NORTHEAST SKATE COMPLEX FISHERY MANAGEMENT PLAN

Update on Thorny Skate Rebuilding

A whitepaper prepared by the
Skate Plan Development Team
New England Fishery Management Council

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SUMMARY OF MAIN POINTS

- Thorny skate are in the twentieth year of a 25-year rebuilding plan and show no signs of rebuilding; biomass is currently 3.5% of the rebuilding target.
- Thorny skate retention has been prohibited since 2003; discards remain at about 1% of total skate discards.
- Thorny skate are widely distributed across the North Atlantic but are experiencing substantial biomass declines throughout the southern part of their range, including in the Gulf of Maine, the southern extent of their range and the main region they are found in U.S. waters.
- Climate change is a considerable challenge for thorny skate, a cold-water and largely sedentary fish, and likely is the greatest impediment to rebuilding. Other less certain obstacles include prey availability and grey seal predation.
- While previous Council priorities for skate have sought to address the failure of thorny skate to respond to rebuilding efforts, additional action beyond possession prohibition has been hampered by competing Council priorities and a delayed skate stock assessment.
- Proposed approaches to address thorny skate rebuilding include continued possession prohibition, gear-modifications or time-area closures targeted to the gear type and/or areas where thorny skate are most encountered, and revisiting the thorny skate rebuilding plan.
- Several ongoing/upcoming studies will inform decision-making on thorny skate, including research on the genetics and population structure of thorny skate across its range and in the Gulf of Maine, and on identifying areas of high risk for thorny skate bycatch.

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1. INTRODUCTION

Thorny skate (*Amblyraja radiata*) is managed under the Northeast Skate Complex Fishery Management Plan (Skate FMP) and is overfished but not experiencing overfishing. While the stock is in year 20 of a 25-year rebuilding plan, abundance has steadily declined, and survey biomass and abundance estimates have shown the stock to be persistently low (Figure 1). In December 2022, the Council approved the development of a white paper detailing potential approaches to support rebuilding thorny skate. This paper summarizes the state of knowledge about thorny skate and progress toward rebuilding and identifies potential approaches to managing the species.

2. THORNY SKATE BIOLOGY

<u>*Habitat and distribution*</u>

The species is broadly distributed and has been found from the Barents Sea to the North Sea, to waters off Iceland, Greenland, and Labrador, down to its southern extent in the Northwest Atlantic Ocean in waters off New York (Map 1). Thorny skates have been found in waters ranging from 20-1,400 meters in depth, across a broad array of substrate types (sand, gravel, mud, broken shell), and water temperatures ranging from -1.3 to 14°C. Comparisons of the NEFSC Bottom Trawl Survey and Cooperative Bottom Longline Survey suggest that thorny skate are caught more on rough bottom than on smooth (Sosebee *et al.* 2016). These surveys also suggest that the species prefers colder, deeper waters, with catch rates highest from depths of 40 - 95m and temperatures below 10°C (Link & Sosebee 2008).

Despite this, thorny skates have concentrated since the 1990s in the shallow, warm, basin of the western Gulf of Maine (Map 2, Map 3) (Sosebee *et al.* 2016). While warming water temperatures have been correlated with thorny skate shifting toward deeper, cooler habitat in its U.S. range (Nye *et al.* 2009) and in the North Sea (Dulvy *et al.* 2008), it is likely not the cause of any shift in the geographic center of biomass. Range contraction has been observed for thorny skate with declines in biomass, consistent with other North Atlantic species such as Atlantic cod (Kulka *et al.* 2006; Swain & Benoît 2006). While thermal barriers seem to not prevent movement toward more suitable habitat, dispersal ability, bottom substrate complexity, prey availability, and changes in ocean chemistry have been suggested as possible obstacles (Kneebone *et al.* 2020a; Pennino *et al.* 2019; Sosebee *et al.* 2016). Additionally, there is little evidence that thorny skate engage in long-distance migration, and the species appears to be sedentary

(Kneebone *et al.* 2020b). With the apparent constriction of their U.S range into the Gulf of Maine, individuals would therefore be less likely to disperse into more suitable habitat and may be reproductively isolated from other sub-populations (Grieve *et al.* 2021; Kneebone *et al.* 2020a). With the pace of ocean warming in the Gulf of Maine so rapid, the quality of habitat for the species may be unlikely to improve.

<u>*Life history*</u>

Thorny skate are a large-bodied species that can reach a total length of up to 105 cm and have a lifespan of up to 20 years (Packer *et al.* 2003). Size-at-maturity varies in different parts of their range, however, with thorny skate in the northeast Atlantic exhibiting a smaller size and age-at-maturity. In the Gulf of Maine and Scotian Shelf, two distinct reproductive morphs have been documented, a smaller phenotype that reaches maturity around 51 cm and a larger one that reaches maturity around 84 cm (Lynghammer *et al.* 2014). Female thorny skates are reproductively active year-round (Packer *et al.* 2003).

<u>*Diet and predation*</u>

Thorny skates have a diverse diet, eating copepods, krill, polychaetes, amphipods, fish, and crustaceans, depending on availability and body size. In the Gulf of Maine, fish are the primary food source, with herrings being especially important (Link & Sosebee 2008; NOAA Fisheries 2017). On the Grand Banks, declines in thorny skate biomass were correlated with similar declines in the biomass of snow crab, an important prey species in that region (Pennino *et al.* 2019).

The egg capsules of the species are a reported food source for Atlantic halibut, monkfish, and Greenland shark, while adults are prey for many large demersal fishes, including cod, as well as sharks, seabirds, other skates, and marine mammals (NOAA Fisheries 2017). Thorny skate are also a minor food source for gray seals, comprising ~6% of their diet based on a study from the Scotian Shelf (Beck *et al.* 2007). Predation from gray seals may be contributing to the natural mortality of thorny skate, particularly as the population of gray seals in Canada has increased dramatically to 424,300 individuals in 2016, and to 27,100 individuals between Maine and Massachusetts in the U.S. (NOAA Fisheries 2017; 2021; Swain *et al.* 2015). If this is occurring, this effect is likely localized, only impacting skates at less than 70m water depth close to gray seal haul-out areas (NOAA Fisheries 2017).

3. FISHERIES AND STOCK STATUS

<u>*Fishing mortality*</u>

Thorny skate was landed in target fisheries before a prohibition of commercial retention in the U.S. in 2003. Thorny skates have been a persistently small proportion of total skate landings, between 0.2% and 1.1%, from 2009 to 2019 (Table 2). Based on port sampling data, the percentage of thorny skate identified in skate wing landings declined from 3.61% in 2005 to 0.01% in 2012 (Curtis & Sosebee 2015)... In the U.S., total catch declined from over 5,000 mt in the late 1960s and 1970s, to 200-300 mt since 2008, with about 100-200 mt attributed to dead discards. The species accounted for ~1% of total skate discards (live and dead), or 400-600 mt. Thorny skate are predominantly caught in bottom trawl fisheries, but also longline, gillnet, and scallop dredge (Sosebee *et al.* 2016).

