Pacific Northwest
NATIONAL LABORATORY

PNNL-32302

Environmental Information for Siting and Operation of Floating Tidal Turbines in U.S. Waters

TEAMER Orbital Marine

November 2021

Andrea Copping
Lysel Garavelli
Dorian Overhus
Levy Tugade

November 2021

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <https://www.ntis.gov/about>
Online ordering: http://www.ntis.gov

PNNL-32302

Environmental Information for Siting and Operation of Floating Tidal Turbines in U.S. Waters

TEAMER Orbital Marine

November 2021

Andrea Copping
Lysel Garavelli
Dorian Overhus
Levy Tugade

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Seattle, Washington 98109

Summary

The deployment and operation of a floating tidal technology in the United States require assessing environmental conditions and satisfying all environmental permitting requirements. Two locations in the United States are chosen to evaluate the potential for deployment of the Orbital Marine Power Ltd. floating technology: San Juan Islands (Washington) and Western Passage (Maine). This report describes the information gathered on logistical, regulatory, and environmental conditions for siting and deploying the technology in the two locations. In each location, the state and federal regulations required for deploying are defined, as well as the additional requirement for social license. To evaluate the potential for siting and deployment, bathymetry and tidal current velocities are assessed, and the presence of species and critical habitats is defined for each location. This information is then used to evaluate the potential environmental effects of floating tidal technologies in coastal waters of the San Juan Islands and Western Passage. This initial assessment of logistical, regulatory, and environmental conditions for the deployment of a floating tidal technology is a first step toward the achievement of environmental compliance.

Acknowledgments

The authors wish to express their gratitude to a number of individuals who helped with gathering the information used in this report, including Oliver Wragg with Orbital Marine Power Ltd. and Russel Guerry of Orcas Power and Light. We are grateful for the support provided by the Department of Energy Waterpower Technologies Office through the Testing and Access to Marine Energy Research (TEAMER) program.

Acronyms and Abbreviations

cm	centimeters
CPS	coastal pelagic species
DOE	U.S. Department of Energy
DPS	distinct population segment
EEZ	Exclusive Economic Zone
EFH	essential fish habitat
EMF	electromagnetic field
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FERC	Federal Energy Regulatory Commission
FMP	fishery management plan
g	grams
HAPC	habitat area of particular concern
IUCN	International Union for Conservation of Nature
kg	kilograms
m	meters
MMPA	Marine Mammal Protection Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
Orbital	Orbital Marine Power, Ltd.
PNNL	Pacific Northwest National Laboratory
T	tons
TEAMER	Testing and Access to Marine Energy Research (program)
U.S.	United States
USFWS	U.S. Fish and Wildlife Service

Contents

Figures

Tables

1.0 Introduction

This report summarizes information collected to inform the deployment and operation of floating tidal technologies in two locations in the United States (U.S.): the San Juan Islands in Washington State and Western Passage in Maine. In particular, environmental data needed to inform regulatory pathways were collected to facilitate the siting and deployment of this new low carbon renewable energy source to these two areas of the United States. For the purposes of this report, the O2 floating tidal technology created by Orbital Marine Power Ltd. (Orbital) was used to represent full-scale floating tidal technologies.

Information collected and analyzed for this report was derived solely from publicly available databases and interactions with researchers and public officials associated with those data. These data allowed the authors to delineate some preferred locations for floating tidal development and to outline those areas where development might lead to conflicts or challenges with vulnerable marine populations and/or other users.

The report is organized into seven sections: 1) floating tidal technology, 2) the U.S. regulatory context for deployment of floating tidal technology, 3) additional requirements necessary in working through regulatory processes, 4) examining areas in the San Juan Islands in relation to floating tidal stream turbines, 5) examining areas in Western Passage in relation to floating tidal stream turbines, 6) an assessment of the potential environmental effects of floating tidal technologies in coastal waters of the San Juan Islands and Western Passage, and 7) an overall assessment of the adequacy of data available for initial development of floating tidal technologies in the San Juan Islands and Western Passage.

2.0 Description of the Technology

The Orbital Marine device is a floating tidal turbine hull with two rotors suspended underneath, anchored to the seafloor with mooring lines (Figure 1). The device is 74 meters (m) long, floating semi-submerged, approximately 1.5 m above the waterline and 2.3 m below the water. The device is 50 m wide, including the span of the blades underwater. The total draft of the operational device is 23.2 m. The device is anchored to the seafloor with four anchors and mooring lines; each anchor has a footprint of approximately 15 m^2, at a preferred deployment depth of 50–100 m. The watch circle for each device is 30–40 m. Orbital is expected to deploy two to four devices in an array. Additional descriptions of the device can be found at https://www.orbitalmarine.com/.

Figure 1. Orbital Marine Technology O2 floating tidal turbine, deployed at the European Marine Energy Center in Orkney, United Kingdom.

3.0 Regulatory Context

Deployment and operation of the Orbital Marine floating tidal turbine must meet federal, state, and, in some limited cases, local regulatory requirements. Descriptions of the regulatory processes (e.g., https://tethys.pnnl.gov/publications/handbook-marine-hydrokinetic-regulatory-processes) provide extensive detail to meet most marine energy regulatory needs. For any deployment of turbines in either the San Juan Islands in the state of Washington, or in Western Passage in the state of Maine, the services of a regulatory specialist will be beneficial. In general, however, the federal and state statutes and regulations that must be followed are summarized, including the cognizant federal or state agencies and the primary receptors (marine animals or habitats) that occur in the San Juan Islands (Table 1) and for Western Passage (Table 2) for which the agencies are responsible.

Table 1. Key federal, state, and local regulations needed for permitting marine energy devices in the San Juan Islands in Washington State.

