American eel

United States of America, North Carolina/Northwest Atlantic

Pots, barriers, fences, weirs, corrals, etc.

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Originally published: November 5, 2018 Updated: June 1, 2020

Seafood Watch Standard used in this assessment: Fisheries Standard v3

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About Seafood Watch

Monterey Bay Aquarium's Seafood Watch program evaluates the ecological 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. Seafood Watch makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. 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.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Watch Assessment. Each assessment synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices," "Good Alternatives" or "Avoid." This ethic is operationalized in the Seafood Watch standards, available on our website here. In producing the assessments, Seafood Watch seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying assessments will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Watch assessments in any way they find useful.

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, we develop an overall recommendation. Criteria ratings and the overall recommendation are color coded to correspond to the categories on the Seafood Watch pocket guide 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 overfished, lack strong management or are 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

This report covers two life stages of American eel (*Anguilla rostrata*) caught on the Atlantic coast of the US: yellow eels, and silver eels. Eels are catadromous, spawning in the Sargasso Sea and migrating up rivers and streams to grow and mature. The report is separated by gear type, with each gear type covering the fishery for a different life stage of eel (pots for yellow eels, and weirs/barriers for silver eels). The North Carolina fishery for yellow eel is rated separately as bycatch concerns for this fishery are reduced.

In the US, the American eel population is managed from Maine to Florida by the Atlantic States Marine Fisheries Commission (ASMFC), which decides the quota, and the states, which implement and enforce federal and state regulations. The largest harvests of yellow eel occur in Maryland. Population assessments of eel are carried out at both the federal and state levels, but the first stock assessment in 2005 failed peer review. The 2012 assessment included more quantitative models, but did not produce estimates of stock status outside of trend analysis. Thus, reference points and fishing mortality have not yet been determined, and this is considered to be primarily because of a lack of sufficient data to estimate them. Using catch records and some fishery-independent surveys, the last benchmark assessment found that the population status of eel was 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.

There is some evidence that species of particular concern caught in eel gear include terrapins (in pot fisheries). Overall, bycatch data for the eel fishery are limited, and much of what is reported here comes from anecdotal accounts, comparisons with similar fisheries (e.g., the pot fishery for blue crab, which uses a different type of pot), and grey literature where available.

Management measures mitigate bycatch, monitor landings in-season, and limit quota overages. There are also measures in place to limit possession of juvenile eels in most states in an attempt to manage the trade of glass eels (not assessed here) which are used for ongrowing in aquaculture facilities in the USA and Asia.

The impact of eel-targeting gear on benthic habitat is relatively low due to the stationary nature of the gear and the habitats being fished.

US American eel fisheries receive an "Avoid" score, with a "Good Alternative" score for eels caught in the North Carolina pot fishery.

Final Seafood Recommendations

SPECIES | FISHERY	CRITERION 1 TARGET SPECIES	CRITERION 2 OTHER SPECIES	CRITERION 3 MANAGEMENT	CRITERION 4 HABITAT	OVERALL RECOMMENDATION
American eel | Northwest Atlantic | Barriers, fences, weirs, corrals, etc. | United States	1.732	1.732	3.000	3.000	**Avoid (2.279)**
American eel | Northwest Atlantic | Pots | United States | North Carolina	1.732	2.236	3.000	3.000	**Good Alternative (2.430)**
American eel | Northwest Atlantic | Pots | United States	1.732	1.732	3.000	3.000	**Avoid (2.279)**

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 US Atlantic coast, in pots (for immature eels or yellow eels) and weirs (for sexually mature silver eels). The "Avoid" rank for American eel comes from a combination of this species' threatened status (including fishing mortality as well as several anthropogenic threats to eel habitat), possible negative impacts of the eel fishery on threatened bycatch species, and illegal harvest. Yellow eel caught using pots in North Carolina are a Good Alternative, as the bycatch concerns regarding daimondback terrapins are reduced in this area.

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*) caught in US waters (freshwater streams and rivers, as well as coastal marine areas), baited pots (used to catch yellow eels), and weirs (mostly used to catch "silver" eels or those outmigrating to marine water). North Carolina pot fisheries are assessed separately as the bycatch concerns identified for the Atlantic coast are not as severe.

Species Overview

American eel (*Anguilla rostrata*) are catadromous, spawning in saltwater and migrating to fresh water to grow and mature. When eels have reached maturity, they migrate 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 eels are targeted as they return to rivers from their ocean spawning areas, yellow eels (2 to 3 years old) are targeted while fish are growing (in fresh or brackish water), and silver eels are targeted in the late summer, as they return downriver to spawn (ASMFC 2012). American eel is also panmictic, composing one genetic population from its northern limit (in Greenland) to its southern limit in French Guiana (ASMFC 2012). Since 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 eels as they return from ocean spawning areas to freshwater, using fyke nets or dip nets to collect glass eels. The yellow eel fishery uses eel pots to capture sexually immature 2 to 3 year old eels. Finally, the silver eel fishery targets outmigrating adult sexually mature eels with weirs across rivers and streams. In the US, the glass eels are used for ongrowing in aquaculture operations either in the US or in Asia, and are therefore not assessed here.

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 1960's, and 1970's, and prices for yellow and silver eels rose. Simultaneously, demand from Asian aquaculture operations increased, raising the prices and fishing effort for glass eels. The population was fished down in the 1970's and 1980's due to this increased export demand, in addition to river damming and an increasing number of hydroelectric facilities on dams, which caused additional mortality (ASMFC 2012). According to the most recent benchmark stock assessment for American eel, it faces other stressors including habitat loss from dams, mortality in turbines, parasites, toxic pollutants, and climate change (ASMFC 2012). There are different exploitation histories for each life stage of eel; for example, silver eels were historically targeted by Native Americans, whereas the earliest commercial records for yellow eels begin in the 18th century.

American eel is managed by the Atlantic States Marine Fisheries Commission (ASMFC), in US 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: as glass eels, yellow eels, and silver eels. 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 2014). Total commercial harvest on the US Atlantic Coast has ranged between 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 eels, of which the majority are 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) {ASFMC 2014}.

