Table 2. Studies into the climate impacts on NAFO-managed species. Habitat loss: The proportion of the species native geographic range projected to become thermally unsuitable. Emergence: The average year when the temperature is projected to exceed the thermal niche of the species across its native geographic range. Risk: The climate risk for the species, considering its projected habitat loss, emergence time, and the available published climate impact studies. Table references are in the supplementary materials.

Highlights	Habitat loss	Emergence	Risk
Atlantic wolffish (*Anarhichas lupus*)			
- Relatively narrow thermal range (-1°C–10°C); (Beese and Kandler, 1969; Albikovskaya, 1982; O'Dea and Haedrich, 2000). - Significantly affected by warming and deoxygenation (Dutil *et al.*, 2014; Bianucci *et al.*, 2016; Brennan *et al.*, 2016; Árnason *et al.*, 2019; Bluemel *et al.*, 2022; Lavin *et al.*, 2022). - Optimal temperature for adult growth is 6.6°C to 8°C for adults (Imsland *et al.*, 2006; Lamarre *et al.*, 2009), and 11.5°C for juveniles (Hansen and Falk-Petersen, 2002). - Altered distribution northward and into deeper waters in response to warming (McCarthy *et al.*, 1999) and shifted migration routes (Orlov *et al.*, 2023).	11%	2087±24	High
Capelin (*Mallotus villosus*)			
- Moderately wide thermal range (-1.5°C–14°C) with a preference for waters between -1°C and 6°C (Rose, 2005). - In the late 1980s, cooling led to an extension of capelin distribution into the southern Gulf of St. Lawrence and eastern Scotian Shelf (Gregoire *et al.*, 2005; Rose, 2005). - Rose (2005) reported temperature changes as small as 1°C associated with changes in distribution over scales of hundreds of kilometers; temperature changes may result in much larger displacements, including the establishment of new spawning sites. - Orlova *et al.* (2005) reported several indirect effects of climate on capelin distribution and energy reserves involving the abundance and species of copepod prey. - Warming affects vertical migration (Davoren and Montevecchi, 2003) and behaviour (Frank *et al.*, 2016) and linked to changes in spawning timing (Murphy *et al.*, 2021). - Climate-driven sea ice reductions affect primary production and prey availability (Buren *et al.*, 2019). - Limited information about the impacts of changing oxygen and pH.	17%	2082±30	High
Greenland halibut (*Reinhardtius hippoglossoides*)			
- Moderately wide thermal range (-1.89°C–15°C) with preferred temperatures between 0 and 7°C (Shackell *et al.*, 2013; Boje *et al.*, 2014; Ruth *et al.*, 2023). - Optimal temperature for aerobic scope of 2.4°C (Ruth *et al.*, 2023), with decreased survival and growth above 7.5°C (Ghinter *et al.*, 2021). - Temperature affects genomic variation, affecting growth and migration patterns (Ferchaud *et al.*, 2022). - Warming associated with vertical distribution shifts to maintain preferred temperatures, with younger individuals showing the largest shifts (Wheeland and Morgan, 2020). - Bottom temperature warming between 1993 and 2003 led to increased growth rates of juveniles of 1.6cm°C^{-1} (Sünksen *et al.*, 2010). - Experiments indicate that juvenile halibut are sensitive to even small reductions in dissolved oxygen, with severe hypoxia reducing the maximum metabolic rate by 55% (Dupont-Prinet *et al.*, 2013a). - Juveniles are more sensitive to hypoxia than adults (Dupont-Prinet *et al.*, 2013a). - Warming and deoxygenation in the Gulf of St. Lawrence projected to reduce the highest density halibut aggregations by 55%; oxygen levels are already at the species limit (Stortini *et al.*, 2017).	4%	2094±15	Moderate
Northern shrimp (*Pandalus borealis*)			
- Narrow thermal range (1°C–6°C) with a preferred range of 1–4°C (Allen, 1959; Shumway *et al.*, 1985; Apollinio *et al.*, 1986; Colbourne and Orr, 2005) with optimum for larvae is reported to be 9°C. One anomalous study reported an upper thermal limit for shrimp of 12°C (Bjork, 1913). - Warming adversely affects recruitment (Wieland and Siegstad, 2012; Jónsdóttir *et al.*, 2013). - Warming decreases growth rates, possibly due to increased metabolic demands, leading to reduced body size (Koeller *et al.*, 2007). - Warming will significantly affect shrimp hatching and recruitment, including altered timing of hatching (Brillon *et al.*, 2005; Koeller *et al.*, 2009; Richards, 2012; Arnberg *et al.*, 2013). - Coherence between shrimp hatching times and phytoplankton seasonal blooms across the North Atlantic driven by bottom temperature (Koeller *et al.*, 2009), suggesting that climate change could lead to a phenological mismatch (Cushing, 1990) and poor recruitment (but see (Chang *et al.*, 2021) for an alternative hypothesis). - Relatively tolerant to hypoxia, with males being more tolerant on average than females (Dupont-Prinet *et al.*, 2013b).	24%	2073±32	High