Jurisdiction	Regulation	Cognizant Agency	Receptor of Concern (where applicable)/Notes
Federal	Endangered Species Act (ESA)	National Oceanic and Atmospheric Administration (NOAA)-National Marine Fisheries Service (NMFS)	Marine mammals, marine and most anadromous fish
Federal	Endangered Species Act	U.S. Fish and Wildlife Service (USFWS)	Land-based and sea birds, certain species of anadromous fish, sea otters

Jurisdiction	Regulation	Cognizant Agency	Receptor of Concern (where applicable)/Notes
Federal	Marine Mammal Protection Act	NOAA-NMFS	Marine mammals
Federal	Migratory Bird Treaty Act	USFWS	Migratory birds
Federal	Rivers and Harbors Act, Clean Water Act	U.S. Army Corps of Engineers	Navigation
Federal	Federal Power Act	Federal Energy Regulatory Commission (FERC)	National Environmental Policy Act process
Federal	PATON (Private Aid to Navigation)	U.S. Coast Guard	Navigation lighting and notice to mariners
State	Clean Water Act (delegated from the U.S. Environmental Protection Agency)	Washington Department of Ecology	Water quality, habitat quality, consistency with federal regulations for shorelines
State	Hydraulic Project Approval	Washington Department of Fish and Wildlife	Fish, wildlife, habitats, includes timing for construction activities
State	Aquatic Use Authorization	Washington Department of Natural Resources	Lease of seabed in state waters
State	Various Statutes	Washington Department of Transportation	Applicable if state roadways or other assets are involved in the project
State	National Historic Preservation Act	Washington Historic Preservation Commission	Tribes with usual and accustomed fishing grounds in the area must be consulted to fulfill these requirements
Local	Shoreline Management Act	San Juan County	Does not appear to be a program in place

Table 2. Key federal, state, and local regulations needed for permitting marine energy devices in Western Passage in Maine.

Jurisdiction	Regulation	Cognizant Agency	Receptor of Concern (where applicable)/Notes
Federal	Endangered Species Act, Magnuson-Stevens Conservation Act, Fish and Wildlife Coordination Act, Federal Power Act, Marine Mammal Protection Act	NOAA-NMFS	Marine mammals, marine and most anadromous fish
Federal	Endangered Species Act, Fish and Wildlife Coordination Act, Federal Power Act, Bald & Golden Eagle Protection Act, Migratory Bird Treaty Act	USFWS	Land-based and sea birds, certain species of anadromous fish, sea otters, migratory birds
Federal	Rivers and Harbors Act (Section 10), Clean Water Act (Section 404), Marine Protection and Sanctuaries Act (Section 103)	U.S. Army Corps of Engineers	Navigation

Jurisdiction	Regulation	Cognizant Agency	Receptor of Concern (where applicable)/Notes
Federal	Federal Power Act, Public Utility Regulatory Policies Act, Energy Policy Act, Electric Consumers Protection Act, National Environmental Policy Act	FERC	National Environmental Policy Act process
Federal	PATON (Private Aid to Navigation)	U.S. Coast Guard	Navigation lighting and notice to mariners
State	Natural Resources Protection Act, Clean Water Act (Section 401[d]), Maine Waterway Development and Conservation Act	Maine Department of Environmental Protection	Significant wildlife habitat, coastal wetlands, water quality
State	Maine Endangered Species Act	Maine Department of Marine Resources	Fish, marine mammals, sea turtles
State	Fish and Wildlife Coordination Act	Maine Department of Inland Fisheries and Wildlife	Fish, marine mammals, sea turtles, seabirds
State	Submerged Lands Leasing Program	Maine Department of Conservation	Lands lease
State	Coastal Zone Management Act	Maine State Planning Office	Consistency with federal regulations for shorelines
State	National Historic Preservation Act	Maine Historic Preservation Commission	Tribes with usual and accustomed fishing grounds in the area must be consulted to fulfill these requirements

4.0 Additional Requirements for Floating Tidal Turbines

Floating tidal developers will be required to fulfill all federal, state, and local regulatory requirements; in addition, gaining the approval of local tribes is necessary to ensure their way of life and harvests are not harmed by the proposed project. Tribal nations are sovereign; they must be consulted as one would another nation and are not considered as merely a stakeholder group. In general, U.S. federal agencies will carry out formal consultations with local tribal governments. However, to ensure a successful outcome gaining the trust and agreement of local tribes, as well as tribes that have usual and accustomed fishing grounds in or around the project is necessary and can be achieved by engaging tribes early in the process and not rely on the formal government to government consultation.

In the state of Washington, tribal nations have legal co-management of all natural resources which support their livelihoods and cultural heritage, decided by the landmark Boldt decision in 1975 and subsequent decisions (United States versus Washington 1975; United States versus Washington 1995), with special significance for salmon and shellfish. The San Juan Islands is home to the Lummi and Samish Tribes, with traditional territories that stretch over a wide region of the Salish Sea in northwest Washington, from the top of the Cascades Mountains to the far western shores of the San Juan Islands. In western Washington, many tribes have treaties reserving their right to fish in "usual and accustomed" fishing areas that often extend well beyond the geographical range of their tribal lands, including the federally recognized Lummi, Nooksack, Swinomish, Upper Skagit, Sauk-Suiattle, Stillaguamish, Tulalip, Muckleshoot, Puyallup, Nisqually, Squaxin Island, Skokomish, Suquamish, Port Gamble S'Klallam, Jamestown S'Klallam, Lower Elwha Klallam, Makah, Quileute, Quinault, and Hoh Tribal Nations (Pacific Fishery Management Council 2021b). The most likely tribes to engage in a project in the San Juan Islands project include the Lummi, Samish, Swinomish, and Tulalip tribes. In Maine, the federally recognized Passamaquoddy Tribe First Nation inhabits the eastern most section of Maine and Charlotte County; in addition, part of the Passamaquoddy First Nation lives in areas of New Brunswick, Canada. The First Nation maintains active land claims in Canada but does not have legal status there as a First Nation.

Gaining social license from stakeholders in each region is also key to establishing a successful project. These stakeholders will range across those that make their livelihood from the sea to those environmentally conscious groups who seek to conserve marine resources and the environment. The key to working through these issues is to engage local expertise and meet early and often with stakeholders and tribes.