The thorny skate catch data provided here are estimates, as problems with skate speciation in the dealer and observer data have made use of these data difficult for species-level reporting. The NEFSC attributes skate catch to species by using catch proportions in the NMFS bottom trawl survey. Thus, estimated landings of thorny skate reported here are based on a proportion at length by species in the survey and may be overestimated, as this proportion was not adjusted based on an assumed rate of fishery compliance. It is likely though that fishery compliance with the possession prohibition is likely very high (Sosebee *et al.* 2016). Methods for attributing skate catch by species are being examined in the 2023 skate management track assessment.

Mandelman et al. (2013) found GOM trawl-caught thorny skate discard mortality to be 23%. This value has been used in place of the 50% discard mortality assumption since the 2014-2015 Specifications

Action. This rate has been further verified by research on longer-term (> 72 hour) discard mortality, which concluded that skate length was the most important predictor of discard mortality (Knotek *et al.* 2019). With the contraction of thorny skate into the western Gulf of Maine (Map 2, Map 3), an area of higher fishing effort, increased fishery interactions are likely occurring and negatively affecting recovery.

Stock status

Like other species managed in the Skate FMP, thorny skate is considered overfished if the most recent three-year moving average of the bottom trawl survey biomass index is below its biomass threshold reference point ($B_{threshold}$), which is ½ $B_{MSY\ proxy.}$ The $B_{MSYproxy}$ is the 75[th] percentile (average for barndoor) of its survey biomass index, measured in kg/tow during a specific set of years for each species (1963-2007 fall survey for thorny). $B_{threshold}$ for thorny skate is 2.06 kg/tow.

Thorny skate have been declared overfished since the establishment of the Skate FMP. Biomass has decreased from 5.6 kg/tow in the NEFSC bottom trawl survey in the 1970s to 0.15 kg/tow in 2019 and 2021 (Figure 2) (NEFMC 2022). Over the past decade, biomass has fluctuated between 0.08 kg/tow and 0.21 kg/tow with no clear trend. With the $B_{MSYproxy}$ rebuilding target for the thorny skate at 4.13 kg/tow, the species is currently at 3.6% of the biomass target.

Additional survey indices for thorny skate serve to reinforce the evidence of a decline (Sosebee *et al.* 2016). The Atlantic States Marine Fisheries Commission shrimp trawl survey indices of thorny skate biomass and abundance are highly variable but have declined over the time series. The Massachusetts Inshore Survey biomass indices also show a decreasing trend in both the spring and fall time series. In the Maine-New Hampshire Inshore Trawl Survey, thorny skate consistently are seen in 10-25% of tows in the spring but were more variable in the fall survey.

Like other skates, thorny skate are subject to overfishing if the percent change in the 3-year moving average of the survey biomass index declines by more than the average coefficient of variation (CV) of the survey time series. If so, fishing mortality is assumed to be greater than F_{MSY}. For thorny skate, the percent change is –20%. Thorny skate was last recommended to be subject to overfishing in 2013 due to the percent change being below that threshold. However, the percent change has been above the threshold ever since, so overfishing is not occurring. For example, the % change between the average index in 2017-2019 and 2019 and 2021 was +19.0%, so overfishing was not occurring. Notably, biomass has fluctuated at very low levels with no clear trend.

In 2011, a petition was filed to list thorny skate under the Endangered Species Act (ESA). NOAA Fisheries determined that a status review was not warranted at that time (76 FR 78891; Grieve *et al.* 2021). A subsequent petition was submitted in 2015, which was followed by a comprehensive status review under the ESA (NOAA Fisheries 2017). The review concluded that the species was unlikely to become extinct, and an ESA listing was unwarranted. This determination was supported by an estimate that the abundance of thorny skate in the Gulf of Maine, Georges Bank, and the Scotian Shelf could be as high as 6,000,000 fish (Sosebee *et al.* 2016), as well as the stability of the current thorny skate population across its wide geographic range..

Greater Atlantic population and management

While highly dispersed across the North Atlantic, the status of thorny skate across its range is highly variable. The population assessment of thorny skate conducted for the International Union for the Conservation of Nature (IUCN) status review in 2019 concluded that while thorny skate in the southern Northwest Atlantic region (Southern Gulf of St. Lawrence to the Gulf of Maine) and southern Northeast Atlantic region (North Sea) were both considered critically endangered, several other regions exhibited strong population growth (Table 1) (Kulka *et al.* 2021).

Thorny skate are one of the most common skate species in Canadian waters. Generally, the species has increased in the waters around the Newfoundland and Labrador shelf, and the northern Gulf of St. Lawrence, while decreasing in the southern Gulf of St. Lawrence, Scotian Shelf, Bay of Fundy, and eastern Georges Bank (Kulka *et al.* 2021). On the Scotian Shelf and Bay of Fundy, where the historical density of thorny skate was very high, there has been a 90% decline in abundance (Figure 3) (DFO Canada 2017; Jubinville *et al.* 2021). On Georges Bank, which was a minor component of the Canadian population, this decline was 62% (DFO Canada 2012). On the Grand Banks, thorny skate experienced a 68% decline between the 1970s and the early 1990s. In general, thorny skate in the northern part of their Canadian range have increased in abundance (NW Atlantic (north), Table 1) (Kulka *et al.* 2021). The species has a status of "Special Concern" by the Committee on the Status of Endangered Wildlife in Canada, defined as "a wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats."

In Canada, thorny skate landings are not prohibited. They are caught in targeted skate fisheries throughout the Atlantic coast, although only on the Grand Banks is a directed thorny skate fishery occurring. Directed fishing for both thorny and winter skate on the Scotian Shelf ended in 2002 due to low biomass (DFO Canada 2012). Thorny skate remain a major source of discards for both the trawl and gillnet fleets (Benoît 2013).

4. FISHERY REGULATIONS AFFECTING THORNY SKATE

Possession prohibition

The original Skate FMP, implemented in September 2003, prohibited possession of thorny skates on all vessels fishing in U.S. waters (largely located in the Gulf of Maine; NEFMC 2003). Skate dealers were also prohibited from purchasing thorny skate.

Rebuilding plan

Thorny skate is the one species in the Northeast Skate Complex that has been overfished since the beginning of the Fishery Management Plan and which remains overfished. The Original Skate FMP (implemented in 2003) established a rebuilding plan for thorny skate but did not adopt a rebuilding schedule due to the lack of critical life history information. Without the ability to determine F_{MSY}, the FMP defined the use of three-year survey averages to evaluate progress towards rebuilding the population to $B_{MSYproxy}$.

Through Amendment 3 (implemented in 2010), based on new life history parameter estimates, it was estimated that thorny skate would take longer than 10 years to rebuild; the Council estimated that it takes a female thorny skate 15 years to replace its own spawning capacity, i.e., its mean generation time (NEFMC 2009). The maximum rebuilding period allowed by the Magnuson-Stevens Act is 25 years (10 years plus one mean generation time) with flexibility to account for the biological and ecological considerations of the stock. Amendment 3 established a 25-year rebuilding period for thorny skate, or by 2028 when counted from the start of the rebuilding period in 2003. It was estimated that, based on biomass at the time (0.42 kg/tow in 2007), it would take an average annual increase of 13.2% to rebuild to the B_{MSY} target of 4.41 kg/tow by 2028 (the target since changed to 4.13). At the time, the PDT advised that the best estimate of the maximum intrinsic rate of population growth was 0.17, so achieving the biomass target within the rebuilding schedule seemed achievable.

