are in place to reduce the impacts of the fishery on bycatch species and when applicable, to minimize ghost fishing? How successful are these management measures? To achieve a Highly Effective rating, the fishery must have no or low bycatch, or if there are bycatch or ghost fishing concerns, there must be effective measures in place to minimize impacts.

Factor 3.3 - Scientific Research and Monitoring

Considerations: How much and what types of data are collected to evaluate the fishery's impact on the species? Is there adequate monitoring of bycatch? To achieve a Highly Effective rating, regular, robust population assessments must be conducted for target or retained species, and an adequate bycatch data collection program must be in place to ensure bycatch management goals are met.

Factor 3.4 - Enforcement of Management Regulations

Considerations: Do fishermen comply with regulations, and how is this monitored? To achieve a Highly Effective rating, there must be regular enforcement of regulations and verification of compliance.

Factor 3.5 - Stakeholder Inclusion

Considerations: Are stakeholders involved/included in the decision-making process? Stakeholders are individuals/groups/organizations that have an interest in the fishery or that may be affected by the management of the fishery (e.g., fishermen, conservation groups, etc.). A Highly Effective rating is given if the management process is transparent, if high participation by all stakeholders is encouraged, and if there a mechanism to effectively address user conflicts.

Factor 3.1 - Management Strategy And Implementation

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.
Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

Moderately Effective

The 2017 benchmark stock assessment determined that the stock was at historically low levels (ASMFC 2017). The 2023 benchmark stock assessment indicates that the abundance of the stock has continued to decline and is at the lowest point in the time series (ASMFC 2023d). This downward trend suggests that the management strategies in place have not been successful at rebuilding the stock. An official overfishing or overfished stock status has not been determined, because the complex life-history and data deficiencies make it difficult to establish reference points for the stock. Despite these challenges, the stock assessors have described the stock as "depleted" (ASMFC 2023c) (ASMFC 2023d).

Management strategies are in place to improve the status of the stock: the fishery management plan (FMP) includes requirements for states to collect additional data on effort and catches (Addendum I), improve upstream and downstream passage for eels in streams and rivers (Addendum II), and establish minimum size limits and gear restrictions (Addendum III), and it sets harvest caps (Addendum IV & V). Although there are management measures in place to improve abundance, they are becoming less stringent. The latest addendum to the FMP (Addendum V in 2018) relaxed the harvest cap and management triggers for reducing the coastwide catch cap (ASMFC 2023a).

It would seem that the management measures are not effective because the abundance of the stock continues to decline. But, there are many external factors that drive abundance of the stock and limit the impact that the management organizations can have on it. American eel's geographic distribution extends from Greenland to French Guiana (ASMFC 2012)(McCleave et al. 2016). The stock is assumed to be panmictic because all spawning occurs in a single location: the Sargasso Sea (McCleave et al. 2016). As a result, fishing in other countries can have a pronounced impact on the abundance of American eel in U.S. waters. There is no international cooperation to manage the species across its range, and this limits the influence that U.S. fishery management strategy can have on the stock's health (McCleave et al. 2016). There are also quite a few nonfishery factors that are having a heavy impact on American eel abundance. These include stressors from habitat loss from dams, mortality in turbines, parasites, toxic pollutants, and climate change (ASMFC 2017). Considering these externalities, the management strategy being implemented in the U.S. is being careful to control the fishery-related factors that would influence the abundance of the stock.

The current TAC and FMP addendums conform to the scientific advice that was available for management when the measures were implemented. The 2023 stock assessment findings indicate that there may be a need for increased precaution and that a rebuilding plan may be warranted. Management was quick to react to the new scientific information when the stock assessment was published in August 2023. ASMFC's American Eel Management Board immediately started drafting addendums to the FMP to address the continued decline in abundance (ASMFC 2023c).

The continued decline in abundance suggests that there is a need for increased precaution in the management measures. The current management strategy is based on the best available scientific information. Management has been quick to react as new scientific information became available. Therefore, this factor scores moderately effective.

Justification:
The American eel FMP requires that all states and jurisdictions establish a minimum recreational size limit for yellow eel (<9 inches, since 2013; Addendum III) and a per-person limit of 50 eels/day (ASMFC 2017). Commercial fishery regulations vary by state, but there is also a 9-inch minimum size limit in all Atlantic states, except Maine and South Carolina, where there are glass eel fisheries. In South Carolina, the 9-inch minimum size limit applies to all commercial pot fisheries.

Currently, the FMP also requires all states to maintain regulations (including catch limits) for all life stages that are the same or more conservative than the values set in 2000, unless otherwise approved by the American Eel Management Board. The 2017 stock assessment for American eel notes that more detailed fishery-independent monitoring of eel populations and fisheries is needed to improve the stock assessment (ASMFC 2017). Addendum I to the eel FMP (February 2016) required that states establish mandatory catch and effort monitoring. South Carolina and Maine initiated daily reporting requirements for eel fisheries (ASMFC 2017). Addendum II to the FMP included more emphasis on improving upstream and downstream passage of eels. Addendum IV to the FMP (October 2014) established a coastwide harvest cap of 907,671 pounds for yellow eel and a quota of 9,688 pounds for glass eel caught in Maine. It also set management triggers for reducing the coastwide cap if it was exceeded by more than 10% in a single year or was exceeded by any amount in two consecutive years (ASMFC 2023a). Addendum V to the FMP (August 2018) increased the coastwide yellow eel harvest cap to 916,473 pounds. It relaxed the management triggers such that the coastwide cap would only be reduced when the cap was exceeded by more than 10% in two consecutive years (ASMFC 2023a).