In the San Juan Islands, the key stakeholder groups include chapters of many of the national NGOs, as well as more local and regional groups. Examples include:

- Surfrider – national NGO with local chapter (https://nws.surfrider.org)
- Washington Environmental Council – coalition of state level NGOs with strong Puget Sound focus (https://wecprotects.org)
- Puget SoundKeeper – local NGO (https://pugetsoundkeeper.org)
- Friends of the San Juans – local NGO (https://sanjuans.org)

In Western Passage, several local chapters of national NGOs are also active in tidal power scrutiny, in addition to local groups. Key to these groups is working with the Island Institute who coordinates and facilitates ocean energy projects.

5.0 Delineating Areas in the San Juan Islands for Floating Tidal Technologies

The San Juan Islands are located in the northwest of Washington state, near the Canadian border (Figure 2). In order to site floating tidal turbines in these waters, it will be necessary to determine where there are adequate tidal flows for energy harvest by assessing the tidal currents speed in locations that might appear favorable. In addition, existing critical infrastructure and services must be identified to avoid conflicts with floating tidal turbines and cables. Similarly, the presence, ranges, and status of populations of marine animals must be determined to minimize interactions.

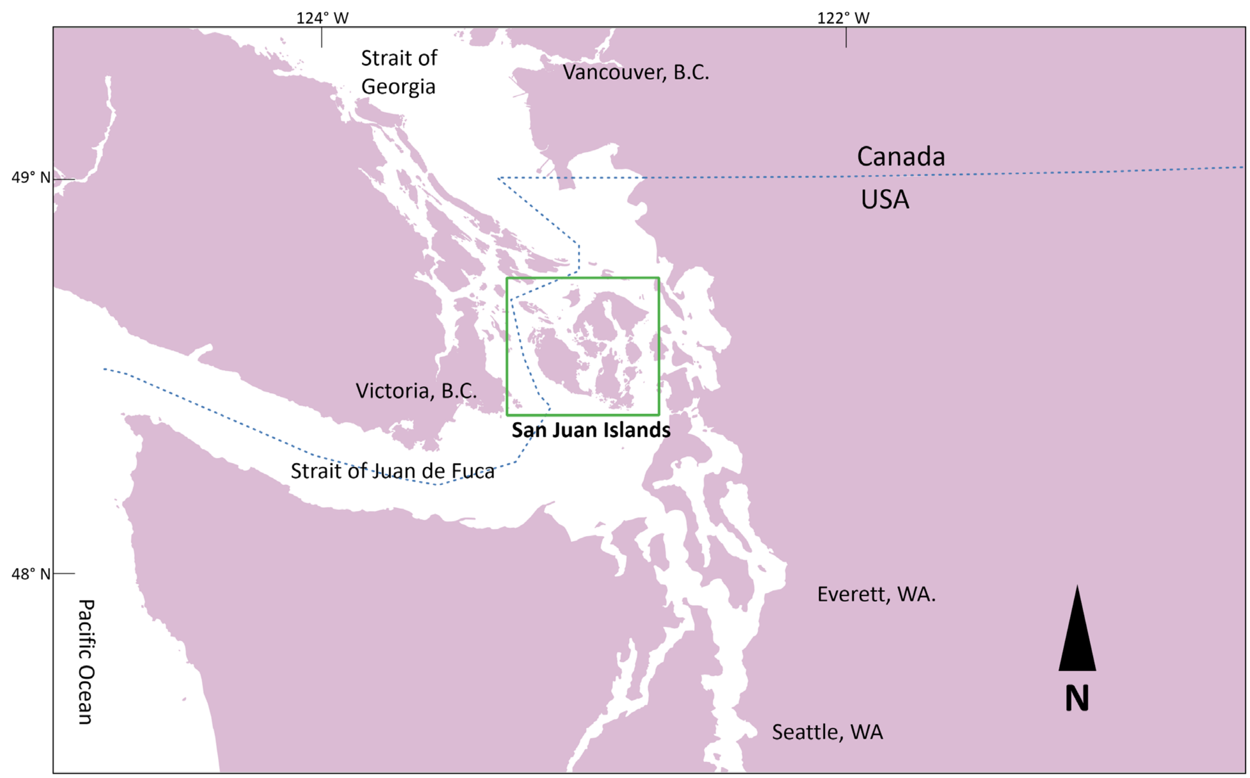

Figure 2. Map of the northern portion of Washington State and southern British Columbia, Canada. The San Juan Island archipelago is noted in the green box.

5.1 Bathymetry and Tidal Resources

Initial resource assessments included a review of the bathymetry of the San Juan archipelago (Figure 3) and the tidal currents at the scale of the archipelago (Figure 4). Based on the results of previously conducted assessments (Yang et al. 2021), it is evident that four channels have sufficient tidal power to warrant further investigation—San Juan Channel, Rosario Strait, Middle Channel (Cattle Point), and Spieden Channel (Figures 5 and 6).