Effort controls

Thorny skate also likely benefits from regulations that reduce effort in the fisheries primarily responsible for bycatch, such as closed areas, days-at-sea, catch limits, and other effort controls within the Northeast Multispecies, Monkfish, and Scallop FMPs. These regulations were not designed to reduce thorny skate bycatch, and their effectiveness is unknown.

5. EMERGING ISSUES

Vulnerability to climate change

The Gulf of Maine is experiencing the warmest water temperatures on record and thorny skate are particularly vulnerable to changing conditions. Projections of expected changes in surface and bottom (50 m) conditions suggest that while temperature is likely to keep increasing throughout the water column, surface salinity will likely decrease while increasing at depth, leading to increased water column stratification (Brickman *et al.* 2021). This is expected to lead to declines in primary productivity, nutrient cycling, and dissolved oxygen (Pershing *et al.* 2021), and recent analysis of a 20-year oceanographic time series of the Gulf of Maine has shown both warm and saline water intruding into the eastern Gulf of Maine at 50-180 meter depths from the North Atlantic Slope, as well as significant declines in primary production over the length of the time series (Balch *et al.* 2022). As thorny skate are a slow-growing and long-lived fish, there is evidence that such decreases in primary productivity can inhibit recovery from overfishing (Hilborn & Litzinger 2009; Hutchings & Reynolds 2004).

Thorny skate may be nearing the upper limit of their thermal range, reducing fitness, and limiting the potential for recovery. As a boreal, sedentary species, thorny skate may be particularly vulnerable to these conditions, potentially resulting in decreased ability to move to novel habitats with unfavorable conditions (Schwieterman *et al.* 2019). A climate change vulnerability assessment found thorny skate to have both a high exposure to climatic stressors as well as a high biological sensitivity to those stressors (Hare *et al.* 2016). One study projected the species' abundance in U.S. waters to decrease by 30-40% by mid-century, and up to ~70% by 2100 if climate emissions are not aggressively mitigated alongside active reduction of atmospheric CO_2 (Figure 4, Figure 5) (Grieve *et al.* 2021).

Vulnerability to offshore wind development

Floating offshore wind, as proposed thus far in the Gulf of Maine, is unlikely to pose an immediate risk to thorny skate. While not conclusive, recent studies suggest that floating offshore wind development in the Gulf of Maine would not pose an immediate risk to thorny skate recovery, however, there are important knowledge gaps, and additional research and monitoring is needed. Offshore wind development is largely being proposed in the Mid-Atlantic and western Georges Bank, however, the state of Maine has applied to the Bureau of Ocean Energy Management to lease 15 square miles for a floating offshore wind research site in the federal waters of the Gulf of Maine and commercial lease area designations are expected to be announced in 2023 (Map 3) (NEFSC 2023). A synthesis of the literature on the effects of floating offshore wind on marine organisms suggests that the effects on marine organisms are likely to be minor, including the effects of electromagnetic fields from transmission cables, habitat alternations, water quality, noise effects, atmospheric and oceanographic dynamics, and structural impediments (Farr *et al.* 2021). For electrosensitive fishes such as skates and other elasmobranchs, the effect of the electromagnetic fields generated from transmission cables is a noted concern. Properly shielded and buried transmission cables substantially limit the strength of the field. Field experiments investigating the effect of ecologically relevant electromagnetic fields on little skate (*Leucoraja erinacea*) found strong behavioral effects on swimming distance and speed, but the fields did not present a barrier to movement (Hutchison *et al.* 2018). There is no evidence yet to suggest that electromagnetic fields generated by transmission cables would have a consequence on the reproduction or mortality of electrosensitive fishes.

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6. Prior Council discussions on the rebuilding of thorny skate

In 2009, habitat closures designed to conserve skates were developed through Amendment 3 to the Skate FMP, but these were considered but rejected by the Council. The rationale for this rejection was that their effectiveness would be limited, as there was low fishing effort in the recommended areas already, and because of the potential for effects on fisheries targeting other species. In the establishment of the 25-year rebuilding period for thorny skate, Amendment 3 cautioned that predicting the pace of rebuilding would be impossible given data limitations and limited understanding of the species' population dynamics.

Despite the prohibition on possession since 2003, thorny skate was considered subject to overfishing in 2013. There was then renewed discussion about potential approaches to address the lack of rebuilding progress. NOAA Fisheries sent a letter to the Council indicating that overfishing needed to be addressed for thorny skate, although no timeline for action was specified. In response, the Skate Committee recommended that the PDT develop alternatives, and there was Committee consensus that a possession prohibition was insufficient. Addressing the lack of rebuilding progress for thorny skate was then listed as a Council priority in 2014, but no timeframe was agreed upon. The status of thorny skate then changed in 2014; overfishing was no longer occurring. In 2015, the PDT brought a memo to the Skate Committee regarding issues about managing skates as a complex. One proposal considered was to manage thorny skate under the Northeast Multispecies FMP. Ultimately, the Committee found this to be overly complicated and likely to create additional confusion. While there was a desire for further exploration of measures that would promote rebuilding, the Council has not set this as a priority since.

In 2020, the Committee recommended that a literature review on recent thorny skate research be conducted by the PDT, and in response, the PDT has been providing research updates in the Annual Monitoring Reports and updating the SSC during specifications setting. In 2021, the Regional Office was prepared to send a letter to Council regarding the failure of thorny skate rebuilding but was waiting until the scheduled skate assessment concluded. However, the assessment was pushed back until the summer of 2023, and no letter was issued. In 2022, the Council set the development of this white paper on thorny skate rebuilding as a 2023 work priority.

7. Potential approaches

Below are some approaches to promote thorny skate rebuilding. The first four listed are within the Council's ability to consider.

Continue prohibition on thorny skate possession

With thorny skate biomass so far below $B_{MSYproxy}$, there is little evidence that the stock can support a fishery, and any additional mortality will negatively affect rebuilding efforts. Continued prohibition would allow the stock the opportunity to rebuild.

The PDT recommends that the prohibition of thorny skate possession continue. The PDT notes that winter, barndoor, and smooth skates have all been rebuilt in the past with possession prohibitions. Notably, thorny skate has not responded to this measure, so perhaps other measures should be considered in addition.

Designate closed areas to minimize thorny skate bycatch

Due to the species aggregating in the western Gulf of Maine where fishing effort is higher, thorny skate bycatch may be an important barrier to rebuilding. Previous work in the Cashes Ledge groundfish closure found that 90% of satellite-tagged skates remained inside the closure for at least 300 days (Kneebone *et al.* 2020b). This supports the conclusion that thorny skate are largely sedentary and suggests that closures might promote the conservation and recovery of the species. Notably, there are several existing fishery closures in the Gulf of Maine (e.g., Northeast Multispecies Closed Areas). Additional closures could be either rolling or permanent to account for seasonal variation in fishing effort in these areas and/or be targeted toward gear types and areas where bycatch is occurring in the Gulf of Maine. Skate closures may be implemented through a framework adjustment (50 CFR 648.321(b)(11)).

The PDT recommends that, if the Committee wishes to pursue this approach, an analysis of the overlap of thorny skate biomass and existing Gulf of Maine closures be conducted to help assess where and when additional protections may be warranted.