Northwest Atlantic | United States | Maine | South Carolina | Fyke nets

Moderately Effective
The 2017 benchmark stock assessment determined that the stock was at historically low levels (ASMFC 2017). The 2023 benchmark stock assessment indicates that the abundance of the stock has continued to decline and is at the lowest point in the time series (ASMFC 2023d). This downward trend suggests that the management strategies in place have not been successful at rebuilding the stock. An official overfishing or overfished stock status has not been determined, because complex life-history and data deficiencies make it difficult to establish reference points for the stock. Despite these challenges, the stock assessors have described the stock as "depleted" (ASMFC 2023c)(ASMFC 2023d).

Management strategies are in place to improve the status of the stock, in general, with some provisions directly addressing the catch of glass eel. Fishing for glass eel is legal only in Maine and South Carolina. Maine is the only state where a significant amount of glass eel is landed. So, when Addendum IV to the FMP was introduced in 2014 to establish a quota for glass eel, it only included a quota for Maine (ASMFC 2023a). Maine's quota is 9,688 lbs, and South Carolina limits catch by restricting the number of licenses available for the fishery (ASMFC 2023a). Addendum IV adds a

supplemental quota of 200 lbs of glass eel that can be caught for grow-out in domestic aquaculture facilities. Only states with approved Aquaculture Plans (Maine and North Carolina) can make use of this supplemental quota (ASMFC 2018). Addendum V revisited these quota amounts in 2018 and did not make any changes to them (ASMFC 2018).

The findings from the 2023 benchmark stock assessment suggest that a rebuilding plan is warranted. Management was quick to react to the new scientific information when the stock assessment was published in August 2023. ASMFC's American Eel Management Board immediately started drafting addendums to the FMP to address the continued decline in abundance (ASMFC 2023c).

Although an official stock status has not been determined, the stock abundance is at historically low levels. The current management strategy is based on the best available scientific information. Management has been quick to react as new scientific information became available. But, the continued decline in abundance suggests that there is a need for increased precaution in the management measures. Therefore, this factor scores moderately effective.

Factor 3.2 - Bycatch Strategy

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets

Moderately Effective
Bycatch amounts in both the fyke net and weir fisheries are unknown. Bycatch is required to be returned to the water alive in both fisheries, but there is no requirement to report bycatch data (Eel Regulations 2023)(NYDEC 2023). The overall effectiveness of releasing bycatch alive is unknown. Regulations in the fyke net fishery limit the amount of soak time to 16 hours (Eel Regulations 2023). This increases the probability that bycatch will still be alive when fishers check their nets.

The lack of bycatch data is addressed in Factor 3.3, whereas Factor 3.2 is scored based on how well management addresses the known bycatch issues. Because there are no data pointing to significant levels of bycatch or bycatch of species of concern, bycatch strategy scores moderately effective.

Northwest Atlantic | United States | North Carolina | Pots

Highly effective
American eel catch from pots is quite clean. None of the bycatch species makes up >5% of the total catch composition (I. Braun, Potomac River Fisheries Commission, unpublished data)(A. Bianchi, North Carolina Department of Environmental Quality, unpublished data). There are no major concerns about bycatch with this gear type in North Carolina because diamondback terrapins are intolerant of the conditions where fishing occurs in Albemarle Sound. The bycatch strategy scores highly effective.

Northwest Atlantic | United States | Pots

Moderately Effective

There are pot restrictions in South Carolina for recreational and commercial fishing licenses (SCDNR 2016). Maine requires license numbers on all pots, ostensibly to aid in the recovery of lost gear and to ameliorate ghost fishing (Eel Regulations 2023). There are also crab pot cleanups in places with heavy crab fishing, including Chesapeake Bay (VIMS 2012). These cleanups likely also retrieve discarded eel pots, although they are much rarer than crab pots and likely do not compose a large proportion of the pots retrieved (VIMS 2012). Finally, bycatch reduction devices (BRD) have been recommended for reducing bycatch of terrapins, but have not yet been widely adopted (Roosenburg et al. 2019)(Radzio and Roosenburg 2005). Because there are some pot restrictions and bycatch mitigation measures but limited information is available in the eel pot fishery, the fishery is rated moderately effective for bycatch strategy.