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Roughhead grenadier (*Macrourus berglax*)			
- narrow thermal range (-0.5°C–5.4°C).	31%	2065±31	High
Splendid alphonsino (*Beryx splendens*)			
- Moderate thermal range (-2°C–17°C).	28%	2072±35	High
Witch flounder (*Glyptocephalus cynoglossus*)			
- Moderately wide thermal range (-1°C–11.4°C), with 15°C an optimal for larval growth (Bidwell and Howell, 2001).	11%	2087±24	High
Yellowtail flounder (*Limanda ferruginea*)			
- Wide thermal range (-1°C–18°C). - Oxygen consumption declines at temperatures above 14°C (MacIsaac *et al.*, 1997). - Preferred temperature range is -1 to 5.8° C (Walsh, 1992a), while optimal feeding is between 6.8°C and 7.1°C (Hyun *et al.*, 2014). - Projected northward shifts from the Gulf of Maine in response to warming (Palacios-Abrantes *et al.*, 2020). - Temperature variation affects growth and development (Benoît and Pepin, 1999) as well as distribution (Pinhorn and Halliday, 2016) and movement (Hyun *et al.*, 2014). - Warming negatively affects recruitment variability (Robertson *et al.*, 2024). - Brodie *et al.,* (2010) reported positive effects of warming on yellowtail flounder on the Grand Bank, with cooling associated with stock declines and warming with recovery. - Distributions were relatively insensitive to temperature fluctuations (Walsh, 1992).	7%	2091±20	High
Atlantic cod (*Gadus morhua*)			
- Wide thermal range (-1.5°C–19°C), yet studies have reported an optimal metabolic scope between 10 and 14.5°C (Tirsgaard *et al.*, 2015). - Optimal growth is higher (15.1°C) for smaller younger individuals (Bolton-Warberg *et al.*, 2015), and smaller cod have been experimentally found to prefer warmer temperatures (Lafrance *et al.*, 2005). - Experiments indicate that at 17°C, cod experience heightened immune activity indicative of stress (Lazado *et al.*, 2023), while at 18°C, they experience energetic limitations (Hu *et al.*, 2016). - At 9°C, cod have been found to experience erratic spawning frequencies (Kjesbu *et al.*, 2023). - Temperature significantly affects the geographic distribution of cod (Edvardsson *et al.*, 2022). - During warmer regimes, cod have been found to inhabit deeper, cooler waters, particularly larger older individuals, while cold regimes led to reduced activity and vertical movement (Freitas *et al.*, 2015; Nian *et al.*, 2021). - Winter *et al.* (2020, 2023) reported that warming exacerbated Allee effects, increasing the risk of population collapse and requiring a larger population size of recovery. - Severe tissue damage at higher CO_2 levels and that continuing increased ocean acidification could affect the survivorship and recruitment of cod (Dahlke *et al.*, 2022). - Controlled warming of 2°C and 4°C showed that warming might accelerate development and increase mortality in larval cod (Oomen *et al.*, 2022). - Holt and Jorgensen (Holt and Jørgensen, 2014) predicted that 2°C warming would lead to increased cod growth rates and larger asymptotic sizes, while others have reported increased cod growth and biomass in response to warming (Kjesbu *et al.*, 2014; Mullowney *et al.*, 2019; Sguotti *et al.*, 2023). - Context dependency of temperature effects: Mantzouni *et al.,* (2010) reported that warming effects were positive on cod recruitment at temperatures below 5°C but negative above it, while Lindmark *et al.* also reported a temperature threshold effect on cod condition (Lindmark *et al.*, 2023). - Cod can be sensitive to acidification, with elevated CO_2 levels altering gene expression, suggesting stress at the molecular level (Mittermayer *et al.*, 2019). - Bioeconomic modelling indicates the harmful effects of acidification on recruitment (Hänsel *et al.*, 2020). - Acidification can cause tissue damage in larval cod, leading to increased susceptibility to infection (Frommel *et al.*, 2012). - Shackell *et al.* (2013) reported that cod in the Canadian northwest Atlantic were impervious to pH changes within the range of values projected to 2100; however, results based on experiments involving Baltic rather than Atlantic cod (Frommel *et al.*, 2013). - Deoxygenation is associated with deteriorating health in cod (Cheung *et al.*, 2022; Lindmark *et al.*, 2023). - Recruitment is influenced by the North Atlantic Oscillation (NAO), with effects varying geographically and temporally. - Recruitment in European waters south of 62°N is particularly sensitive to climatic changes driven by the NAO when the spawning stock biomass is low (Brander, 2005). - The effect of NAO on recruitment is modulated by the existing population size of the stock. - Correlation between NAO and recruitment success evident in some time periods but not others (Solow, 2007).	3%	2095±13	Moderate

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Redfish (*Sebastes* spp.)			