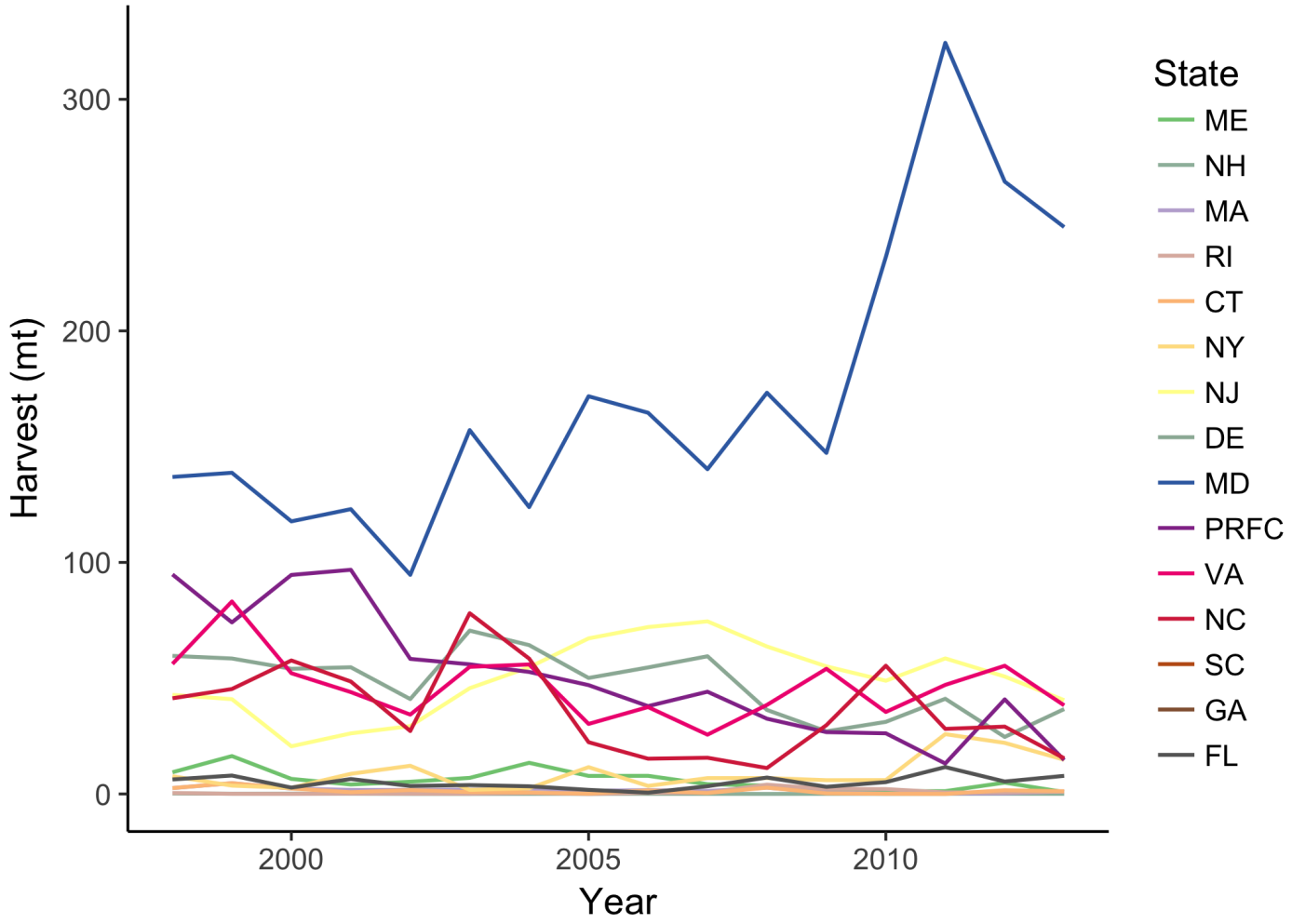

Figure 1: Total harvest of yellow eel by state. PRFC = Potomac River Fisheries Commission.

Recreational harvest of eel has ranged from 353 to 157,155 lb/yr between 1981 to 2009 (ASMFC 2012).

The value of the fishery varies depending on the life stage: Glass eels are the highest value fishery, with prices often at least $200 to 300 per pound. In 2012, the market price for glass eels was $2000 per lb. Market prices for yellow eels, on the other hand, have declined from $3–4/lb to $1.25–1.75/lb (USFWS). The total value of US commercial landings of American eel have ranged from a few hundred thousand dollars (pre 1980s) to a peak of $6.4 million in 1997 (Figure 2).

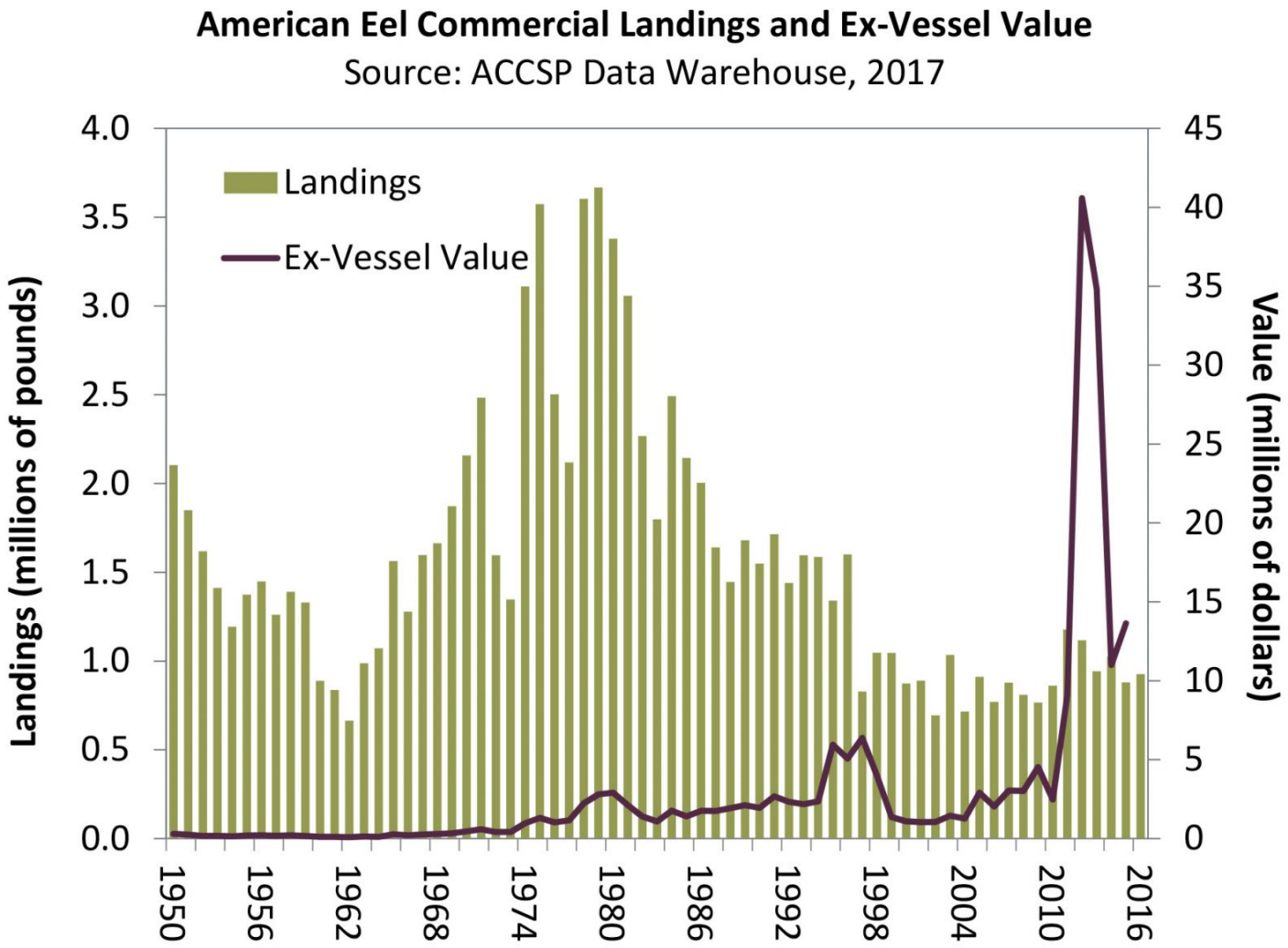

Figure 2: Total commercial landings and value of A. rostrata. From the ASMFC American eel stock assessment overview (ASMFC 2017).