Factor 3.3 - Scientific Data Collection and Analysis

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets
Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

Moderately Effective

There are a variety of fishery-dependent and fishery-independent surveys that are used to estimate American eel population trends and abundance (ASMFC 2023d). The peer-reviewed stock assessment lacks reference points, but that is not for want of trying (ASMFC 2023c)(ASMFC 2023d). Reference points are difficult to establish for the species because of its unique life-history characteristics, the assumed panmictic stock, its large geographic range, and the lack of data from large portions of the range (ASMFC 2023d)(ICES 2023)(McCleave et al. 2016). In the absence of reference points, the stock assessment has explored a variety of data-limited and data-poor assessment methods for tracking abundance (ASMFC 2023c)(ASMFC 2023d). These include delay-difference models, traffic light analysis, surplus production models, an egg-per-recruit model, and 14 index-based methods for tracking abundance (ASMFC 2023c)(ASMFC 2023d).

Bycatch monitoring could be improved by implementing an independent monitoring program. Landings data from the pot fishery indicate that bycatch with this gear type is minimal (I. Braun, Potomac River Fisheries Commission, unpublished data)(A. Bianchi, North Carolina Department of Environmental Quality, unpublished data). The fyke net and weirs fishers are required to release bycatch alive (Eel Regulations 2023)(NYDEC 2023). So, landings data do not capture bycatch data. An independent monitoring program, such as an observer program, would be required to adequately quantify bycatch. Even though the fishery does not have an observer program in place, both gear types have a limited impact on bycatch species. Thus, minimal monitoring is required to implement appropriate bycatch management strategies for these gear types.

Surveys are collecting data to track the abundance and health of the stock. Data-limited methods are being employed to inform management strategies. There is minimal monitoring of bycatch; however, it is likely that increased monitoring is unnecessary. Therefore, this factor scores moderately effective.

Factor 3.4 - Enforcement of and Compliance with Management Regulations

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.
Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

Moderately Effective
Eel trafficking is a major issue worldwide (DOJ 2022). Canada is currently dealing with significant poaching issues in the glass eel fishery, which led to the 2023 fishing season closing early (Fisheries Management Order FMO-2023-01R 2023)(SeafoodSource 2023)(Withers 2023). This emphasizes that there is serious pressure on ASMFC and each state to focus on enforcement. Enforcement of ASMFC management measures varies by state, and each state may have additional measures in place to address enforcement concerns (ASMFC 2023a). ASMFC has a Law Enforcement Committee to review the enforceability of measures in fishery management plans and to bring attention to significant enforcement concerns (ASMFC 2016). Major concerns were raised about the glass eel fishery in 2013 and 2014 (ASMFC 2016)(ASMFC 2014b)(ASMFC 2013)(ASMFC 2013b). Because the glass eel fishery is only prosecuted with fyke nets in Maine and South Carolina, those concerns are addressed in the fyke net section of this assessment. There have not been any reports of widespread noncompliance in the yellow eel fishery; however, there seems to be a dearth of independent scrutiny on yellow eel poaching. Given the large threat of poaching and trafficking, it cannot be assumed that a lack of noncompliance reports means that the enforcement system is effective. The effectiveness of the enforcement systems in place remains uncertain. Therefore, enforcement of and compliance with management regulations scores moderately effective.

Northwest Atlantic | United States | Maine | South Carolina | Fyke nets

Moderately Effective
Poaching and smuggling of eel species is one of the world's major wildlife trafficking issues, and there is a considerable black market for American eel elvers (DOJ 2022). The price for a pound of elvers, also known as glass eels, has steadily risen to more than $2,000 (Associated Press 2019). Poaching has been such a large issue that the United States Fish and Wildlife Service led a multi-agency program (Operation Broken Glass) that aimed to address the illegal harvest and sale of glass eel. The operation was conducted in collaboration with 19 agencies, including the Maine Marine Patrol and the South Carolina Department of Natural Resources Law Enforcement Division (DOJ 2018). Evidence of illegal activity was collected as part of Operation Broken Glass between 2014 and 2016. Convictions for these crimes were issued between 2017 and 2018 (US v. Sheldon et al. 2018)(US v. Austin 2017)(US v. Im et al. 2017)(US v. Zhou 2017).

Maine instituted a swipe-card system in 2014 to combat the sale of illegal catch (Norchi et al. 2016). Fishers are required to use the swipe cards when selling their catch, and sales can no longer be made with cash. Dealers must submit data about their sales to Maine DMR daily, even if they did not buy any glass eel that day. This serves as a near-real-time tracking system for quota and sales (Norchi et al. 2016).

Ostensibly, the swipe-card system has improved compliance. Maine reports that the number of

citations issued annually dropped after the swipe-card system was implemented. Before 2014, about 200 citations were issued annually, whereas this dropped to around 20 per year after 2014 (Norchi et al. 2016). There is some concern about whether or not the change in the number of citations indicates that the core issue of widespread poaching has been addressed. The 2018 glass eel season was cut short when Maine DMR became aware of a significant amount of catch that was sold by circumventing the swipe-card system (MDMR 2018). The season was closed at a point when 9,090.629 lb of the 9,688 lb quota had been legally harvested. The emergency season closure notice does not say how much glass eel was illegally harvested and sold, but it does say that the quota would have already been met if the sales had been recorded via swipe card (MDMR 2018). This means that at least 598 lb, or 6% of the quota, were sold illegally. Such a large-scale circumvention of the swipe-card system is cause for concern. In 2019, Maine introduced regulations for exporting glass eel that required a Marine Patrol Officer to be present when the eels were weighed and packaged for export. The officer affixes a seal to the packaging that attests to the weight of the package and serves as a tamper-evident seal (Eel Regulations 2023).