Consider gear configurations that reduce thorny skate bycatch

Skate-specific gear restrictions could be developed that target specific gear types fishing in the western Gulf of Maine and may be implemented through a framework adjustment (50 CFR 648.321(b)(11)). Prior research on fishing gear configurations that reduce flatfish catch should be considered. The PDT has noted to the Committee in the past (e.g., March 10, 2021 memo) that the Skate FMP does not have specific gear requirements. If a vessel has a federal limited access fishing permit, it must make a federal declaration or declare out of fishery (DOF). All vessels fishing for skates while on a declared NE multispecies, monkfish, or scallop trip using a day-at-sea must follow the gear regulations for the declared fishery. Any modifications to gear regulations in those fisheries would need to be revised within those FMPs. There are a few scenarios where a vessel can declare out of the fishery and have skate-specific gear requirements, such as if a vessel is fishing within a skate exemption area in Southern New England or the Mid-Atlantic. In that case, possession and landings of skate or skate parts must be at most 10%, by weight, of all other species on board, or 500 lb of skate wings, whichever is less.

The PDT recommends that, if the Committee wishes to pursue this approach, the PDT could conduct a literature review to determine what information may be available on reducing skate discards via gear modifications (also suggested in March 10, 2021 memo). The PDT is unaware of fishing gear that would exclude thorny skate specifically.

Revisit rebuilding plan

If a species is not rebuilt within the timeline identified in its rebuilding plan, the plan needs to be reviewed by either the relevant Council or NMFS Regional Fisheries Office, the reasons for failure evaluated, and a new rebuilding plan implemented. While such review is typically initiated after a letter from NMFS to the Council regarding the failure of a stock to rebuild, the Council may initiate this process at any time.

The PDT recommends that the Council expect to revisit the rebuilding plan for thorny skate. Should the 2023 skate assessment conclude that thorny skate continues to be overfished, it is likely that NOAA Fisheries will inform the Council that there has been inadequate progress toward rebuilding.

Other potential approaches beyond the Council process

As the decline in thorny skate biomass in the Gulf of Maine parallels similar declines in Northwest Atlantic Fisheries Organization (NAFO) management areas on the Scotian Shelf, there may be an opportunity to facilitate an international agreement through NAFO to promote thorny skate recovery across the Northwest Atlantic.

8. ONGOING RESEARCH AND RESEARCH NEEDS

Several ongoing research projects and identified research needs will facilitate a greater understanding of thorny skate life history and interaction with fishing gear as well as refine current estimates of biomass in the Gulf of Maine.

Investigate differences in distribution and abundance trends of the two reproductive morphs of thorny skate

Further analysis into the two distinct reproductive morphs of thorny skate may allow for management actions that exploit differences in life history or behavior. Current genetic research is investigating the spatial population structure of thorny skate across its range and determining if there may be any genetic distinctions between the two reproductive morphs within the Gulf of Maine (Kneebone, personal communication).

Consideration of survey data sources beyond the Bottom-Trawl Survey for assessing thorny skate biomass

Additional surveys, such as the Atlantic States Marine Fisheries Commission Shrimp Survey, the Massachusetts Division of Marine Fisheries spring and fall trawl surveys of inshore waters, and the Maine-New Hampshire Inshore Trawl Survey, could supplement the NEFSC Bottom Trawl Survey area coverage. The NEFSC Gulf of Maine Longline Survey has greater catchability for thorny skate and can sample hard bottom habitat. An integrated survey dataset could provide better precision in monitoring rebuilding efforts. Indices from surveys in addition to the bottom trawl survey are expected to be updated during the 2023 skate management track assessment.

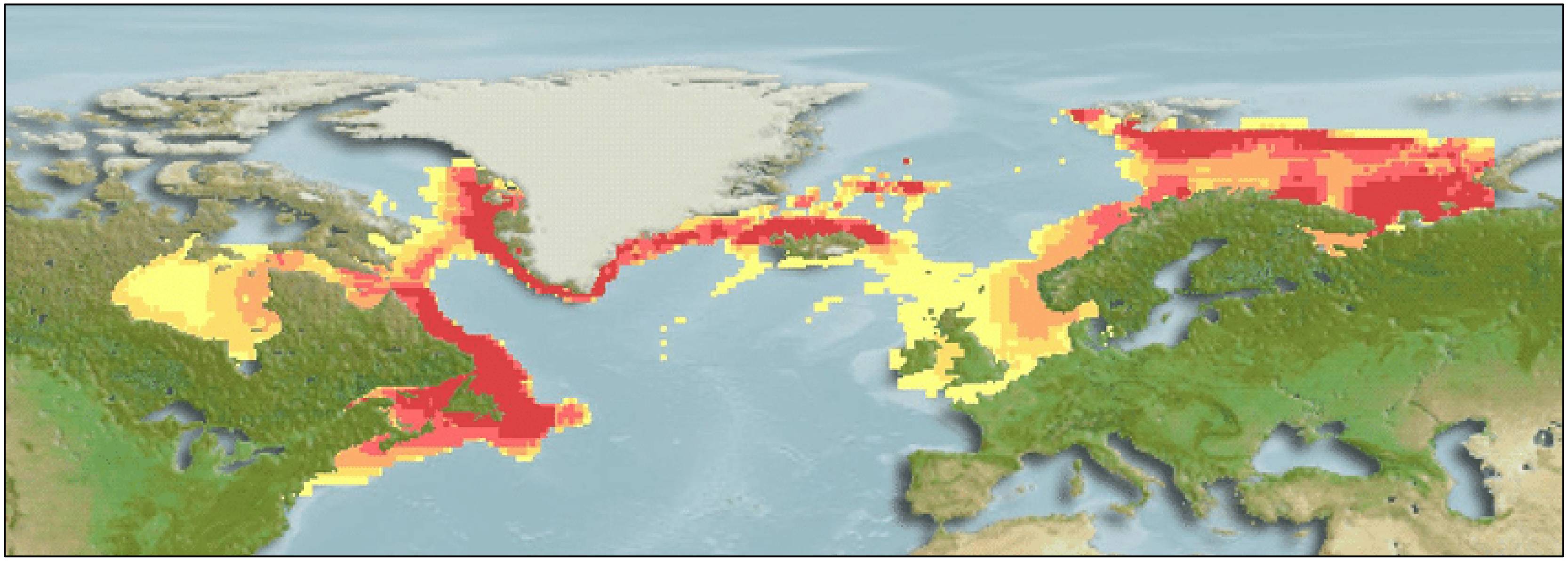
Analysis of thorny skate bycatch hotspots

An upcoming study on thorny skate bycatch hotspots in the Gulf of Maine could help identify areas and seasons that would see the greatest benefit of a closure or other avoidance measures (Kneebone, personal communication).