Importance to the US/North American market.

The majority of the capture of *A. rostrata* in North America have 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 US. The majority of all eel imports to the US (including *A. rostrata* as well as *A. japonica*, *A. anguilla*, and *A. australis*) come from China (4,578 metric tons (MT) in 2016), Taiwain (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).

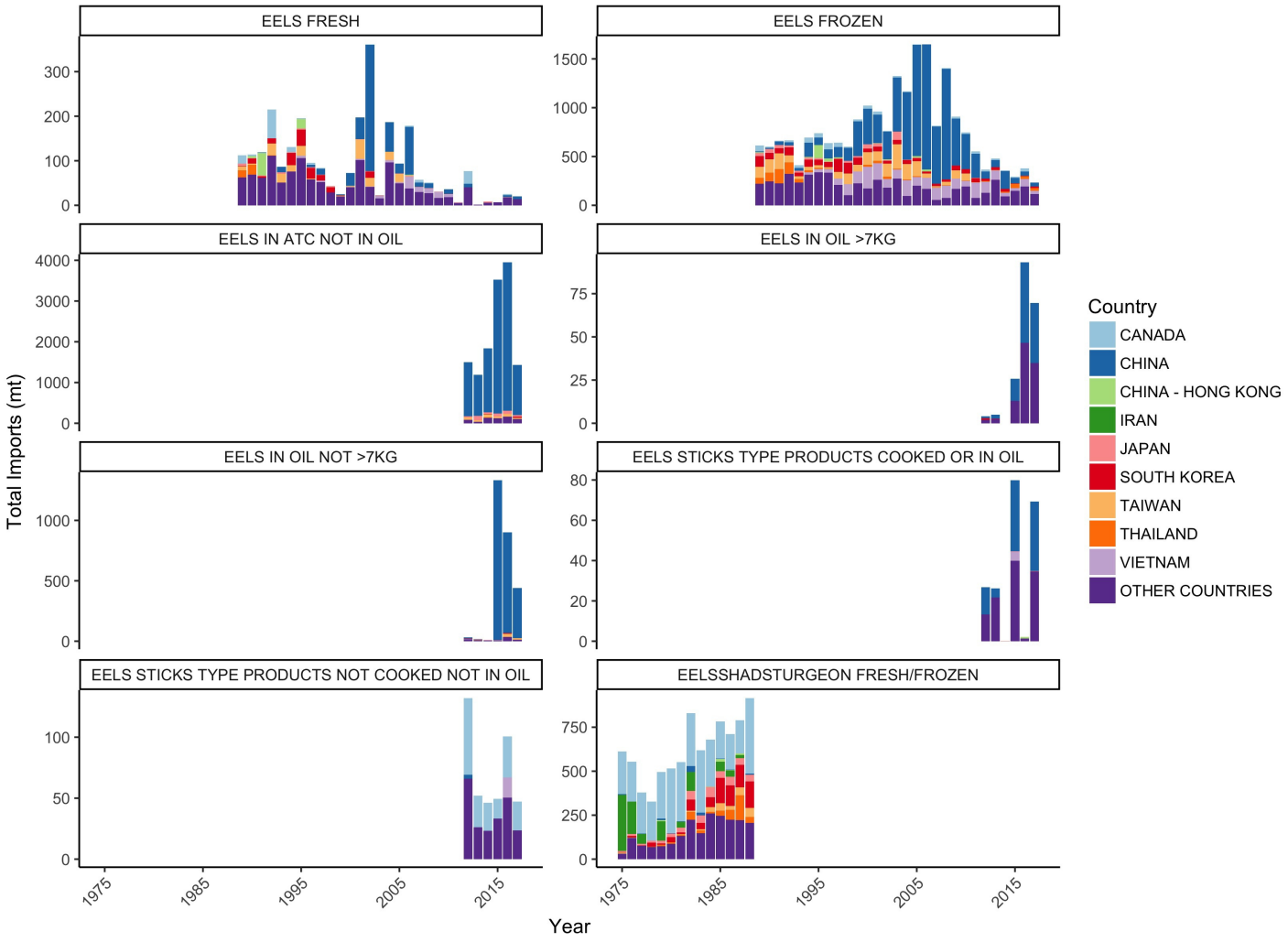

Figure 3: Imports of eel to the US since 1975 (data from NMFS). Eel is not separated by species in import data, so these data include a combination of A. rostrata, A. japonica, A. anguilla, and A. australis.

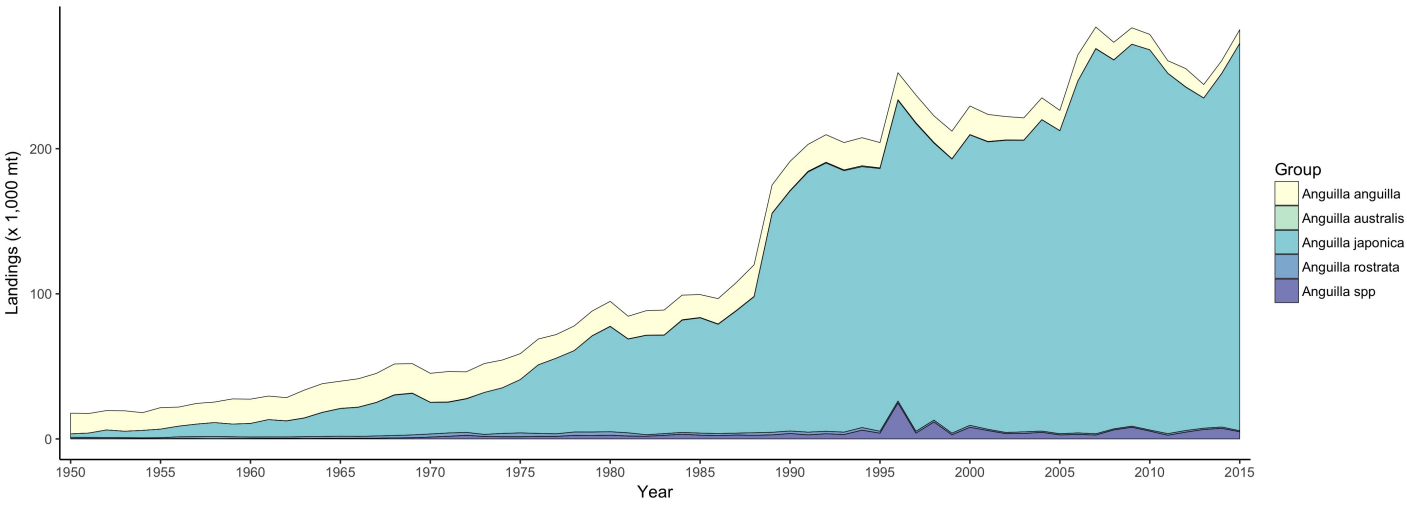

Figure 4: Total global landings of eel since 1950 by species (data from FAO).