After 2018, there are no reports about poaching in this fishery. A challenging aspect of analyzing illegal, unreported, and unregulated fishing (IUU) issues is that a lack of reporting on poaching from a fishery could mean that the situation has improved or that there is not enough scholarship looking into the issue. To fill in the gaps, we turn to trends in glass eel poaching, which indicate that there is still a thriving black market. In 2023, NMFS published a proposed rule in the Federal Register that would add all *Anguilla* species to the Seafood Import Monitoring Program (SIMP) (U.S. Office of the Federal Register 2022). The SIMP adds increased reporting and record-keeping requirements for imports of seafood species groups that are at high risk of IUU practices (NOAA 2023). In the proposed rule, NMFS cites Operation Broken Glass as one of the indicators of an issue. Their reasoning is that the convictions that came out of Operation Broken Glass indicate a wider problem with enforcement and compliance. The Department of Justice says that, since the crackdown from Operation Broken Glass, some smugglers shifted their focus from American eel to European eels (DOJ 2022). But, poaching of American eel elvers in Canada has been increasing (Fisheries Management Order FMO-2023-01R 2023)(SeafoodSource 2023)(Withers 2023). This indicates that there is still high demand and illegal fishing pressure placed on American eels.

There have not been any high-profile enforcement operations or reports of systematic noncompliance since 2018. The demand for American eel elvers has increased, and the black market worldwide for eel is a growing concern. The lack of independent scrutiny on the current regulations is worrisome and it means that the effectiveness of the 2019 changes have not been evaluated. Because enforcement measures are in place and their effectiveness is uncertain, this factor is scored moderately effective.

Factor 3.5 - Stakeholder Inclusion

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets
Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

Highly effective

A request for "nontraditional stakeholders" to be included in the ASMFC American Eel Advisory panel was released in 2005, and there are public comment periods when feedback about management structure is requested from stakeholders. Whenever the Management Board meets or there are proposed changes to the Management Plan, the public is able to attend and provide public comment (pers. comm., K. Rootes-Murdy 2018). This information is then summarized by the Advisory Panel to make recommendations to the Management Board. Subsistence catches are recommended for investigation in the most recent benchmark stock assessment, which mentions that knowledge about subsistence fisheries is lacking for eel. Overall, because the management structure incorporates public comment and stakeholder groups, it is rated highly effective.

Criterion 4: Impacts on the Habitat and Ecosystem

This Criterion assesses the impact of the fishery on seafloor habitats, and increases that base score if there are measures in place to mitigate any impacts. The fishery's overall impact on the ecosystem and food web and the use of ecosystem-based fisheries management (EBFM) principles is also evaluated. Ecosystem Based Fisheries Management aims to consider the interconnections among species and all natural and human stressors on the environment. The final score is the geometric mean of the impact of fishing gear on habitat score (factor 4.1 + factor 4.2) and the Ecosystem Based Fishery Management score. The Criterion 4 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Guiding principles

- Avoid negative impacts on the structure, function or associated biota of marine habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.
- Follow the principles of ecosystem-based fisheries management.

Rating cannot be Critical for Criterion 4.

Criterion 4 Summary

FISHERY	FISHING GEAR ON THE SUBSTRATE	MITIGATION OF GEAR IMPACTS	ECOSYSTEM-BASED FISHERIES MGMT	FORAGE SPECIES?	SCORE
Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.	Score: 3	Score: 0	Moderate Concern		**Yellow (3.000)**
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets	Score: 3	Score: 0	Moderate Concern		**Yellow (3.000)**
Northwest Atlantic | United States | North Carolina | Pots	Score: 3	Score: 0	Moderate Concern		**Yellow (3.000)**
Northwest Atlantic | United States | Pots	Score: 3	Score: 0	Moderate Concern		**Yellow (3.000)**

Criterion 4 Assessment

SCORING GUIDELINES

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate
Goal: The fishery does not adversely impact the physical structure of the ocean habitat, seafloor or associated biological communities.

- *5 - Fishing gear does not contact the bottom*
- *4 - Vertical line gear*
- *3 - Gears that contacts the bottom, but is not dragged along the bottom (e.g. gillnet, bottom longline, trap) and is not fished on sensitive habitats. Or bottom seine on resilient mud/sand habitats. Or midwater trawl that is known to contact bottom occasionally. Or purse seine known to commonly contact the bottom.*
- *2 - Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Or gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Or bottom seine except on mud/sand. Or there is known trampling of coral reef habitat.*
- *1 - Hydraulic clam dredge. Or dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)*
- *0 - Dredge or trawl fished on biogenic habitat, (e.g., deep-sea corals, eelgrass and maerl)*
  Note: When multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, the score will be based on the most sensitive, plausible habitat type.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts
Goal: Damage to the seafloor is mitigated through protection of sensitive or vulnerable seafloor habitats, and limits on the spatial footprint of fishing on fishing effort.