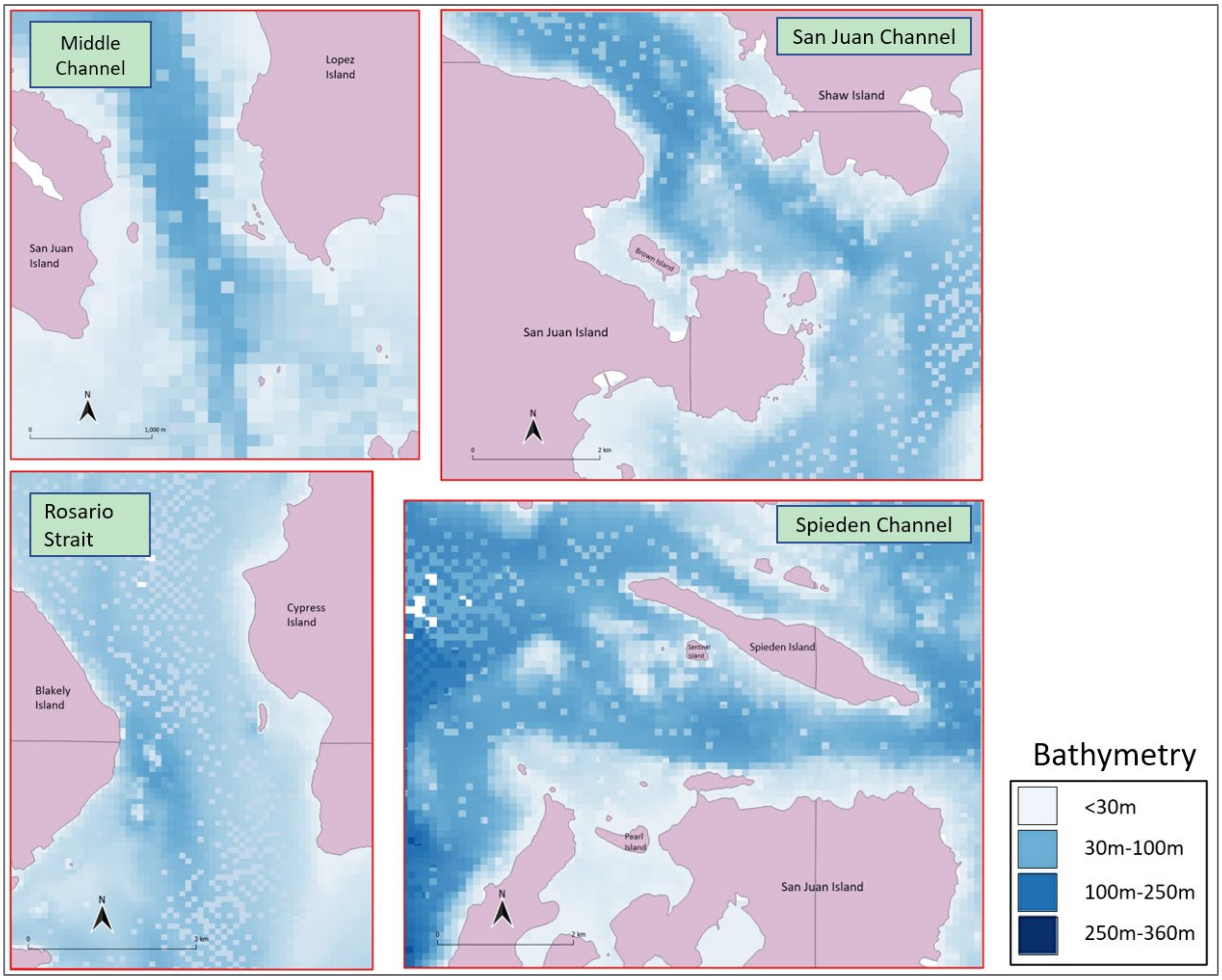

Figure 3. Bathymetric charts of the four channels that have sufficient tidal power for a floating tidal device (Yang et al. 2021). Areas without sufficient data are shown as white pixels.