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

Eels are sold whole or skinned as steak or fillets. Smoked, jellied, or cured eels are also available in US 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 | Barriers, fences, weirs, corrals, etc. | United States	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Northwest Atlantic | Pots | United States | North Carolina	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Northwest Atlantic | Pots | United States	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 | Barriers, fences, weirs, corrals, etc. | United States
Northwest Atlantic | Pots | United States | North Carolina
Northwest Atlantic | Pots | United States

High Concern
While stock status relative to reference points is uncertain, the most recent stock assessment states that American eel is "highly likely" to be depleted. This determination is based on several approaches, including a trend-based approach and DB-SRA (a data-poor stock assessment) (ASMFC 2017). Nearly all of the methods used to determine stock status indicate that American eel is depleted and is at or near historically low levels, although official stock status cannot be determined due to uncertainty in these reference points. Because eel are diadromous and undergo long-distance migrations between feeding and spawning grounds, they face different threats throughout their 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 impacted eel populations. Finally, temperature is considered one of the triggers for upstream migration, so eel are sensitive to temperature changes at multiple spatial scales (Greene 2009). According to a recent update to the Biological Report on American eel by US Fish & Wildlife, trends in eel abundance are stable by some metrics and declining by others (Shepard 2015). Because eel is considered likely to be depleted and declining by some metrics of abundance, and because it faces uncertain threats in the future, American eel is ranked as "high" concern.
Justification:
Assessments for American eel are based on fishery-independent surveys, standardized with generalized linear models (GLMs); followed by a power analysis to determine the ability of the survey to detect trends; Mann-Kendall tests, which detect monotonic trends; meta-analysis to indicate coherence of trends over space, and general geographical and temporal trends, detected with ARIMA time series models and traffic light analysis (described below).

Biological reference points for American eel are determined using three distinct methods. Depletion-based stock reduction analysis (DB-SRA); time series models (ARIMA) with standardized abundance indices from fishery-independent yellow eel surveys, to estimate the probability that abundance in any given year was less than the 25th percentile of all abundance data points; and the "Traffic Light Approach" (TLA), which provides a summary of the status in each year and geographic location based on abundance relative to long-term patterns. The TLA gives a location a score of "green," "yellow," or "red" based on the abundance index relative to the long-term percentiles; a "'red" score indicates that the stock is below the 25th percentile, "yellow" is between the 25th and 75th percentiles, and "green" is above the 75th percentile. DB-SRA does not include observations in a likelihood or least-squares framework, but is able to estimate yield given depletion (ASMFC 2017).

In the 2012 benchmark assessment, the Review Panel approved the use of DB-SRA for determining whether the stock was depleted, but had reservations about the model, including significant error in catch reporting, uncertainty about reference points used in DB-SRA, and assumptions about population structure and dynamics that are implicit in the model structure. Thus the Review Panel did not approve DB-SRA for the estimation of reference points or determination of overfished/overfishing status. Neither the DB-SRA nor the TLA were updated in the 2017 assessment update (ASMFC 2017). As of the 2017 assessment update, none of the calculated reference points have been endorsed by the Peer Review Panel for use in management. Due to concerns about uncertainty in the reference points, the Peer Review Panel recommended not using DB-SRA for management use; as of the 2017 update, official stock status could not be determined.

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 {Shephard 2015} (Beguer-Pon et al. 2012), marine mammals (Lidgard et al. 2014) (Westerberg 2014), and predation on juvenile glass eels by striped bass (Shepard 2015).

Factor 1.2 - Fishing Mortality

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

Moderate Concern
DB-SRA (the data-poor stock assessment tool used for this fishery) is currently improving in its ability to assess fishing mortality, but is currently only able to detect trends in F. The most recent DB-SRA analysis (ASMFC 2017) suggests that overfishing has been occurring since the 1980s, but does not make a definitive statement about whether or not overfishing is occurring because of uncertainty about reference points (ASMFC 2017). Thus, the benchmark assessment notes that it is "highly likely" that the American eel stock is depleted. Because F is unknown, and reference points are still highly uncertain, American eel is considered "moderate" concern for fishing mortality.
Justification:
Although overfishing status relative to reference points is still highly uncertain for American eel, efforts to reduce fishing mortality have been implemented. In Addendum IV to the benchmark stock assessment, the ASMFC imposed a glass eel harvest quota that halved the allowable catches from 2013 to 2014 levels. Total catches have been stable in the last decade, while indices of abundance are mostly stable or decreasing (ASMFC 2017), which may be evidence that fishing mortality is high.

Fishing mortality caused by the bycatch of eels in other fisheries is considered "minor" according to the 2012 benchmark assessment. The Marine Recreational Fisheries Statistical Survey (MRFSS) indicate that eel is commonly caught as bycatch in hook-and-line recreational fisheries in the NW Atlantic, but catch numbers in other fisheries have been declining since the 1980s (ASMFC 2012). Yellow eels also appear as bycatch in derelict traps, primarily for crab, although they composed <4% of the total bycatch in one study in Chesapeake Bay (Giordano et al. 2009) and <3.1% in Virginia (Bilkovich 2016). Additionally, Addendum IV "capped" total coastwide landings at 907,671 lb for the yellow eel fishery.

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 | Barriers, fences, weirs, corrals, etc. | United States	1.732	1.000: < 100%	Red (1.732)
Northwest Atlantic | Pots | United States | North Carolina	2.236	1.000: < 100%	Yellow (2.236)
Northwest Atlantic | Pots | United States	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 | BARRIERS, FENCES, WEIRS, CORRALS, ETC. | UNITED STATES			
SUB SCORE: 1.732	DISCARD RATE: 1.000	**SCORE: 1.732**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Alewife	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
American eel	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Atlantic salmon	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Rainbow smelt	1.000: High Concern	3.000: Moderate Concern	Red (1.732)

NORTHWEST ATLANTIC | POTS | UNITED STATES			
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)
Catfish (unspecified)	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

NORTHWEST ATLANTIC | POTS | UNITED STATES | NORTH CAROLINA			
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)
Catfish (unspecified)	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

Very little information is available on bycatch in any of the three eel fisheries (glass, yellow, and silver eels). Bycatch varies in these fisheries because they occur in different habitats (fresh, brackish, and marine waters). Because of the scarcity of species composition data for catches, species that have historically been caught are all included as main species in this report. These historical occurrences have been taken from personal communications with state-level managers in Maine, a summary of the eel and glass eel fisheries from the Maine Department of Marine Resources website, and one report on bycatch mitigation for the eel pot fishery {Radzio and Roosenburg 2005}. Species of concern within this group include terrapins, which have appeared as bycatch in the pot fisheries.