- *+1 —>50% of the habitat is protected from fishing with the gear type. Or fishing intensity is very low/limited and for trawled fisheries, expansion of fishery's footprint is prohibited. Or gear is specifically modified to reduce damage to seafloor and modifications have been shown to be effective at reducing damage. Or there is an effective combination of 'moderate' mitigation measures.*
- *+0.5 —At least 20% of all representative habitats are protected from fishing with the gear type and for trawl fisheries, expansion of the fishery's footprint is prohibited. Or gear modification measures or other measures are in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing that are expected to be effective.*
- *0 —No effective measures are in place to limit gear impacts on habitats or not applicable because gear used is benign and received a score of 5 in factor 4.1*

Factor 4.3 - Ecosystem-Based Fisheries Management
Goal: All stocks are maintained at levels that allow them to fulfill their ecological role and to maintain a functioning ecosystem and food web. Fishing activities should not seriously reduce ecosystem services provided by any retained species or result in harmful changes such as trophic cascades, phase shifts or reduction of genetic diversity. Even non-native species should be considered with respect to ecosystem impacts. If a fishery is managed in order to eradicate a non-native, the potential impacts of that strategy on native species in the ecosystem should be considered and rated below.

- *5 — Policies that have been shown to be effective are in place to protect species' ecological roles and ecosystem functioning (e.g. catch limits that ensure species' abundance is maintained at sufficient levels to provide food to predators) and effective spatial management is used to protect spawning and foraging areas, and prevent localized depletion. Or it has been scientifically demonstrated that fishing practices do not have negative ecological effects.*
- *4 — Policies are in place to protect species' ecological roles and ecosystem functioning but have not proven to be effective and at least some spatial management is used.*

- *3 — Policies are not in place to protect species' ecological roles and ecosystem functioning but detrimental food web impacts are not likely or policies in place may not be sufficient to protect species' ecological roles and ecosystem functioning.*
- *2 — Policies are not in place to protect species' ecological roles and ecosystem functioning and the likelihood of detrimental food impacts are likely (e.g. trophic cascades, alternate stable states, etc.), but conclusive scientific evidence is not available for this fishery.*
- *1 — Scientifically demonstrated trophic cascades, alternate stable states or other detrimental food web impact are resulting from this fishery.*

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.

Score: 3
Weirs and barriers are scored similarly to bottom gillnets; therefore, they are given a score of 3.

Northwest Atlantic | United States | Maine | South Carolina | Fyke nets

Score: 3
Fyke nets are installed in rivers and streams. They are affixed to the bottom with poles and the net portion periodically contacts the substrate.

Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

Score: 3
Because they are fixed gear that comes in contact with the bottom, traps and pots receive a score of 3.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.

Score: 0
Fishing effort with weirs on eel is likely to be low relative to other gear types, but weirs potentially have habitat impacts similar to those of other barriers, which can have significant impacts on the habitat available to migrating eels. There is no evidence of measures currently in place to reduce the impact of weirs or fences on the substrate. Therefore, weirs and fences score 0 for this factor.

Northwest Atlantic | United States | Maine | South Carolina | Fyke nets

Score: 0
No significant modifications have been made to reduce substrate impacts from the fyke nets used in this fishery.

Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

Score: 0
For eel pots, as with other pot fisheries, derelict pots are a potential concern, and there is no information about the number of derelict eel pots that remain. In Maryland, compared to crab pots, eel pots are a much smaller proportion of the derelict gear collected; thus, they have less of an influence on existing populations (VIMS 2012). But, there are no modifications to eel pots that are designed specifically to protect the benthic habitat from gear, so this factor receives a score of 0.

Factor 4.3 - Ecosystem-based Fisheries Management

Northwest Atlantic | United States | Barriers, fences, weirs, corrals, etc.
Northwest Atlantic | United States | Maine | South Carolina | Fyke nets
Northwest Atlantic | United States | North Carolina | Pots
Northwest Atlantic | United States | Pots

Moderate Concern

A broad goal of the fishery management plan is to protect ecosystem health and functionality (ASMFC 2023a). Eels are thought to be important contributors to the movement of nutrients to upstream locations. In addition, nonfishery-related sources of mortality and impediments to migration are important to consider when setting the quotas (ASMFC 2012). It is unclear how these ecosystem considerations are incorporated into decision-making, because there are no provisions in the FMP that specifically address ecosystem concerns or otherwise indicate that ecosystem management is a key consideration (ASMFC 2023a). The fishery lacks spatial management or other policies to protect ecosystem functioning and account for capture species' ecological roles, but detrimental food web impacts are not likely. Therefore, ecosystem-based fishery management scores a moderate concern.