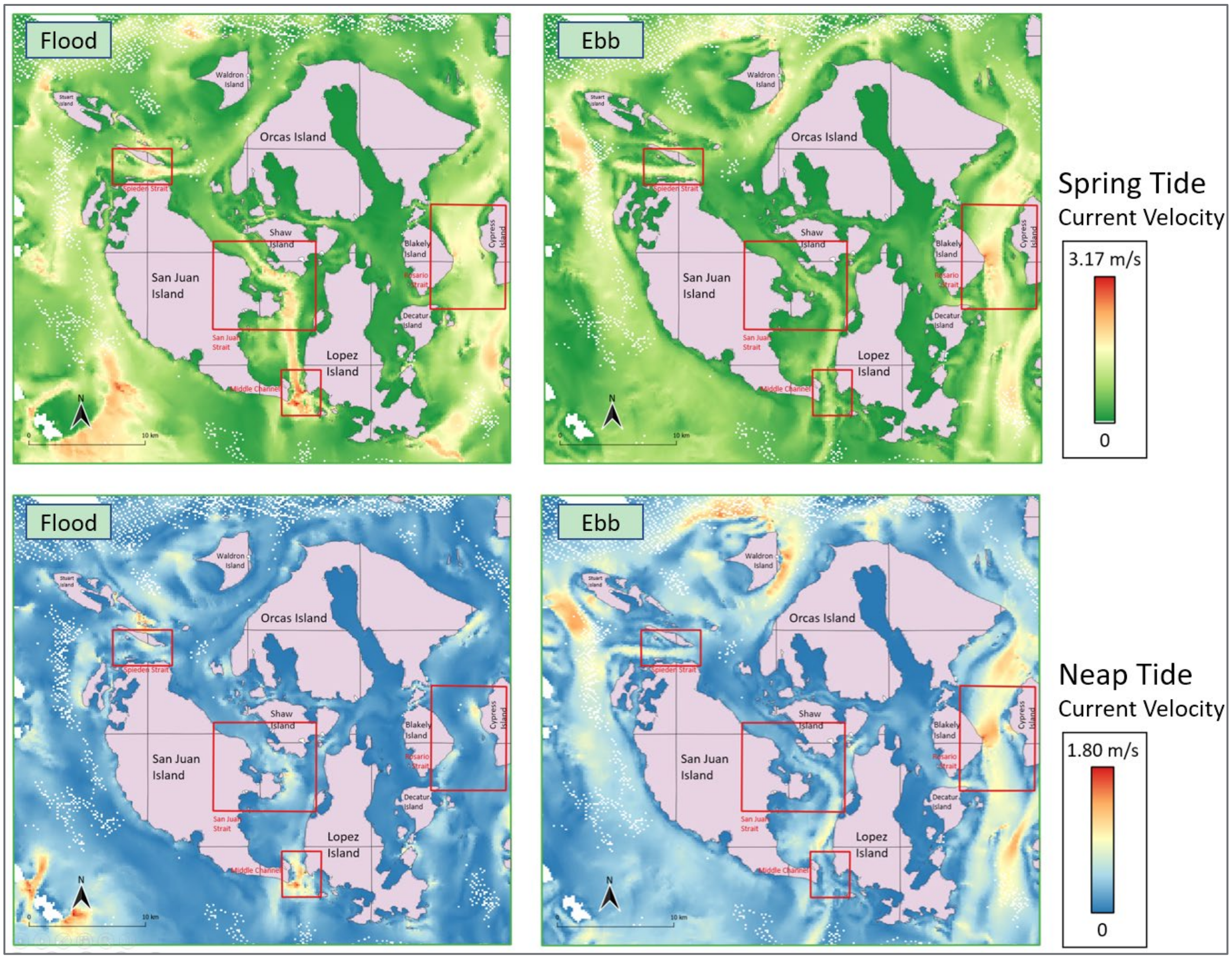

Figure 4. Maximum current velocity around the San Juan Islands during the spring tide in the upper panels and neap tide in the lower panels (Yang et al. 2021). The red boxes outline the areas of investigation in each of the four channels. Areas without sufficient data are shown as white pixels.

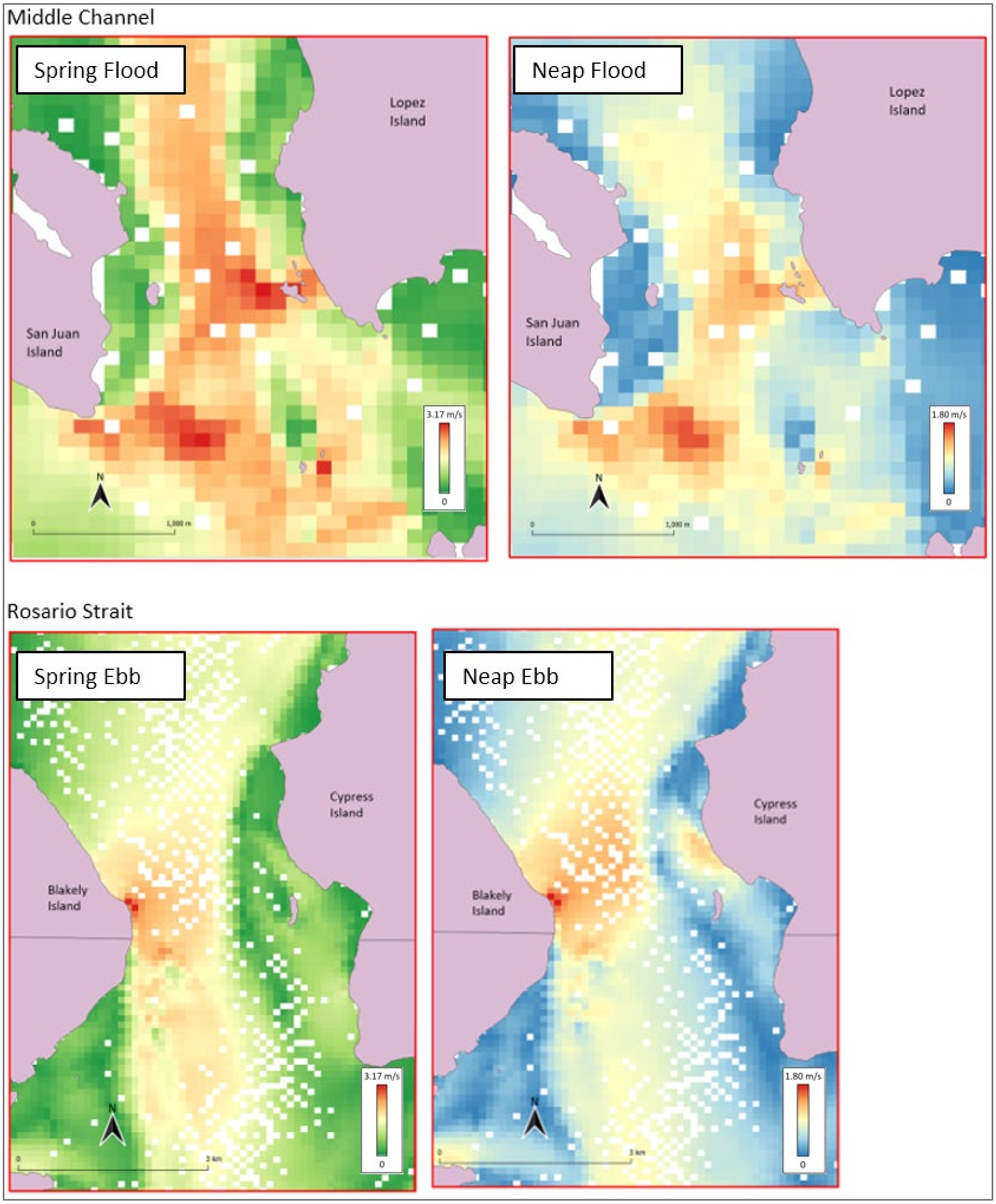

Figure 5. Tidal velocity maps for Middle Channel and Rosario Strait, during the periods that have the highest recorded relative velocity (Yang et al. 2021). Areas without sufficient data are shown as white pixels.