Bycatch in the eel fishery varies by targeted life stage and gear type. The amount of bycatch in the glass eel fishery is largely unknown, and likely varies by state. Bycatch in the glass eel fishery in Maine is unlikely to be more than 5% of the total catch by weight (pers. comm., G. Wippelhauser), but there is little information available on the species composition of bycatch and there are hundreds of licensed fishers in Maine. These numbers may not be representative of bycatch in other states, like South Carolina where there are only ten licensed fishers. In Maine, glass eel nets are required to have escape panels for larger species, and all non-target species are required to be returned alive to the water. Study nets for surveying glass eels in Maine have caught shiners, sticklebacks, small sunfishes, salamanders, tadpoles, leeches, and other invertebrates (pers. comm., J. Bartlett 2018), so these species may also occur as bycatch in the dip net fisheries for glass eels. Since the exact composition of bycatch is unknown, these species are included as a precaution. There is anecdotal evidence that perches and sunfish are caught in pots occasionally but because these groups are highly abundant, mortality in eel pots is unlikely to be a significant contributor to mortality in these species and they are not included in the main species list.

Pots and traps used to catch eel have risks of bycatch from trapping and entanglement similar to other pot and trap fisheries. Bycatch in pots includes catfish, sunfish, and perches, although there are no publicly available data on the overall species composition of the catch. Capture and drowning in eel pots and traps is one suspected source of mortality for terrapins in the northwest Atlantic {Radzio and Roosenburg 2005}. Terrapins are near threatened and have been caught as bycatch in an experimental study on bycatch mitigation for eel pots {Radzio and Roosenburg 2005}, and are thus included here as main species. As with other pot and trap fisheries, there are risks of entanglement of protected species in the lines connecting the pots to marker buoys, including marine mammals and sea turtles. It is unknown whether eel pot locations overlap significantly with either of these two groups.

In the silver eel fishery with weirs, traps, and barriers there is some concern about bycatch of rainbow smelt, alewives, trout, and wild Atlantic salmon {Maine DMR 2016}, but there are no publicly available observer data on bycatch yet in this fishery.

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

Alewife

Factor 2.1 - Abundance

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

High Concern

This scoring is taken from the Seafood Watch report on Atlantic striped bass {SFW 2016}. Alewives are listed as a species of concern by NMFS (Federal Register 2013) because of declining populations throughout most of their range, so alewife is scored as "high" concern.

Justification:

The following is from the Seafood Watch Atlantic herring report, which includes alewife and blueback herring both as secondary species (Seafood Watch 2014):

In 2012, 52 alewife and blueback herring river stocks were assessed, and 22 were found to be depleted, 1 was increasing, and the other 28 were considered unknown due to a lack of sufficient data (1 was not classified) (ASMFC 2012). Biological reference points could not be established due to a lack of data. The Natural Resources Defense Council (NRDC) petitioned the National Marine Fisheries Service (NMFS) to list both alewife and blueback herring as threatened under the Endangered Species Act (ESA). On August 13, 2013, NMFS declared that listing alewife or blueback herring under the ESA was not warranted because there are many conservation efforts currently underway to improve their habitat conditions as well as to reduce incidental catch in marine fisheries, such as the Atlantic herring and mackerel fisheries (78 Federal Register 155). There is a high level of concern about the stock, since the majority of stocks are in decline; but they were not listed as endangered and there are significant conservation efforts underway. Alewives are also petitioned to be listed under the ESA. They are scored as "high" concern.

Factor 2.2 - Fishing Mortality

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

Moderate Concern

This scoring was modified from the Seafood Watch report for Atlantic striped bass {SFW 2016}. Landings of river herring (a category which includes alewives and blueback herring) are only allowed in Maine, New Hampshire, New York, North Carolina, and South Carolina (ASMFC 2015c). The amount of alewife bycatch in the eel fishery is unknown, therefore this species is given a score of "moderate" concern.

Atlantic salmon

Factor 2.1 - Abundance

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

High Concern
The abundance of North American Atlantic salmon has declined since the early 1990's, with many subpopulations persisting at low abundance. These declines are thought to be the function of physical and biological changes in their habitat (Mills et al. 2013). Despite conservation efforts, runs of Atlantic salmon in the Gulf of Maine have very low abundances relative to historical levels, with an estimated extinction risk of 19 to 75% within the next 100 years (Fay et al. 2006). Because wild Atlantic salmon has historically low abundances and currently have a negative trend in abundance, they are scored as "high" concern.

Factor 2.2 - Fishing Mortality

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

Moderate Concern
There is only anecdotal evidence that Atlantic salmon might be captured in the weir fisheries for glass eels and silver eels. Fishing mortality of Atlantic salmon in the weir fisheries is unknown and therefore scored as "moderate" concern.

Catfish (unspecified)

Factor 2.1 - Abundance

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

Moderate Concern
Blue and channel catfish (*Ictalurus* spp.) are occasionally caught in pot fisheries for eel in the Northwest Atlantic; there is anecdotal evidence that they are caught in Maine (pers. comm., J. Bartlett 2018) and it is unclear whether they are also caught in South Carolina pot fisheries. Blue catfish are considered invasive species and are not a species of concern in terms of their abundance in Maine or further south where eels are caught. Channel catfish do not have a formal assessment so it cannot be determined whether they are above a historical reference point, although they are a species of "Least Concern" according to IUCN (IUCN 2013). According to a series of interviews of catfish managers in 1999, many of the population estimates that are currently available are based on CPUE methods {Michaletz and Dillard 1999}. Because blue catfish are "low" concern by Seafood Watch standards and the status of channel catfish relative to reference points is unknown (usually classified as "moderate" concern), catfish in general as bycatch are ranked "moderate" concern.

Factor 2.2 - Fishing Mortality

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

Moderate Concern
There is no information about the prevalence of catfish in catches from eel pots, or post-release mortality of catfishes that are returned after being caught. Catfish bycatch in the blue crab trap fishery tends to consist of <5% of catfishes, so it is unlikely that these species are significantly impacted by trap fisheries for eel. However, because of the lack of data, American eel is ranked "moderate" concern.

Diamondback terrapins (unspecified)

Factor 2.1 - Abundance

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

High Concern
Diamondback terrapins live along the US Atlantic Coast from Cape Cod to Galveston Bay in the Gulf of Mexico (Roosenburg 1991) and throughout the range, the population sizes in the states are primarily unknown or declining and few are considered stable (Butler et al. 2006) {Siegel and Gibbons 1995}. Seven distinct subspecies are managed as different units. Diamondback terrapins are federally recognized as a species of special concern by the US Fish and Wildlife Service and are classified on the IUCN Red List as "Near Threatened." For this reason, they are considered "high" concern for abundance.
Justification:
Terrapins are long-lived and have low reproductive output. Thus, sources of mortality that impact older individuals can have a strong impact on the population.

Factor 2.2 - Fishing Mortality

Northwest Atlantic | Pots | United States

Moderate 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, 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 terrapins are 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 to be between 15 to 78% of the population per year {Butler and Heinrich 2007}.