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Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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References

ASMFC (Atlantic States Marine Fisheries Commission). 2012. American Eel Benchmark Stock Assessment. ASMFC, Stock Assessment Report No. 12-01, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2013. Draft addendum III enforcement considerations. ASMFC, Law Enforcement Committee Memorandum, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2013b. Draft addendum III enforcement comments. Law Enforcement Committee Memorandum, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2014a. Addendum IV to the Interstate Fishery Management Plan for American Eel. Atlantic States Marine Fisheries Commission, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2014b. Glass eel enforcement. ASMFC, Law Enforcement Committee Memorandum, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2016. Interstate fisheries management program charter. ASMFC, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2017. 2017 American Eel Stock Assessment Update. ASMFC, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2018. Addendum V to the interstate fishery management plan for American eel. ASMFC, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2023a. Review of the interstate fishery management plan: American eel (*Anguilla rostrata*). ASMFC, 2021 Fishing Year, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2023b. American eel. ASMFC. July 25, 2023. https://asmfc.org/species/american-eel

ASMFC (Atlantic States Marine Fisheries Commission). 2023c. ASMFC stock assessment overview: American eel. ASMFC, Arlington, Virginia.

ASMFC (Atlantic States Marine Fisheries Commission). 2023d. American eel benchmark stock assessment and peer review report. ASMFC, Arlington, Virginia.

Associated Press. 2019. As elver season opens, fishermen hope for year free of poaching, shutdowns. Maine Public. March 22, 2019. https://www.mainepublic.org/business-and-economy/2019-03-22/as-elver-season-opens-fishermen-hope-for-year-free-of-poaching-shutdowns

Beguer-Pon, M., J. Benchetrit, M. Castonguay, K. Aerestrup, S.E. Campana, M.J.W. Stokesbury, and J.J. Dodson. 2012. Shark predation on migrating adult American eels (*Anguilla rostrata*) in the Gulf of St. Lawrence. PLOS One 7(10):1-11.

Bianchi, A. North Carolina Department of Environmental Quality. Unpublished data accessed on July 7, 2023 via email correspondence.

Bilkovich, D.M., H.W. Slacum, K.J. Havens, D. Zaveta, C.F.G. Jeffrey, A.M. Scheld, D. Stanhope, K. Angstadt, K. and J.D. Evans. 2016. Ecological and Economic Effects of Derelict Fishing Gear in the Chesapeake Bay (2015/2016). Virginia Institute of Marine Science, Final Assessment Report (Revision 2), Gloucester Point, Virginia.

Braun, I. Potomac River Fisheries Commission. Unpublished data accessed on May 22, 2023 via email correspondence.

Butler, J.A. 2000. Status and distribution of the Carolina diamondback terrapin, Malaclemys terrapin centrata, in Duval County, Florida. Final Report. Tallahassee: Florida Fish and Wildlife Conservation Commission, 52 pp.

Butler, J.A. 2002. Population ecology, home range, and seasonal movements of the Carolina diamondback terrapin, Malaclemys terrapin centrata, in northeastern Florida. Final Report. Tallahassee: Florida Fish and Wildlife Conservation Commission, 65 pp.

Butler, J.A. and G.L. Heinrich. 2007. The effectiveness of bycatch reduction devices on crab pots at reducing capture and mortality of diamondback terrapins (*Malaclemys terrapin*) in Florida. Estuaries and Coasts 30:179–185.

Butler, J.A., Heinrich, G.L. and Seigel, R.A. (2006) Third Workshop on the ecology, status, and conservation of diamondback terrapins (Malaclemys terrapin): Results and recommendations. Chelonian Conservation and Biology 5, 331–334.

DOJ (U.S. Department of Justice). 2018. Maine men sentenced for illegally trafficking American eels. DOJ. May 3, 2018. https://www.justice.gov/opa/pr/maine-men-sentenced-illegally-trafficking-american-eels

DOJ (U.S. Department of Justice). 2022. Major seafood dealer and eight individuals indicted for international wildlife trafficking. DOJ. April 29, 2022. https://www.justice.gov/opa/pr/major-seafood-dealer-and-eight-individuals-indicted-international-wildlife-trafficking

Eel Regulations. 2023. Maine Revised Statutes, Chapter 32.

Fisheries Management Order FMO-2023-01R. 2023. Fisheries management order prohibiting fishing for eels less than 10cm in length (elvers) in Nova Scotia and New Brunswick (renewal). Fisheries Management Order, Dartmouth, Nova Scotia.

Flaherty, N. 2018. Why Maine is the only state in the US with a 'significant' elver fishery. Maine Public. July 31, 2023. https://www.mainepublic.org/business-and-economy/2018-05-01/why-maine-is-the-only-state-in-the-us-with-a-significant-elver-fishery

Gillum, Z.D., 2014. Analysis of a 41-year data set: Environmental influences on the fish assemblages of Albemarle Sound, North Carolina. Graduate Thesis. East Carolina University, Greenville, North Carolina.

Greene, K. E., J. L. Zimmerman, R. W. Laney, and J. C. Thomas-Blate. 2009. Atlantic coast diadromous fish habitat: A review of utilization, threats, recommendations for conservation, and research needs. Atlantic States Marine Fisheries Commission Habitat Management Series No. 9, Arlington, Virginia.