Maps, Tables and Figures

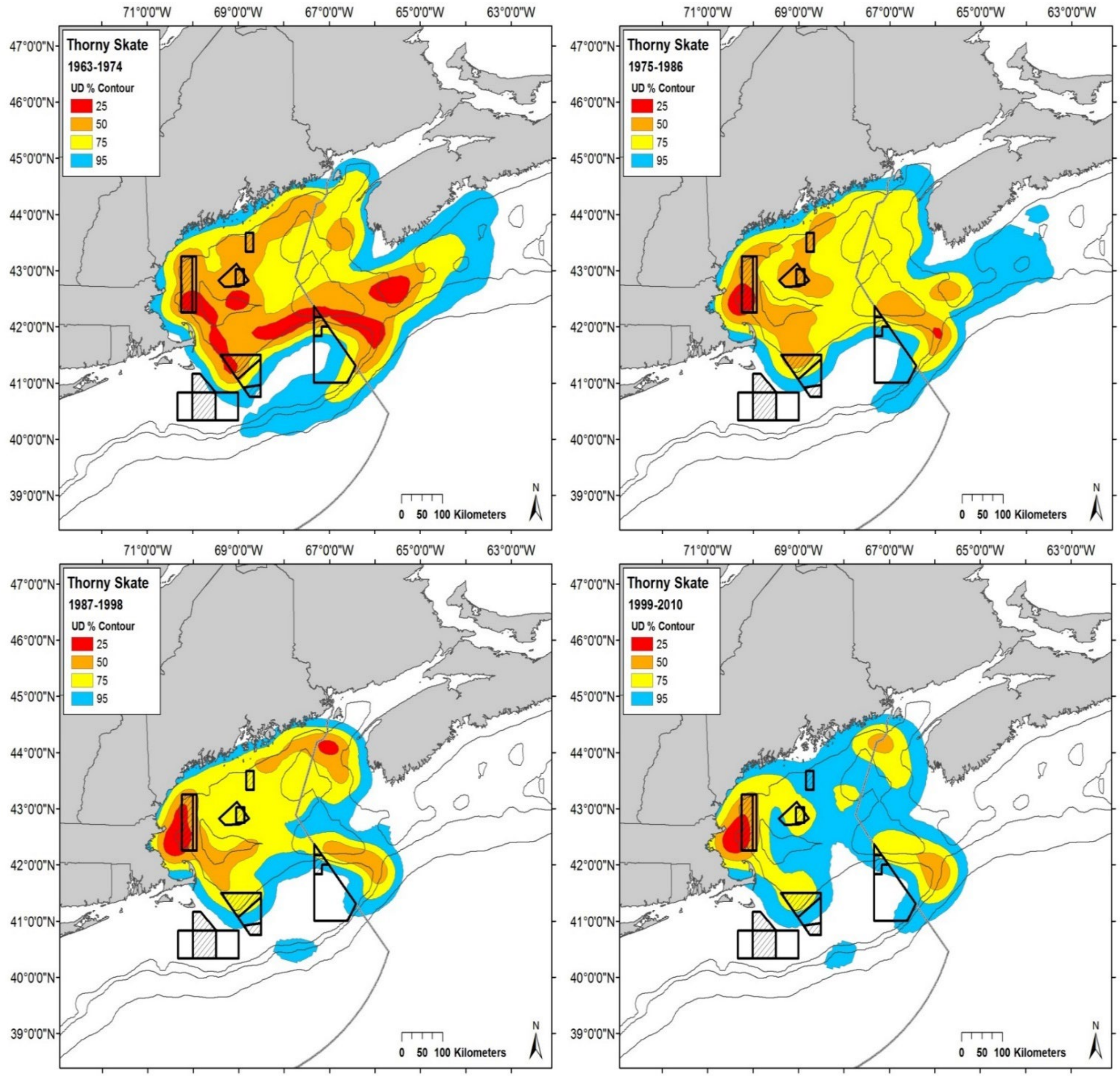
Map 1. Thorny skate range and probability of occurrence.

Source: NOAA Fisheries (2017).



Map 2. Fixed kernel utilization distribution (UD) of positive thorny skate tows for four time periods from the NEFSC bottom trawl survey. Northeast multispecies year-round closed areas and habitat closed areas shown; warmer colors indicate higher density of thorny skate presence.

Source: Prior work of the Skate PDT.



Map 3. Biomass (kg/tow) of thorny skate from the NEFSC Fall Bottom-Trawl Survey, 2010 – 2019, with warmer colors indicating areas of higher observed biomass. The orange polygon delineates the Gulf of Maine Draft Call Area released in January 2023 by the Bureau of Ocean Energy Management.

Source: Northeast Ocean Data Portal, accessed May 2023.

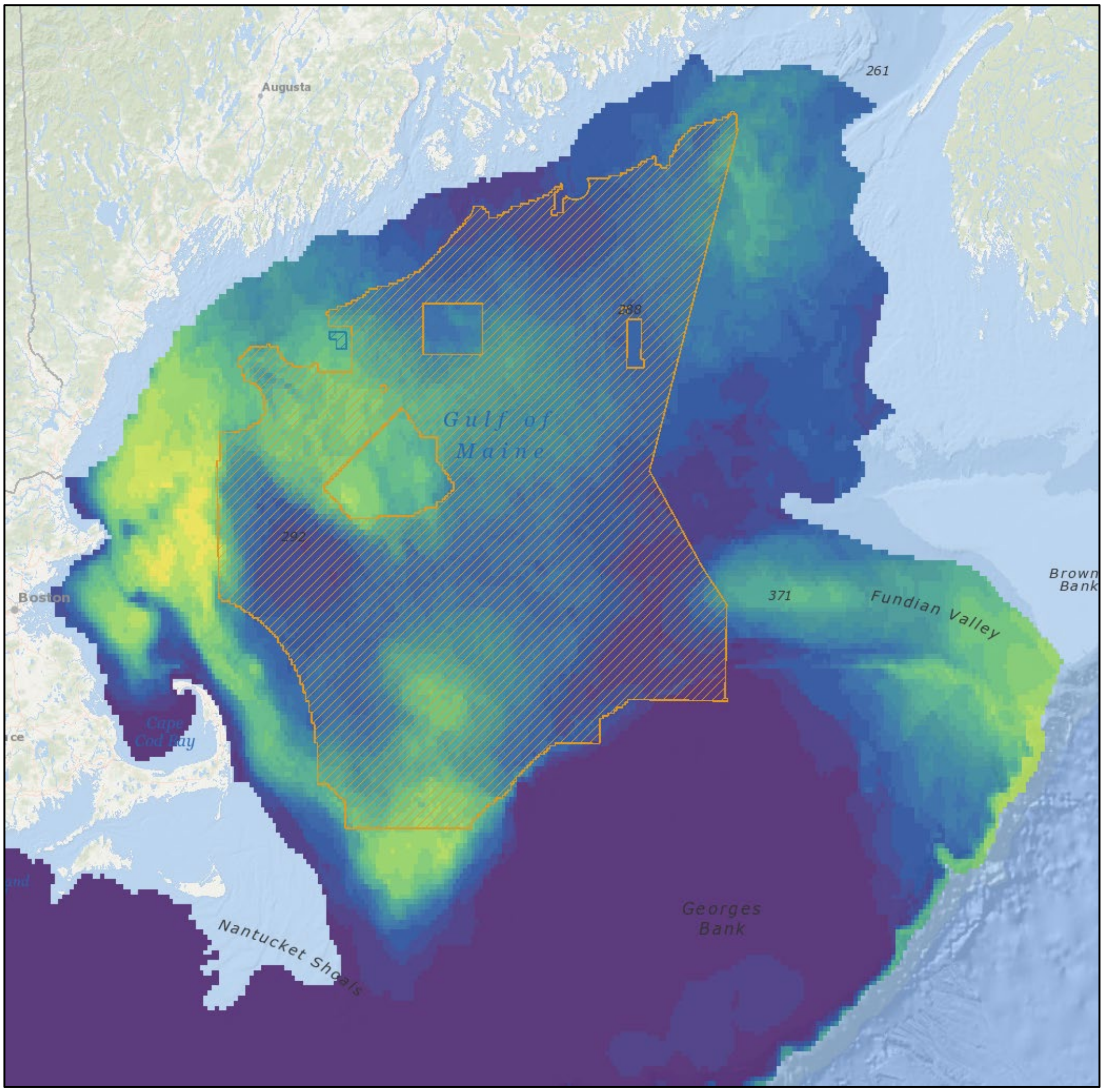


Table 1. Thorny skate population change by region (%) and probability for changes falling within the IUCN Red List categories.

