

Atlantic Cod

Species Climate Vulnerability:

Atlantic cod (*Gadus morhua*) is projected to be moderately vulnerable to climate change due to exposure to changing ocean temperature and acidification and sensitivity in terms of stock status (overfished with overfishing occurring), slow population growth rates, stock status, and specific early life history requirements (e.g., dependence on specific circulation patterns for larval retention and specific nursery habitats). Atlantic cod are projected to be negatively affected by climate change caused by resulting decreases in recruitment and suitable habitat (Hare et al. 2016). Temperature plays an important role in Atlantic cod recruitment, growth, and survival, and several studies have reported declines in populations in the southern extent of the range due to projected increased temperature (Drinkwater 2005; Fogarty et al. 2008; Pershing et al. 2015; Planque and Fredou 1999).

Habitat Dependence:

A number of estuarine and marine habitats are important to Atlantic cod. These include firm hard bottom habitat (corresponding to the HCVA categories of marine intertidal rocky bottom, marine rocky bottom <200 m, estuarine intertidal rocky bottom, and estuarine subtidal rocky bottom) and loose coarse bottom habitat (corresponding to the HCVA categories of marine intertidal rocky bottom, marine rocky bottom <200 m, estuarine intertidal rocky bottom, and estuarine subtidal rocky bottom). In addition, loose fine bottom habitat (corresponding to the HCVA categories of marine intertidal mud, marine intertidal sand, marine mud <200 m, marine mud >200 m, estuarine intertidal mud, estuarine intertidal sand, estuarine subtidal mud, and estuarine subtidal sand) and structured sand (corresponding to the HCVA categories of marine intertidal sand, marine sand <200 m, estuarine intertidal sand, and estuarine subtidal sand) were identified as important to Atlantic cod. Marine and estuarine water column habitats are important for all life stages, particularly for the survival and distribution of eggs and larvae (Clark et al. 2003). Egg and larval life stages use marine shallow/inner shelf and marine shelf surface water column habitats, while juveniles and adults are primarily demersal and use estuarine water column, marine shallow/inner shelf, and marine shelf bottom water column habitats.

Aquatic vegetation habitat is also critical to the species, as various life stages rely on mesohaline and polyhaline species habitat (corresponding to HCVA classifications marine submerged aquatic vegetation and estuarine submerged aquatic vegetation) and seaweed habitat (corresponding to HCVA classifications of marine kelp, estuarine kelp, marine red, green, and small brown algae and estuarine red, green, and small brown algae).

Habitat Climate Vulnerability:

All habitats ranked as important to Atlantic cod are vulnerable to projected increased sea surface and bottom temperatures (Farr et al. 2021). Marine and estuarine sand and rocky bottom habitats have moderate to high dependence for juvenile, adult, and spawning adult Atlantic cod. These habitats range from low vulnerability to climate

change (e.g., estuarine subtidal rocky bottom) to high vulnerability (marine intertidal rocky bottom and sand). Spawning is known to occur on the continental shelf, and eggs and larvae inhabit the water column both nearshore and offshore. Although the estuarine water column habitat was ranked as highly vulnerable, surface and bottom water column habitats were ranked as low. However, water column habitats were not included in ACFHP's assessment of habitat dependency and finer-scale information on the importance of specific pelagic habitats is needed for the species.

Critical points of high dependency and high vulnerability exist for Atlantic cod with mesohaline and polyhaline species habitat (corresponding to HCVA classifications marine submerged aquatic vegetation and estuarine submerged aquatic vegetation) and multiple intertidal habitats including firm hard bottom habitat, loose coarse bottom habitat, and structured sand habitat.

Mid-Atlantic

While the ACFHP matrix did assess Atlantic cod habitats in the Mid-Atlantic, they are not included in this summary document due to the limited population and resulting absence of a directed commercial fishery for the species in the Mid-Atlantic.

New England

Habitat dependency for Atlantic cod is based solely on the New England region.

Habitat dependence by life stage:

- *Eggs/larvae:*
 - Marine shallow/inner shelf water column habitat.
 - Marine shelf surface water column habitat.
 - Marine water column shelf bottom habitat.
- *Juveniles/Young-of-the-year, and Adults:*
 - Firm hard bottom habitat has high dependence.
 - Loose coarse bottom habitat has high dependence.
 - Loose fine bottom habitat has medium dependence.
 - Mesohaline and polyhaline species habitat has high dependence.
 - Structured sand habitat has high dependence.
 - Marine shallow/inner shelf water column habitat.
 - Marine shelf bottom water column habitat.
 - Estuarine water column habitat.
- *Spawning adults:*
 - Firm hard bottom habitat has high dependence.
 - Loose coarse bottom habitat has high dependence.
 - Loose fine bottom habitat has medium dependence.
 - Mesohaline and polyhaline species habitat has high dependence.
 - Structured sand habitat has high dependence.
 - Marine shallow/inner shelf water column habitat.
 - Marine shelf bottom water column habitat.

Atlantic Cod (New England)					
		Life Stage Dependency			
Habitat Type	HCVA Climate Vulnerability Rank	Egg/ Larvae	Juvenile/ YOY	Adult	Spawning Adult
Firm Hard Bottom	Marine intertidal rocky bottom- High (juveniles/YOY only)				
	Estuarine intertidal rocky bottom- Moderate (juveniles/YOY only)		H	H	H
	Estuarine subtidal rocky bottom- Low Marine rocky bottom <200m- Low				
Loose Coarse Bottom	Marine intertidal rocky bottom- High (juveniles/YOY only)				
	Estuarine intertidal rocky bottom- Moderate (juveniles/YOY only)		H	H	H
	Estuarine subtidal rocky bottom- Low Marine rocky bottom <200m- Low				

Loose Fine Bottom	Marine intertidal mud- High (juveniles/YOY only)				
	Marine intertidal sand- High (juveniles/YOY only)				
	Estuarine intertidal mud- Moderate (juveniles/YOY only)				
	Estuarine intertidal sand- Moderate (juveniles/YOY only)		M	M	M
	Estuarine subtidal mud- Moderate				
	Marine mud <200m- Low				
	Marine sand <200m- Low				
	Estuarine subtidal sand- Low				
Mesohaline and Polyhaline Species	Marine submerged aquatic vegetation- High				
	Estuarine submerged aquatic vegetation- High				
			H	H	H
Structured Sand	Marine intertidal sand- High (juveniles/YOY only)				
	Estuarine intertidal sand- Moderate (juveniles/YOY only)				
	Estuarine subtidal sand- Low				
	Marine sand <200m- Low		H	H	H
Marine Water Column, Shallow Inner Shelf	Low		X	X	X

Marine Water Column, Shelf Surface	Low	X			
Marine Water Column, Shelf Bottom	Low	X	X	X	X
Estuarine Water Column	High		X	X	

Key: M=medium dependency H=high dependency VH=very high dependency
X: Water column habitat dependency ranking is not available in ACFHP matrix