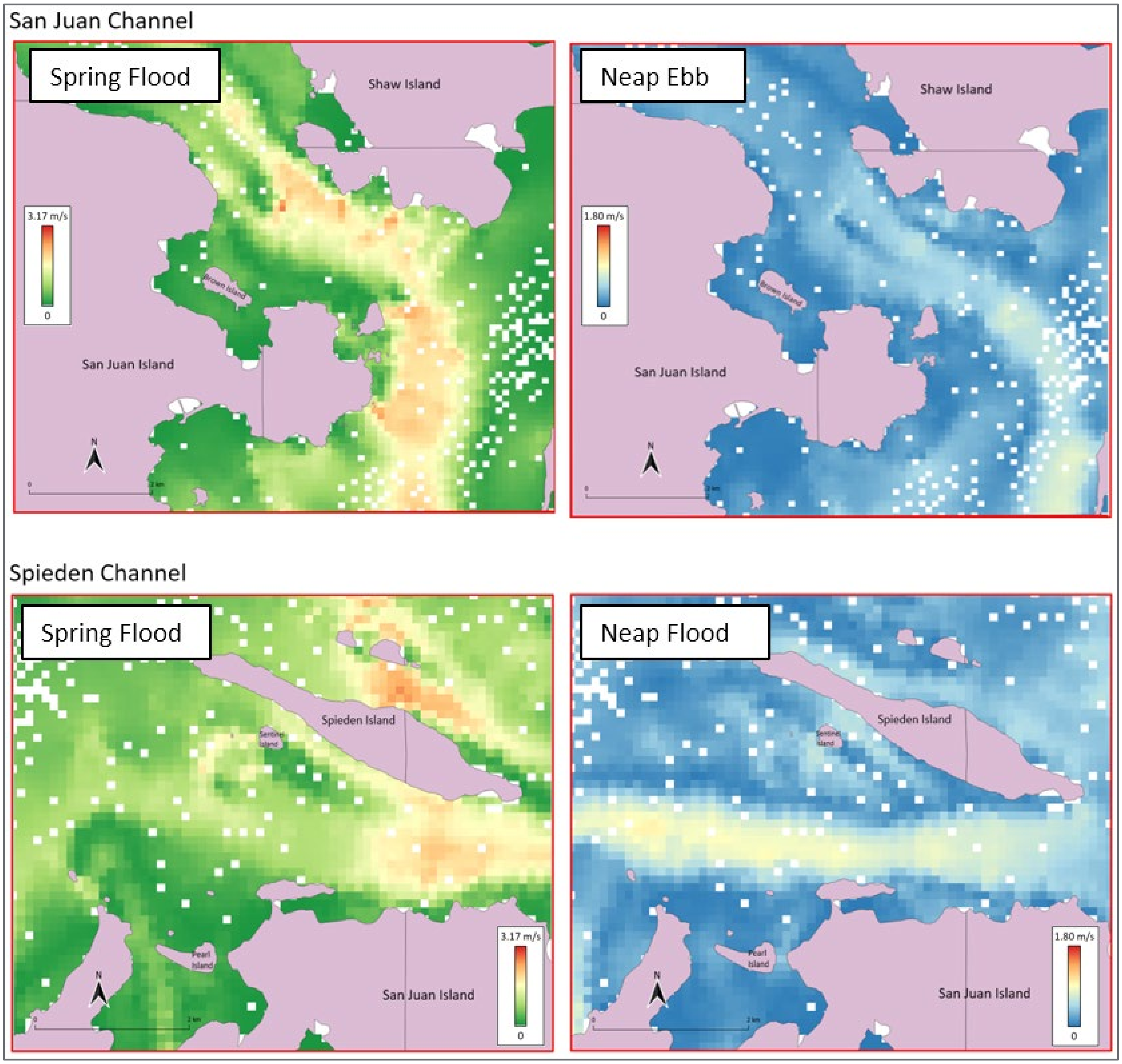

Figure 6. Tidal velocity maps for San Juan Channel and Spieden Channel, shown during the periods that have the highest recorded relative velocity (Yang et al. 2021). Areas without sufficient data are shown as white pixels.

5.2 Protected and Sensitive Marine Animals and Habitats around San Juan Islands

Regulatory processes associated with species and habitats are driven by the presence of endangered or threatened species, species protected under other statutes, and habitats that are critical to the support for populations of concern and that support a wide range of species. The species and habitats that will drive placement of a tidal project in the San Juan Islands are described here, under the specific protection mechanisms of importance.

5.2.1 Species and Critical Habitats around San Juan Islands

The following aquatic species are federally listed or listed in the state of Washington and are known to be present year round or seasonally in Puget Sound (Table 3). Most are found in the San Juan Islands at least periodically.

Table 3. Federal or state status (threatened, endangered) of the marine species that can potentially occur in San Juan Islands.

	Threatened		**Endangered**		
Species	State of Washington	Federal	State of Washington	Federal	Notes
Southern resident killer whale (*Orcinus orca*)			X	X	Distinct population segment (DPS) (70 FR 69903); designated critical habitat (71 FR 69054)
Humpback whale (*Megaptera novaeangliea)*	X			X	79 FR 20802
Bocaccio (*Sebastes paucispinis)*				X	Puget Sound/Georgia Basin DPS (75 FR 22276); designated critical habitat (79 FR 68041)
Chinook salmon (*Oncorhynchus tshawytscha*)	X	X		X	Puget Sound evolutionarily significant unit (ESU) (79 FR 20802); designated critical habitat (79 FR 20802)
Steelhead (*Oncorhynchus mykiss*)	X	X			Puget Sound DPS (72 FR 26722)
North American green sturgeon (*Acipenser medirostris*)	X				Southern DPS (71 FR 17757); designated critical habitat (74 FR 52300)
Pacific eulachon (Columbia River smelt) (*Thaleichthys pacificus*)			X		Southern DPS (75 FR 13012)
Puget Sound yelloweye rockfish (*Sebastes ruberrimus*)		X			Puget Sound/Georgia Basin DPS (75 FR 22276); designated critical habitat (79 FR 68041)

5.2.2 Endangered Species around San Juan Islands

The description and distribution patterns of the species listed as endangered under the ESA of 1973 are found below.

5.2.2.1 Southern Resident Killer Whale

Figure 7. Killer whale (NOAA Fisheries).

Killer whale (*Orcinus orca*), often referred to as orca, is the largest member of the dolphin family, weighing up to 11 tons and measuring up to 10 m long. It is considered to be the ocean's top predator. The killer whale lifespan ranges from 30 to 90 years. Killer whales are largely black on the top with white undersides and white patches near the eyes, and they have a large dorsal fin (Figure 7). Resident, transient, and offshore killer whales are recognized in the northeastern Pacific Ocean. In the United States, resident killer whales are distributed from Alaska to California and include four distinct populations of resident killer whales: Southern, Northern, Southern Alaska, and Western Alaska (70 FR 69903). During the late spring, summer, and fall, the Southern Resident DPS resides in the inland waters of Washington State and British Columbia (Strait of Georgia, Strait of Juan de Fuca, and Puget Sound). Three pods (J, K, and L) are identified in the Southern Resident DPS and are considered to be critically endangered. Critical habitat for the southern resident killer whale includes the Strait of Juan de Fuca, Puget Sound, Haro Strait, and the waters around the San Juan Islands (71 FR 69054), excluding areas shallower than 6.1 m. Physical and biological features essential to the conservation of the southern resident killer whale include 1) water quality to support growth and development; 2) prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth; and 3) passage conditions that allow for migration, resting, and foraging. Specific breeding, calving, and resting areas are not currently documented. Southern resident killer whales consume salmon, with a preference for Chinook salmon, and other fish.