Eel pots do capture diamondback terrapins, especially pots with large funnel entrances {Radzio & Roosenburg 2005} {Radzio & Roosenburg 2002}. 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, terrapins are scored as "moderate" concern.
Justification:
A review of derelict gear in Chesapeake Bay found the majority of derelict gear were crab pots (relative to eel pots; (Bilkovich 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.

Northwest Atlantic | Pots | United States | North Carolina

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 & Roosenburg 2005}

However, in North Carolina the American eel fishery is concentrated in Albemarle Sound (as indicated by the landings data in Table 1) which has a very low salinity in the range of 0-5psu (Molina 2002) (Gillum 2014). Diamondback terrapins are an exclusively brackish water species, typically found in salinities of 11-35psu (Williard et al 2019) and are intolerant to freshwater over an extended period (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 NCDMF. From 1971 to 2017, a total of 649 diamondback terrapins were encountered across 173 unique locations; from this data there are only 2 known interactions in Albermarle Sound (Figure 4) (NCDMF 2020). 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 5 (NCGAP 2005). The map shows that while presence of diamondback terrapins 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 takes place in North Carolina, it is unlikely that the fishery is having a negative impact on the diamondback terrapin population therefore fishing mortality is considered to be a low conservation concern.

Justification:

North Carolina Division of Marine Fisheries Surveys

As noted above, NCDMF conducts fishery-dependent and independent surveys on an annual basis 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.
- 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.
- 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.
- 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 (2009-2018). (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
2009-2018	52,945	96.6	54,890	112	91.07	124

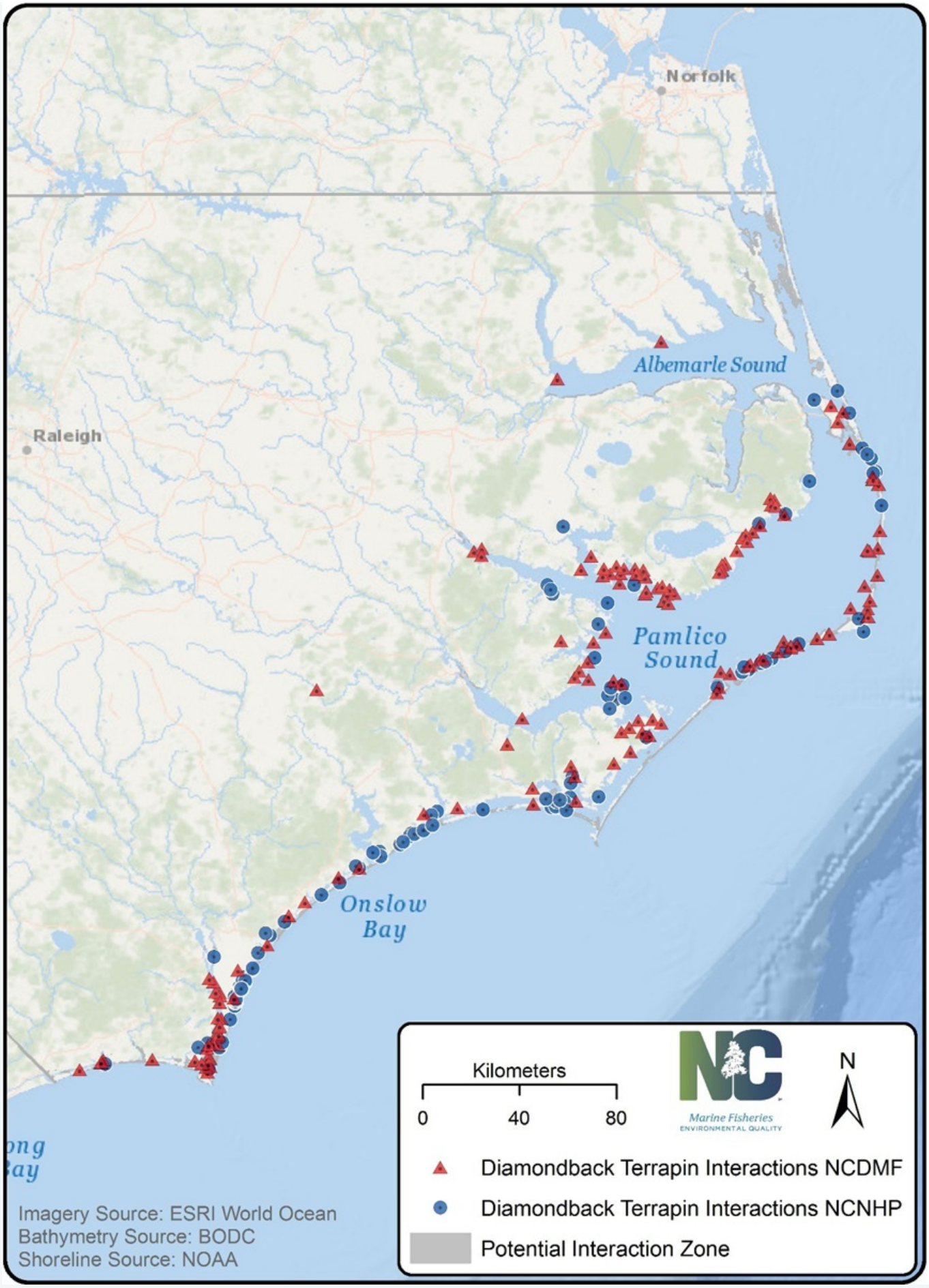

Figure 5: A map of coastal North Carolina showing known interactions with Diamondback Terrapins from NCDMF (1971-2015) and NCNHP data. (From NCDMF 2019)

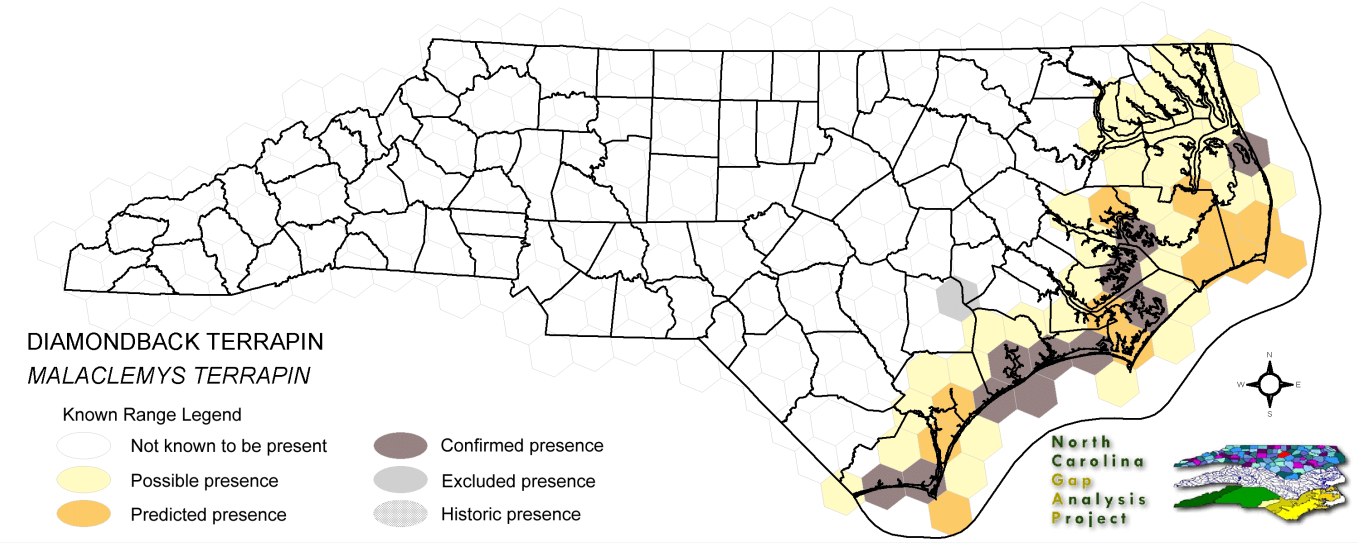

Figure 6: Known Range of the Diamondback Terrapin, Malaclemys terrapin, in North Carolina. From North Carolina GAP Analysis Project.