Region		Generation Length (Years)	Time Series	Proportional Area Weighting	Population Median % change	LC	NT	VU	EN	CR	Likely status
NW Atlantic	South	16.0	1963-2018	0.15	-96.0	0	0	0	0	**100**	**CR**
	North	10.6	1973-2018	0.25	8.5	**82**	9	8	1	0	**LC**
N Atlantic	W. Greenland	10.6	1992-2017	0.1	52.9	**86**	4	6	4	0	**LC**
	Iceland	10.6	1986-2020	0.1	-42.8	0	5	**83**	12	0	**VU**
NE Atlantic	South	10.6	1980-2020	0.25	-83.2	0	0	0	26	**74**	**CR**
NE Atlantic	North	10.6	2003-2016	0.15	226.2	**100**	0	0	0	0	**LC**
Global						**54**	3	11	6	26	**LC**

Note: Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), and Critically Endangered (CR). "Likely status" is based on IUCN assessment criteria and is assigned based on the category containing the highest probability, with the exception that NT is also selected where LC obtained the highest probability, but it is < 50%. All probabilistic statements are based on the rate of change over three generation lengths. Global change is based on weighting the regional posterior probabilities by the proportional area weighting.

Source: Table adapted from the 2019 IUCN assessment supplementary materials provided by Kulka et al. (2021).

Table 2. Skate landings, CY 2009 to 2019.

Calendar Year	Skate Landings (mt)								
	Winter	Little	Barndoor	Smooth	Clearnose	Rosette	Thorny	Total	Thorny Skate as % of total
2009	12,767	5,191	672	19	883	108	90	**19,731**	0.45%
2010	12,370	4,409	1,030	48	617	8	203	**18,683**	1.09%
2011	10,616	4,586	1,066	21	542	12	120	**16,963**	0.71%
2012	9,227	4,563	2,470	3	802	7	71	**17,144**	0.41%
2013	8,119	3,914	1,683	12	829	18	123	**14,698**	0.84%
2014	8,888	3,981	2,326	3	516	13	177	**15,904**	1.11%
2015	8,134	5,169	1,331	4	787	15	93	**15,532**	0.60%
2016	9,404	5,443	591	47	200	11	103	**15,799**	0.65%
2017	8,961	4,751	521	4	205	5	23	**14,470**	0.16%
2018	8,461	5,152	426	5	242	12	42	**14,341**	0.29%
2019	7,681	3,430	562	15	818	7	46	**12,559**	0.36%

Note: Skate landings use dealer-reported total landings, which are then attributed to species using NEFSC survey proportions at length. Thus, landings by species reported here may not exactly match actual landings composition.
Source: NEFSC data, accessed February 2023.

Table 3. Estimated discards and landings of thorny skate, CY 2009 to 2019.

Calendar Year	Estimated Discards (mt)				Estimated Discards (mt)	Estimated Landings (mt)	Dealer Reported landings (mt)	Estimated Total Catch (mt)
	Longline	Otter Trawl	Sink Gillnet	Scallop Dredge				
2009	1	69	9	27	106	90	< 1	**196**
2010	4	89	12	23	127	203	8	**330**
2011	2	73	9	29	112	120	< 1	**232**
2012	1	62	7	34	104	71	< 1	**175**
2013	2	89	8	44	142	123	0	**266**
2014	1	74	7	53	135	177	3	**312**
2015	2	57	6	73	137	93	3	**230**
2016	1	60	8	37	106	103	4	**209**
2017	1	37	8	38	82	23	< 1	**106**
2018	0	61	5	58	124	42	< 1	**167**
2019	0	63	3	55	122	46	< 1	**167**

Note: Estimated discards and landings of skates are attributed to species using NEFSC survey proportions at length by area. A 50% discard mortality rate is assumed for all gear except for otter trawl, which used a 23% rate.
Source: Estimated discards from NEFSC data accessed February 2023, Dealer reported landings from CAMS, accessed May 2023.

Figure 1. Abundance of thorny skate (*Amblyraja radiata*) from the NEFSC spring (circles) and fall (squares) bottom trawl surveys from 1963-2015 in the Gulf of Maine to Southern New England offshore region.

Source: Sosebee *et al.* (2016).

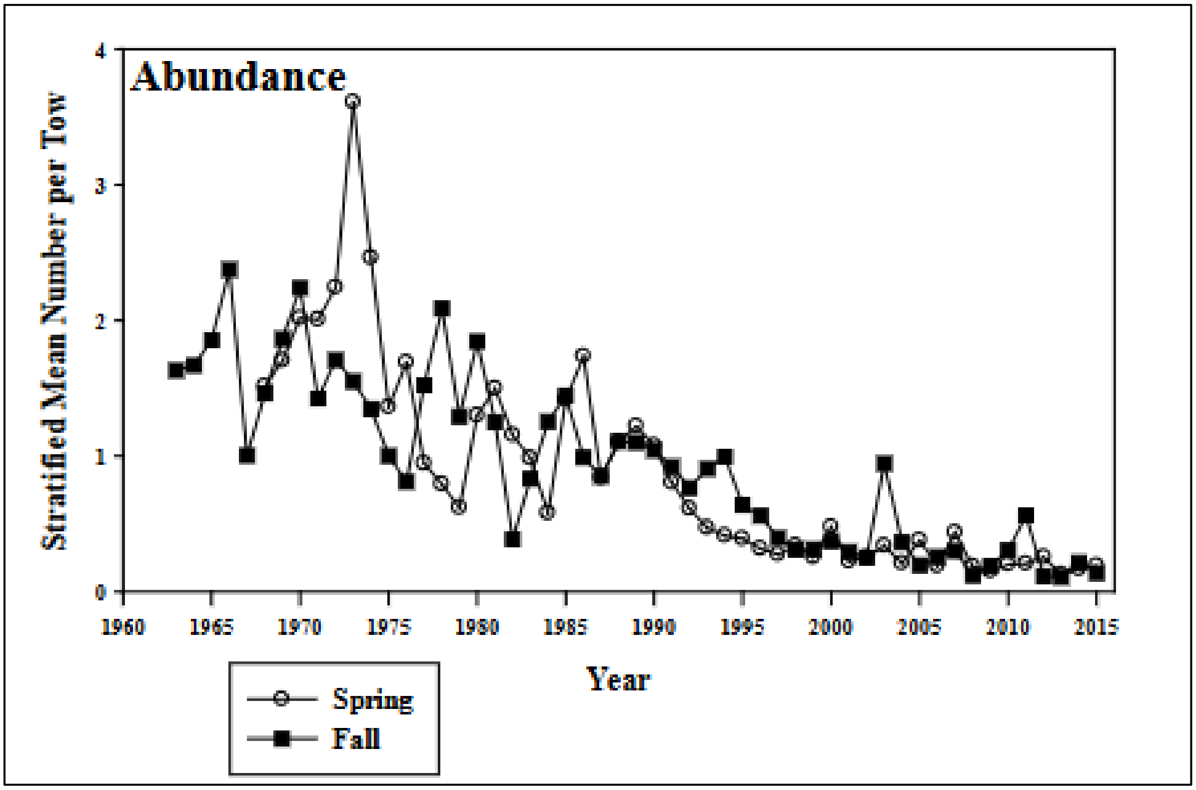


Figure 2. NEFSC survey biomass index for thorny skate (kg/tow). Thin line with symbols is annual indices, thick line is 3-year moving average, the thin horizontal lines are the biomass threshold and target developed through 2007/2008 with consistent strata set.