In the Salish Sea, Olson et al. (2018) documented sightings of southern resident killer whales between 1976 and 2014 (Figure 8). Density estimates were higher in Haro Strait, Boundary Pass, Swanson Channel, Spieden Channel, and Middle Channel than adjacent areas in the Salish Sea (Figure 8). Other areas with lower densities included the northern side of the Strait of Juan de Fuca, around the mouth of the Fraser River, Rosario Strait, San Juan Channel, and in the Puget Sound.

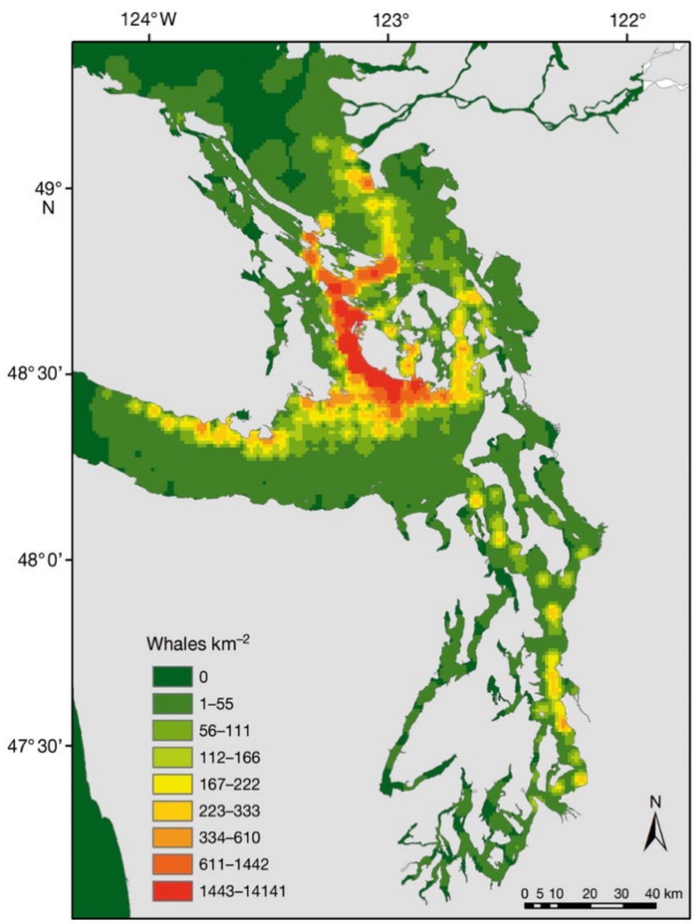

Figure 8. Southern resident killer whale density (number of whales per square kilometer) based on effort-corrected data in the Salish Sea, 1976–2014 (Olson et al. 2018).

5.2.2.2 Humpback Whale

Figure 9. Humpback whale (NOAA Fisheries).

Humpback whales (*Megaptera novaeangliae*) live in all oceans of the world, migrating very long distances (up to 8,000 km). They may weigh up to 40 tons, measure up to 18 m long, and have a lifespan of 80 to 90 years. Their bodies are primarily black with differing amounts of white on their pectoral fins, bellies, and under their tails (Figure 9). The Central America population of humpback whales feeds off the West Coast of the United States and southern British Columbia during summer and is listed as endangered under the ESA (86 FR 21082). Humpback whales are protected under the Marine Mammal Protection Act of 1972 (MMPA) throughout their range. The California/Oregon/Washington stock is designated as depleted and is defined to include humpback whales that feed on plankton, crustaceans, and small fish off the West Coast of the United States. Humpback whales in the North Pacific feed in coastal waters from California to Russia and in the Bering Sea. Humpbacks migrate south to wintering destinations off Mexico and Central America (Calambokidis et al. 2000). Humpbacks filter feed on tiny crustaceans (mostly krill), plankton, and small fish. Humpback whales are sighted in the inland waters of Washington and British Columbia from June to October (Falcone et al. 2005).

5.2.2.3 Puget Sound Bocaccio

Figure 10. Boccacio (NOAA Fisheries).

Bocaccio (*Sebastes paucispinis*) are large Pacific Coast rockfish that weigh up to 9.5 kilograms (kg) and measure up to 90 cm long (Figure 10). They are late to mature (5–20 years old) and their lifespan is approximately 50 years. They are distributed from Punta Blanca, Baja California, to areas off the Krozoff and the Kodiak Islands in the Gulf of Alaska. The Puget Sound/Georgia basin DPS of bocaccio is listed as endangered because the population has not recovered from overfishing (75 FR 22276). Bocaccio larvae are pelagic and generally occur in the upper 80 m in the ocean, before they settle onto bottom habitats, such as rocky areas or kelp forests. Adult bocaccio inhabit rocky habitats between 50 and 425 m deep. In Puget Sound, they have been documented in other habitats, such as sand or mud. Critical habitat for the Puget Sound/Georgia Basin DPS bocaccio include 1) benthic habitats or sites deeper than 30 m that possess or are adjacent to areas of complex bathymetry consisting of rock or highly rugged or corrugated habitat and 2) juvenile settlement habitats located in the nearshore with substrates such as sand, rock, and/or cobble that support kelp (79 FR 68041). Bocaccio have been documented in the San Juan Islands. The San Juan/Strait of Juan de Fuca Basin has the rockiest shoreline and benthic habitats of the U.S. portion of the DPS. Most of the San Juan Islands have rocky shorelines with extensive, submerged aquatic vegetation and floating kelp beds necessary for juvenile settlement. The critical habitats for bocaccio are illustrated in Figure 11.