Rainbow smelt

Factor 2.1 - Abundance

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

High Concern
According to the Maine Department of Natural Resources, current status of rainbow smelt populations for the majority of the Gulf of Maine is not well known. Commercial landings of rainbow smelt in Maine historically declined from 1.6 million lb to less than 200,000 lb by 1950 and remained low through the 1960s. Recently a semi-annual review of finfish fisheries in Maine resulted in an assessment of rainbow smelt population size. When rainbow smelt were assessed in 2004, they were federally listed as "Species of Concern." Because of their potential low abundance, rainbow smelt are ranked as "high" concern.

Factor 2.2 - Fishing Mortality

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

Moderate Concern
There is only anecdotal information about possible bycatch of smelt in weirs and fences used to fish silver eels, so smelt are ranked as "moderate" concern for fishing mortality.

Factor 2.3 - Discard Rate/Landings

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

< 100%

Weirs and other barriers are treated as gill nets by Seafood Watch standards, with regards to bycatch. Set gillnets can have high discard rates, ranging from 0 to 66% of the total catch (Kelleher 2005). The Northwest Atlantic on average is reported to have a low discard rate of 9.3% (Table 4 in (Kelleher 2005)), but this information is based on marine fishes; upstream weirs targeting silver eels may be more similar to freshwater fisheries. Weirs and similar fisheries catch species in moving water, and may have large discard rates depending on location and target species. However, since there is no strong evidence of substantial bycatch in weirs targeting silver eels, this fishery is scored as having a discard rate of <100%.

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

< 100%

There is very little information available about bycatch in pots targeting yellow eels, let alone post-release mortality of bycatch. However, a review of discard rates based on gear type reports that pots targeting finfish often have low discard rates (~5%, (Kelleher 2005)) and NMFS does not report bycatch for pot fisheries in New England (NMFS 2013). Additionally, pots are generally assumed by Seafood Watch to have low post-release mortality rates, so there is no discard modification for pots included here.

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	RESEARCH AND MONITORING	ENFORCEMENT	INCLUSION	SCORE
Northwest Atlantic | Barriers, fences, weirs, corrals, etc. | United States	Moderately Effective	Moderately Effective	Moderately Effective	Moderately Effective	Highly effective	**Yellow (3.000)**
Northwest Atlantic | Pots | United States	Moderately Effective	Moderately Effective	Moderately Effective	Moderately Effective	Highly effective	**Yellow (3.000)**
Northwest Atlantic | Pots | United States | North Carolina	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 | Barriers, fences, weirs, corrals, etc. | United States
Northwest Atlantic | Pots | United States | North Carolina
Northwest Atlantic | Pots | United States

Moderately Effective
The American eel FMP includes size and catch limits, although these are not currently based on the status of the stock relative to reference points. This is because stock status is highly uncertain, and the status relative to reference points is sensitive to the range of values assumed for current depletion (biomass relative to K). The most recent assessment states that the stock is "highly likely" to be depleted, but that status relative to reference points cannot be determined with confidence. Management strategies are in place to improve the status of the stock: the FMP includes requirements for states to collect additional data on effort and catches (Addendum I), and improve upstream and downstream passage for eels in streams and rivers (Addendum II). These measures are expected to increase eel abundance, but their effectiveness has not yet been quantified.

Whether current management measures will improve the status of American eels will depend on implementation at the state level and the responsiveness of management to changes in status. The most recent assessment update confirms that stock status (and thus management effectiveness for improving status) could be determined with more certainty when there are more data on catches, effort, and population size, but it is unclear how much additional data will be sufficient to determine stock status with any degree of certainty (ASMFC 2017). Between the 2012 assessment and the 2017 assessment update, there has been little improvement in the quality of abundance estimates, and it's likely that substantial data and assessment improvements will be needed before reference points can be estimated and used for management. Although there are measures in place to improve abundance and they are expected to be effective, they have not been in place long enough to evaluate their success. Therefore, eel is considered "moderately effective" for management strategy and implementation.
Justification:
The American eel FMP requires that all states and jurisdictions establish a minimum recreational size limit for yellow eels (<9 inches, since 2013; Addendum IV) 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 in 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 most recent stock assessment for American eel notes that more detailed fishery-independent monitoring of eel populations and fisheries is needed in order to improve the stock assessment (ASMFC 2017). Addendum I to the eel FMP (February 2016) mandated that states establish mandatory catch and effort monitoring. South Carolina and Maine recently 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. These measures are expected to improve abundance, but their effectiveness for improving population status is currently unknown, so the eel fishery is scored as "moderate." It is possible that this status will change with the next assessment.

Factor 3.2 - Bycatch Strategy

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

Moderately Effective
There is no information about bycatch rates in the silver eel fishery, although the slats in traditional weirs targeting silver eels likely prevent the bycatch of smaller fish. Potential bycatch includes resident and other anadromous and catadromous species, including wild Atlantic salmon, but there is no data available on the species caught as bycatch or the rules for returning live bycatch to the river. Weirs used to catch larger eels occasionally include gear modifications to prevent bycatch of other species and to protect younger age classes of the same species. Because bycatch reduction techniques are employed but their effect on bycatch rates is unknown, the weir fishery targeting silver eels is considered "moderately effective" for bycatch management.

Northwest Atlantic | Pots | United States

Moderately Effective
There are pot restrictions in South Carolina for recreational and commercial fishing licenses. Maine requires license numbers on all pots, ostensibly to aid in the recovery of lost gear and ameliorate ghost fishing. There are also crab pot cleanups in places with heavy crab fishing, including Chesapeake Bay. 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. Finally, bycatch reduction devices (BRDs) have been recommended for reducing bycatch of terrapins, but have not yet been widely adopted {Radzio and Roosenburg 2002}. 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 this factor.