Source: NEFMC (2022).

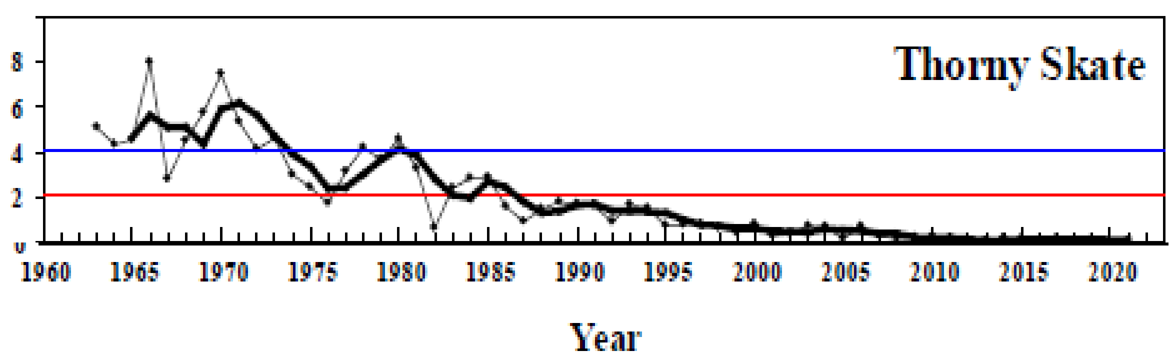


Figure 3. Biomass index for thorny skate in NAFO Div. 4X (Western Scotian Shelf and Bay of Fundy) from the DFO-MAR summer research survey represented by the solid black line. The straight long dashed-dot line indicates the long-term survey average (1970-2016). The dashed line represents the medium-term 15-year average (2002-16), and the short, dotted line represents the short-term 5-year average (2012-16).

Source: DFO Canada (2017).

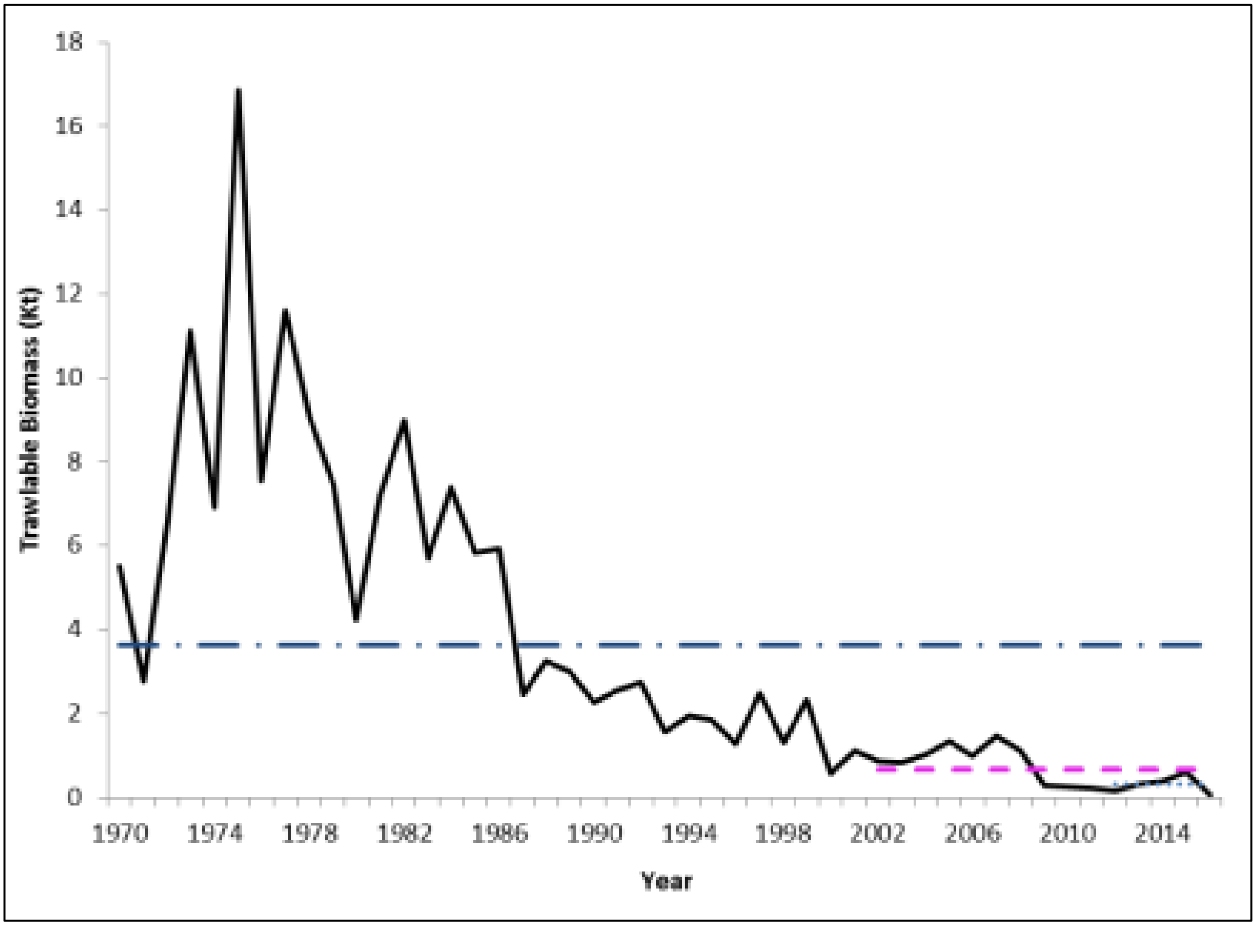


Figure 4. Projected change in catch per unit effort of thorny skate in an area by the 2046–2065 period from the 1986-2005 period under a "business as usual" emissions scenario. Subplots are split by season and capture methodology of training data set. Bottom trawl models (a, b, d, e) are split by length of the training series, while longline models (c, f) were trained with all available years.

Source: Grieve *et al.* (2021).