ICES (International Council for the Exploration of the Sea). 2023. Working group on the American eel (WGAMEEL; outputs from 2022 meeting). ICES Scientific Reports 5:29, Copenhagen, Denmark.

Lidgard, D. C., W. D. Bowen, I. D. Jonsen, and S. J. Iverson. 2014. Predator-borne acoustic transceivers and GPS tracking reveal spatiotemporal patterns of encounters with acoustically tagged fish in the open ocean. Marine Ecology Progress Series 501:157–168.

Machut, L.S., K.E. Limburg, R.E. Schmidt, and D. Dittman. 2007. Anthropogenic Impacts on American Eel Demographics in Hudson River Tributaries, New York. Transactions of the American Fisheries Society 136:1699–1713.

McCleave, J., D. Cairns, and B. Costa-Pierce. 2016. American eel: A symposium. Session one. Ocean and Coastal Law Journal 21(1):7-37.

MDMR (Maine Department of Marine Resources). 2018. Chapter 32.65 Closure of 2018 Elver Season. Notice of agency emergency rule-making, Augusta, Maine.

Miller, M.J. and J.M. Casselman. 2014. The American Eel: A fish of mystery and sustenance for humans. Pages 155-169 *in* K. Tsukamoto and M. Kuroki, editors. Eels and humans. Humanity and the Sea, Tokyo, Japan.

Molina, J.R., 2002. Estuarine exchange model of the Pamlico and Albemarle Sounds. Graduate Thesis. North Carolina State University, Raleigh, North Carolina.

Molina, J.R., 2002. Estuarine exchange model of the Pamlico and Albemarle Sounds. Graduate Thesis. North Carolina State University, Raleigh, North Carolina.

NCDMF 2019 pers comm. Memorandum received from North Carolina Division of Marine Fisheries regarding Seafood Watch assessment of US American eel fisheries. November 26, 2019.

NCDMF 2020 pers comm. Email received from North Carolina Division of Marine Fisheries regarding details of NCDMF fishery-dependent and independent surveys conducted in Albemarle Sound. April 9th, 2020.

NCDMF 2023 pers comm. Email received from North Carolina Division of Marine Fisheries updating findings of NCDMF fishery-dependent and independent surveys conducted in Albemarle Sound. May 16th, 2023.

NCDMF, 2020. North Carolina Blue Crab (Callinectes sapidus) Fishery Management Plan Amendment 3. North Carolina Division of Marine Fisheries. North Carolina Department of Environmental Quality, North Carolina Division of Marine Fisheries, 3441 Arendell Street, P. O. Box 769, Morehead City, NC 28557.

NOAA (National Oceanic and Atmospheric Administration). 2023. Seafood import monitoring program.

https://www.fisheries.noaa.gov/international/seafood-import-monitoring-program

Norchi, C., D. VanderZwaag, J. Dettmers, R.W. Sears, L. Hussey-Bondt, and M. Waine. 2016. American eel: A symposium. Session five. Ocean and Coastal Law Journal 21(1):113-141.

North Carolina Division of Marine Fisheries, 2019. Personal Communication. Memorandum: Information regarding the American eel fishery in North Carolina and bycatch of diamondback terrapins. Nov. 26 2019.

North Carolina GAP Analysis Project, 2005. Species Report: Diamondback Terrapin, Malaclmeys terrapin. NC-GAP Analysis Project, Dept. of Zoology NCSU, Raleigh, North Carolina.

NYDEC (New York Department of Environmental Conservation). 2023. Hudson & Delaware River permits. https://www.dec.ny.gov/outdoor/28662.html

Radzio, T.A. and W.M. Roosenburg. 2005. Diamondback terrapin mortality in the American eel pot fishery and evaluation of a bycatch reduction device. Estuaries, 28(4):620–626.

Roosenburg, W. M. 1991. The diamondback terrapin: population dynamics, habitat requirements, and opportunities for conservation. Pages 237-244 *in* A. Chaney and J.A. Mihursky, editors. New perspectives in the Chesapeake system: A research and management partnership. Chesapeake Research Consortium, Proceedings of a Conference, Baltimore, Maryland.

Roosenburg, W.M., P.J. Baker, R. Burke, M.E. Dorcas, and R.C. Wood. 2019. *Malaclemys terrapin*, Diamonback terrapin. The IUCN Red List of Threatened Species 2019: e.T12695A507698.

SCDNR (South Carolina Department of Natural Resources). 2023. Nongame device - eel pots. SCDNR. August 2, 2023. https://www.dnr.sc.gov/fish/devices/eelpot.html

SeafoodSource. 2023. Maine's elver fishery nears close after lucrative year, while Canada's remains plagued by poaching. Accessed at: https://www.seafoodsource.com/news/supply-trade/maine-s-elver-fishery-nears-close-after-lucrative-year-while-canada-s-remains-plagued-by-poaching

Seigel, R. A., and J. W. Gibbons. 1995. Workshop on the ecology, status, and management of the diamondback terrapin (*Malaclemys terrapin*), Savannah River Ecology Laboratory, 2 August 1994: final results and recommendations. Chelonian Conservation and Biology 1:240–243.