Northwest Atlantic | Pots | United States | North Carolina

Moderately Effective
Bycatch reduction devices (BRDs) have been recommended for reducing bycatch of terrapins, but have not yet been widely adopted {Radzio and Roosenburg 2002}. However, the likelihood of the eel fishery interacting with terrapins in North Carolina is reduced as most of the fishing effort and harvest occurs in Albemarle Sound (see table 1) where salinities are in the range of 0-5psu (Molina 2002)(Gillum 2014) and terrapins are intolerant to freshwater for extended periods of time (NCGAP 2005). Due to the reduced risk in interactions there is a low level of concern regarding the impact of the eel fishery on diamondback terrapins, thus reducing the need for the introduction of mitigation measures. The fishery is rated "moderately effective" for this factor.

Factor 3.3 - Scientific Research And Monitoring

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

Moderately Effective
As of the 2017 stock assessment update for American eel, several fishery-dependent and fishery-independent surveys are used to estimate population trends and abundance. These surveys provide information on catches, but are focused on early life stages (e.g., the YOY surveys) and are not very effective for determining adult biomass. The first assessment to pass peer review was in 2012 (after the 2005 assessment did not pass peer review), and reference points have not yet been established, so the effectiveness of the monitoring scheme is unknown. More accurate commercial catch and effort data, fishery independent surveys, and additional length, age, and sex information for yellow and silver eels were all noted as data needs for improved assessments in the benchmark assessment (ASMFC 2017). Illegal catches are suspected to be a major source of mortality for eel, but are also uncertain. Information about stock productivity and mortality rates is also lacking, but data goals (such as improved assessments of recruitment and mortality) have been set for the fishery. Because a diverse dataset was used for the assessment, and data needs have been identified, the eel fishery as a whole is ranked as "moderately effective" for scientific research and monitoring.
Justification:
Fishery-independent surveys used in the eel stock assessment are all evaluated using the same set of criteria. The states and jurisdictions in ASMFC are required to carry out annual young of the year (YOY; these are glass eels) abundance surveys, which are used to quantify recruitment. These data are published in the stock assessment, and the Maine Department of Marine Resources is quantifying upstream migration of YOY eels as part of their American Eel Project (http://www.maine.gov/dmr/science-research/searun/programs/eels.html). States are required to weigh and count eel catch and report CPUE for each sampling day. There are standardized survey locations, and states are also recommended to provide biological samples, which are measured, weighed, and assigned to a pigmentation stage {ASFMC 2012}. States send YOY monitoring data to ASMFC annually.

Factor 3.4 - Enforcement Of Management Regulations

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

Moderately Effective
Enforcement of ASMFC management measures varies by state. The state of Maine implemented an electronic fisherman-dealer buying system that was designed to track glass eel from the point of harvest to sale and export (pers. comm., Feigenbaum to S. Roberts 2018). In Maine, state enforcement officers check eel fishing licenses and transaction cards (which allow harvesters to sell glass eels). South Carolina regulates glass eel harvest by capping the number of permit holders at 10 individuals, who must abide by effort controls and report their harvest to the state (ASMFC 2017). In 2016, preliminary landings from the yellow eel fishery (928,359 t) were above the coastwide cap, and although these landings are not yet finalized, they may indicate that enforcement has not been as effective as it should be to maintain the stock. In April 2018, a draft of Addendum V was released for public comment, which proposes changes to management triggers and coastwide caps (ASMFC 2018). There is significant concern about illegal harvest in all states where eel are present, including states with legal eel fisheries, and illegal export and harvest occurs throughout their range. Because there are federal management regulations in effect, but there is still a significant amount of illegal harvest, American eel is scored as "moderately effective" for this criterion.
Justification:
Eel farming, which is responsible for nearly all production of *Anguilla* spp. worldwide, relies on the wild capture of glass eels. Demand for glass eels has led to a high price per lb in these fisheries. This high demand has benefitted many eel fishermen, but is thought to be responsible for an increase in illegal harvesting and trade of live glass eels. Eels can be legally shipped overseas from the US from states with legal fisheries, even if they are illegally caught. This makes it especially difficult for the ASFMC's Law Enforcement Committee (LEC) to monitor and control a limited harvest of glass eels (ASMFC 2014). Addendum IV to the American eel FMP states that more complex quota systems will be more difficult to enforce (ASMFC 2014), but that enforcement agencies are increasing patrols, coordinating more with local enforcement authorities, and communicating the importance of glass eel cases to judiciary officials {ASFMC 2014}. Additionally, states have been encouraged to change regulations to facilitate field enforcement and penalties, especially given the inter-state nature of the illegal glass eel trade {ASFMC 2014}.

The US Fish & Wildlife Service and the Justice Department’s Environmental Crimes Section in collaboration with several local jurisdictions, have an ongoing investigation into illegal eel harvests in the US, "Operation Broken Glass," which has resulted in several indictments and guilty pleas so far (DOJ 2018).

Factor 3.5 - Stakeholder Inclusion

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

Highly effective
A request for "non-traditional stakeholders" to be included in the ASMFC American Eel Advisory panel was released in 2005, and there are public comment periods during which 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. However, 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	SCORE
Northwest Atlantic | Barriers, fences, weirs, corrals, etc. | United States	3	0	Moderate Concern	**Yellow (3.000)**
Northwest Atlantic | Pots | United States	3	0	Moderate Concern	**Yellow (3.000)**
Northwest Atlantic | Pots | United States | North Carolina	3	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 - Impact of Fishing Gear on the Habitat/Substrate

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

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

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

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

0
Fishing effort on eels with weirs is likely to be low relative to other gear types, but could potentially have similar habitat impacts to other barriers, such as dams, 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 as 0 for this criterion.

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

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 (Center for Coastal Resources Management; http://ccrm.vims.edu/marine_debris_removal/index_temp.html). However, there are no modifications to eel pots that are designed specifically to protect the benthic habitat from gear, so American eel has a score of 0 for this criterion.

Factor 4.3 - Ecosystem-based Fisheries Management

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

Moderate Concern

There is no explicit inclusion of ecosystem-based fishery management in the American eel FMP (ASMFC 2012). The FMP mentions that eels are thought to be important contributors to the movement of nutrients to upstream locations, and that other sources of mortality and impediments to migration are important to consider when setting the quotas, but it is unclear whether these are incorporated into decisions for quota setting or gear restrictions. The fishery lacks spatial management or other policies to protect ecosystem functioning and account for capture species' ecological role, but detrimental food web impacts are not likely {Seafood Watch Criteria 2016}. Therefore, the American eel fishery as a whole is is ranked as "moderate" concern.

Acknowledgements

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.

Seafood Watch would like to thank Megsie Siple for originally authoring this report, Fisheries Program Manager Sam Wilding for compiling the update, and several anonymous reviewers for graciously reviewing this report for scientific accuracy.

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Appendix B: Review Schedule

This report was updated in June 2020 to include a new rating for North Carolina pot fisheries, based on data and information supplied by North Carolina Division of Marine resources which demonstrated that interactions with Diamondback Terrapins (the limiting factor in Criterion 2 for pot fisheries) were unlikely due to the low salinity of Albemarle Sound where eel fishing takes place.

In addition, the rating for the glass eel fishery was removed from the report as it was identified that this fishery supplies eels for aquaculture operations rather than for a human consumption market.