Estuarine kelp

System: Estuarine
Class: Aquatic Bed
Sub Class: Kelp
Geographic area: Entire Area

Overall Vulnerability Rank = High
Habitat Sensitivity = High
Climate Exposure = High

	Estuarine kelp	Attribute Mean	Data Quality	Distribution of Expert Scores
Sensitivity attributes	Habitat condition	3.2	2.2	
	Habitat fragmentation	3.2	2.2	
	Distribution/Range	3.2	2.2	
	Mobility/Ability to spread or disperse	2.8	2.2	
	Resistance	3.2	2.2	
	Resilience	3.2	2.2	
	Sensitivity to changes in abiotic factors	3.4	2.2	
	Sensitivity and intensity of non−climate stressors	3.4	2.2	
	Dependency on critical ecological linkages	3.4	2	
	Sensitivity Component Score	High		
Exposure variables	Sea surface temp	4	2.5	
	Bottom temp	1	0	
	Air temp	1	0	
	River temp	1	0	
	Surface salinity	1.9	2.1	
	Bottom salinity	1	0	
	pH	4	2	
	Sea level rise	2.4	2.2	
	Precipitation	1	0	
	River flow	1	0	
	Exposure Component Score	High		
Overall Vulnerability Rank		High		

Low
Moderate
High
Very High

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Habitat name: Estuarine kelp
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Sub-class: Kelp
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Habitat Description: Kelp are non-rooted, brown algae of the order Laminariales, are important components of nearshore, subtidal benthic communities, and can form dense beds on rocky bottom habitat in the photic zone to depths of 10–25 m (Merzouk and Johnson 2011). Lopez et al. (2014) reported few kelp occur deeper than 5 m in Long Island Sound. Suitable habitat for kelp is associated with areas rocky bottom and well mixed waters. Although several species of kelp occur in Canadian and Arctic waters, the two largest brown algae species in the U.S. are sugar kelp (*Saccharina latissima*) and horsetail kelp (*Laminaria digitata*). The historic U.S. range is Gulf of Maine to Long Island Sound, although the densities of both species in Long Island Sound are substantially reduced (Auster P, pers. comm.; Lopez et al. 2014; Merzouk and Johnson 2011; Van Patton and Yarish 2009; Wilson et al. 2019). This habitat subclass also includes aquaculture (i.e., kelp farms). Commercial aquaculture of macroalgae is predominantly for rockweed (*Ascophyllum nodosum*), although *S. latissima* and *L. digitata* are also cultured.

Overall Climate Vulnerability Rank: High (99% certainty from bootstrap analysis).

Climate Exposure: High. The overall high exposure score was influenced by two very high attribute means: sea surface temperature and pH (4.0 for both). The exposure attribute scores for surface salinity and sea level rise were 1.9 and 2.4, respectively. The current geographic range of kelp in the study area include Long Island Sound and the Gulf of Maine, where sea surface temperature is projected to have the greatest change. Although the projected change in pH for the Gulf of Maine is less than southern New England and the Mid-Atlantic, it is still expected to drastically increase from historic levels.

Habitat Sensitivity: High. Eight of the nine sensitivity attribute means were ≥ 3.2, while the attribute mean for "mobility/ability to spread or disperse" was also relatively high (2.8). The three attributes with the highest sensitivity means were "sensitivity to changes in abiotic factors", "sensitivity and intensity of non-climate stressors", and "dependency on critical ecological linkages".

Data Quality & Gaps: The data quality scores for three of the four climate exposure factors were relatively low (≤ 2.2). This likely is attributed to the low resolution of CMIP5 projections for estuaries and nearshore, shallow coastal areas. In addition, because comprehensive mapping and baseline data for kelp in the study area is lacking, text descriptions for spatial distribution of kelp were used for the climate exposure scoring.

For habitat sensitivity, data quality for all of the nine attributes were scored relatively low (2.2 and 2.0). This may reflect the lack of comprehensive assessments for kelp in the study area.

Positive or Negative Climate Effect in the Northeast U.S. Shelf: The effect of climate change on marine kelp in the Northeast U.S. Shelf is expected to be negative (95% of the experts' scores were negative).

Climate Effects on Habitat Condition and Distribution: Higher mean temperatures and heat waves have been attributed to reductions in abundance and range of kelp in the Gulf of Maine (Witman and Lamb 2018; Krumhansl et al. 2016) and Long Island Sound (Lopez et al. 2014), and climate projections indicate

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these trends will continue. Northward shift of the trailing edge attributed to reductions in growth and complete mortality was projected for kelp species in Northwestern Atlantic, and 36% habitat loss of *L. digitata* and 21% of *S. latissima* habitats for the end-of-century time-frame under the RCP8.5 scenario (Wilson et al. 2019). Witman and Lamb (2018) reported higher kelp mortality with more storm disturbance, and suggested increasing wave disturbance from climate change, as well as warmer temperatures, may also contribute to the future loss of kelp foundation species.

Marine macroalgae species appear to have higher growth rates under experimental elevated pCO2 conditions through higher photosynthetic and growth rates (Young and Gobler 2016); Gledhill et al. 2015), which could mitigate some climate-related impacts associated with warming waters.

<u>Habitat Summary</u>: Kelp are increasingly threatened by a variety of non-climate local stressors, and regional variation of these drivers may affect kelp populations. Sea urchins are a natural predator of large brown algal species, including kelp, and in some areas urchins have decimated kelp beds (i.e., "urchin barrens"). There is evidence that overfishing of top predators may be a contributing factor to explosions of urchin populations (Steneck et al. 2002).

Warming ocean waters have been shown to eliminate thermal barriers that historically limit reproductive success of marine invasive species (e.g., *Botrylloides violaceus*), which may impact kelp abundance and distribution. Increased reproduction of marine invasive species, combined with limited biological resistance in regions with cooler water temperatures, may lead to a community state change (Dijkstra et al. 2017). Wilson et al. (2019) suggested potential climate-induced shifts in dominance from native kelp species to invasive species such as green algae (*Codium fragile*), and a loss of kelp may facilitate the transition to a turf algae dominated ecosystem (Filbee-Dexter & Wernberg 2018). Marine invasive species, likely introduced via maritime transport vectors, are known to compete for space and foul benthic substrates (Pappal 2010) and may replace kelp species in portions of the study area (Scheibling and Gagnon 2006; Trott and Entreline 2019). *S. latissima* underwent a significant 36.2% decrease in abundance between 1987 and 2015 on Cashes Ledge, concurrent with a rapid warming of the GOM and invasion by the kelp-encrusting bryozoan *Membranipora membranacea* (Witman and Lamb 2018).

Kelp requires moderate nutrient levels and well-mixed waters for optimal growth, as well as exposed rocky bottom (Steneck et al. 2002). Kelp abundance decreases in very wave sheltered areas (Bekkby et al. 2019), and offshore densities of *S. latissima* were over 150 times greater than at coastal sites with similar but lower magnitude trends for congeneric *S. digitata* (Witman and Lamb 2018). This suggests kelp in marine waters may be more resilient to change compared to kelp in estuarine waters. In addition, kelp in estuarine waters may have greater vulnerabilities because of their higher exposure to anthropogenic impacts, such as storm water pollution, dredging and filling, higher turbidity, and higher water temperature and eutrophication due to shallower water and partial enclosure of estuaries.

Kelps require rock bottom habitat to attach to the substrate, so placement of revetments, jetties, groins, and other structures may increase habitat availability if other habitat requirements are met. Although commercial and recreational harvest and culturing of kelp and rockweed occurs in Maine, there is little documentation of widespread impacts associated with controlled harvesting.

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