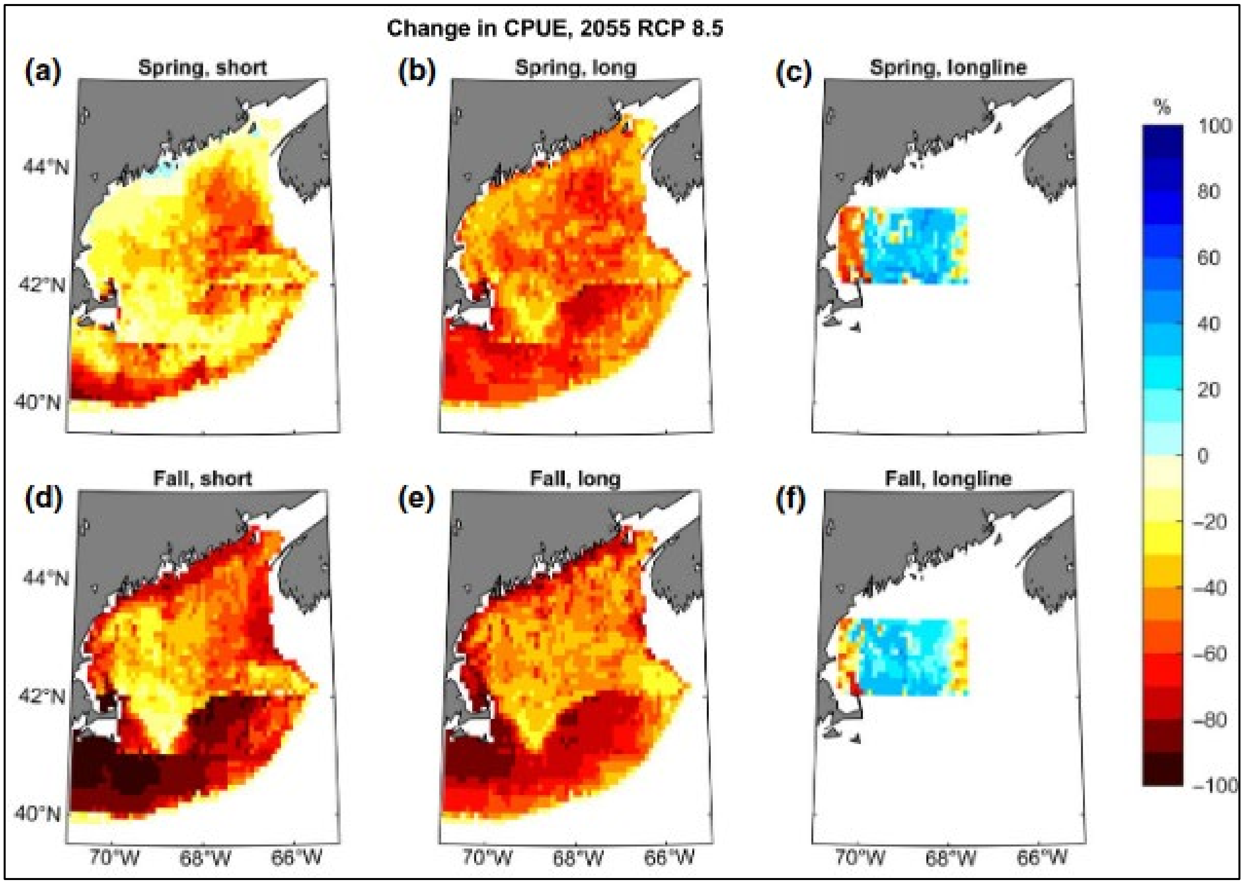
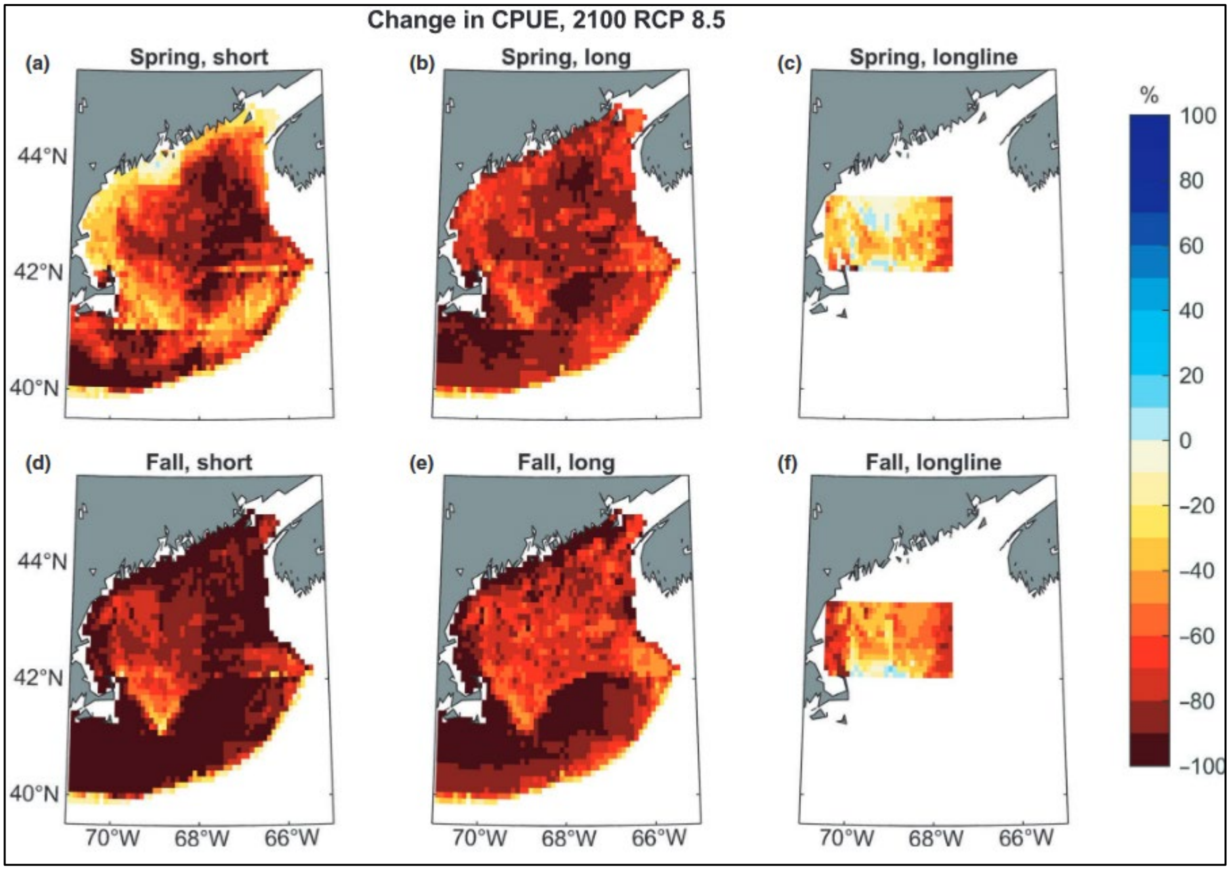


Figure 5. Projected change in catch per unit effort of thorny skate in an area by the 2081–2100 period from the 1986–2005 period under a "business as usual" emissions scenario. Subplots are split by season and capture methodology of training data set. Bottom trawl models (a, b, d, e) are split by length of the training series while longline models (c, f) were trained with all available years.

Source: Grieve *et al.* (2021).



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The document was also informed by input of the Skate Committee and the Skate Advisory Panel, particularly the Chair of the Skate AP, Dr. Jeff Kneebone of the New England Aquarium. Dr. Kneebone is a scientist specializing in thorny skate.

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