Shepard, S.L. 2015. American eel biological species report. U.S. Fish and Wildlife Service, Supplement to: Endangered and Threatened Wildlife and Plants; 12-Month Petition Finding for the American Eel (*Anguilla rostrata*) Docket Number FWS-HQ-ES-2015-0143, Hadley, Massachusetts.

Thaler, J., S. Shepard, G. Wippelhauser, and J. Truebe. 2016. American eel: A symposium. Session three. Ocean and Coastal Law Journal 21(1):61-86.

U.S. Office of the Federal Register. 2015. Endangered and Threatened Wildlife and Plants; 12-Month Findings on Petitions To List 19 Species as Endangered or Threatened Species (FWS–HQ–ES–2015–0143). Federal Register 80:195(8 October 2015):60834-60850.

U.S. Office of the Federal Register. 2022. Magnuson-Stevens Fishery Conservation and Management Act; Seafood Import Monitoring Program, proposed rule (Docket No. 221215–0273). Federal Register 87:248(28 December 2022):79836-79848.

US v. Austin. 2017. No. 2:17-CR-0019 (E.D. Va.)

US v. Im et al. 2017. Nos. 2:16-CR-00126, 127, 129 (D. Maine)

US v. Sheldon. 2018. Nos. 2:16-CR-00123, 2:17-CR-00032 (D. Maine)

US v. Zhou. 2017. No. 2:17-CR-00009 (E.D. Va.)

VanderZwaag, D., S. Denny, A. Giles, D. Dow, M. Feigenbaum, and G. Carey. 2016. American eel: A symposium. Session two. Ocean and Coastal Law Journal 21(1):39-60.

VIMS (Virginia Institute of Marine Science). 2012. CCRM marine debris location & removal project. Center for Coastal Resources Management. http://ccrm.vims.edu/marine_debris_removal/index_temp.html

Westerberg, H. 2014. Marine Migratory Behavior of the European Silver Eel. Pages 81–104 in H. Ueda, and K. Tsukamoto, editors. Physiology and Ecology of Fish Migration.

Withers, P. 2023. Hundreds of baby eel poachers hit Maritime rivers each day before fishery was closed, Ottawa says. Canadian Broadcasting Corporation. April 20, 2023. https://www.cbc.ca/news/canada/nova-scotia/canada-faced-hundreds-of-baby-eel-poachers-every-day-1.6816097

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

Appendix A: Review Schedule

Rating Review Changes

2020

This report was updated in June 2020 to include a new rating for North Carolina pot fisheries, based on data and information supplied by the North Carolina Division of Marine Resources, which demonstrated that interactions with diamondback terrapin (the limiting factor in Criterion 2 for pot fisheries) were unlikely due to the low salinity of Albemarle Sound, where eel fishing occurs. In addition, the rating for the glass eel fishery was removed from the report, because it was determined that this fishery supplies eel for aquaculture operations rather than a human consumption market.

2023

A reassessment was conducted in 2023 using version F4 of the Fisheries Standards. "Fyke nets" was added as a new gear type, with an overall Yellow rating. The overall rating for the "barriers, fences, weirs, corrals, etc." gear type (hereafter referred to as "weirs") improved from Red to Yellow. The two ratings for pots remained the same overall.

Information in the report was updated to reflect the findings from the 2023 benchmark stock assessment, the availability of catch composition data, and potential enforcement concerns.

Introduction: Landings data and trade data were updated.

Criterion 1: No score changes. The findings from the 2023 benchmark stock assessment were added.

Criterion 2, Synthesis: The C2 score for weirs improved from Red to Green. The C2 score for pots in North Carolina improved from Red to Yellow. These score changes were the result of C2 species being removed from the assessment. Seafood Watch was able to review catch composition data for the pot fishery and discuss catch composition with experts on the weir fishery. Based on this information, the following C2 species were removed from the assessment: alewife, Atlantic salmon, catfish (unspecified), and rainbow smelt. Diamondback terrapin remains as a C2 species for pot gear outside of North Carolina.

Criterion 3, Factor 3.1: No score changes. Added information from the findings of the 2023 benchmark stock assessment. Added context about mortality from fisheries outside the U.S. and mortality from nonfishery sources.

Factor 3.2: Pots in North Carolina improved from moderately effective to highly effective. Catch composition data show that bycatch in the fishery is extremely low and there are no C2 species for this fishery. No score changes occurred for other gear types. The answer for weirs was updated to acknowledge that there are methods in place to reduce bycatch mortality.

Factor 3.3: No score changes. Added information from the preliminary findings of the 2023 benchmark stock assessment.

Factor 3.4: No score changes. Added contextual information about poaching concerns in Canada.

Factor 3.5: No score changes.

Criterion 4: No score changes. Factor 4.3 was updated with information about how the FMP incorporates ecosystem concerns.