- Moderate thermal range (-0.8°C–13°C) with a reported core thermal habitat between 5.5°C and 8.5°C (Eriksen *et al.*, 2015). - Warming a major factor driving the spatial redistribution of redfish in the Irminger Sea (Pedchenko, 2005). - Warming linked to earlier spawning, altered prey, and trophic mismatch on the Flemish Cap (Anderson, 1994) and to reduced size at maturity in the Gulf of St. Lawrence (Brûlé *et al.*, 2024). - Acidification adversely affects survival and behaviour during early life stages. - Reported higher redfish fecundity under warming on the Flemish Cap between 1996 and 2020. (González-Carrión and Saborido-Rey, 2022)	4%	2093±16	Moderate
Thorny skate (*Amblyraja radiata*)			
- Moderately broad thermal range (-0.5°C–12.5°C) (Pennino *et al.*, 2019; Kneebone *et al.*, 2020), with a preference for temperatures between -0.5°C and 3°C (Pennino *et al.*, 2019). - Shifted vertical distribution in response to temperature variation (Swain and Benoît, 2006), suggesting that temperature drives their distribution. - Warming is associated with increased metabolic demands in the Gulf of Maine and a reduced tolerance for hypoxia (Schwieterman *et al.*, 2019). - Positive relationship between thorny skate and snow crab distribution, suggesting that temperature-driven shifts in crab could impact skate abundance and distribution (Pennino *et al.*, 2019).	6%	2092±18	Moderate
American plaice (*Hippoglossoides platessoides*)			
- Relatively wide range of temperatures (-1.3°C–14°C). - Optimal temperature range for growth and development is between 6 and 10°C (Howell and Caldwell, 1984). - Most common between -1°C and 5°C (Shackell *et al.*, 2013). - Temperature preference for plaice varies with their ration level (Morgan, 1993), suggesting that the productivity regime and prey availability could affect their climate sensitivity. - Temperature affects recruitment and survival rates either directly or by affecting prey availability, with effects being both positive and negative (Walsh, 1994; Swain *et al.*, 1998; Shepherd *et al.*, 2000). - Temperature affects swimming endurance, suggesting that temperature could affect their catchability (Winger *et al.*, 1999). - Little is known of the effects of hypoxia or pH on plaice.	2%	2095±11	Low
White hake (*Urophycis tenuis*)			
- Wide thermal tolerance range (-0.6°C–21°C). - Temperature-driven northward shifts in white hake distribution across the northeast US continental shelf between 1968 and 2008, influenced by the position of the Gulf Stream and the Atlantic Multidecadal Oscillation (Frederich and Lancaster, 2024).	1.4%	2096±9	Low
Shortfin squid (*Illex illecebrosus*)			
- Wide thermal range (0.5°C–27.3°C) with a preference between 4°C and 14°C (Bazzino *et al.*, 2005; Chiu *et al.*, 2017) and spawning associated with temperatures between 16°C and 18°C (Wang *et al.*, 2018). - Chang *et al.* (2015) and Ying *et al.* (2024) reported a squid preference for cooler water temperatures with adverse effects under warming.	3%	2094±14	Low