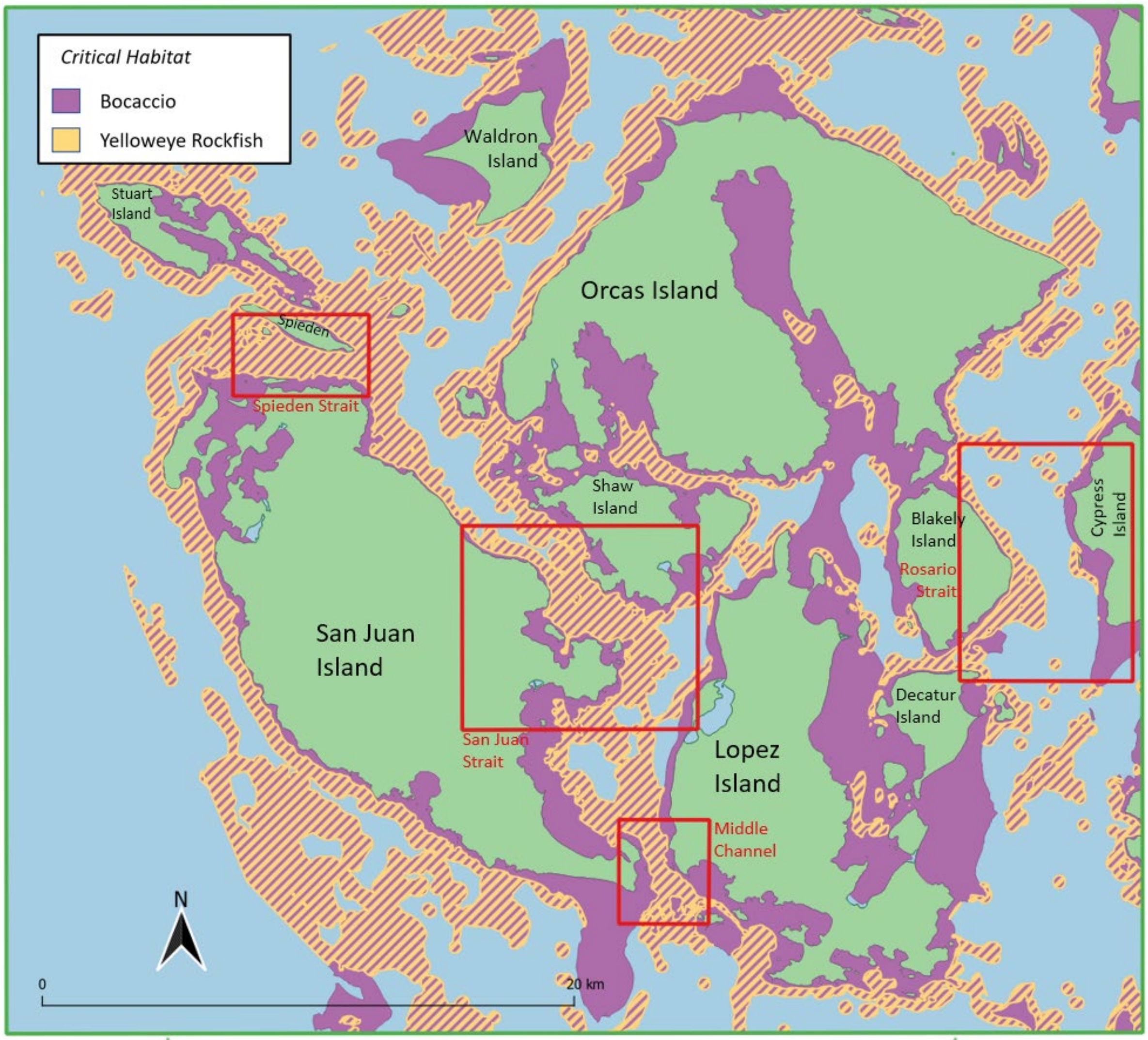

Figure 11. Critical habitat map for the endangered bocaccio (*Sebastes paucispinis*) and threatened yelloweye rockfish (*Sebastes ruberrimus*) (NOAA Fisheries). The red boxes delineate the four channels that have been examined for tidal resources.

5.2.3 Threatened Species

The description and distribution patterns of the species listed as threatened under the ESA are presented below.

5.2.3.1 Puget Sound Chinook Salmon

Chinook salmon (*Oncorhynchus tshawytscha*) live in both freshwater and saltwater; spawning and rearing of juveniles occur in rivers, and they migrate to saltwater to feed, grow, and mature. Their average weight is 18 kg, but they can grow to 54 kg, measuring about 90 cm long, and they can live up to 6 years (Figure 12). The Puget Sound Chinook salmon ESU includes naturally spawned Chinook salmon from rivers and streams flowing into

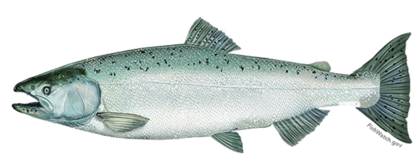

Figure 12. Chinook salmon (NOAA Fisheries).

Puget Sound from eastward of the Elwha River (70 FR 37160), including rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington State. Puget Sound Chinook salmon run timings are in summer, fall, and spring. The Puget Sound Chinook salmon populations closest to the San Juan Islands spawn in the Nooksack River, Skagit River, and Dungeness River. Limited information exists about Chinook salmon habitat use of marine waters. Critical habitat includes all nearshore marine areas of the Strait of Georgia, Puget Sound, Hood Canal, and the Strait of Juan de Fuca from the line of extreme high tide out to a depth of 30 m (70 FR 52629). Juvenile Chinook could occupy the nearshore, while subadult and maturing fish tend to occupy deeper water. Juveniles prey on insects, amphipods, and other crustaceans, while adults primarily prey on smaller fish. Chinook critical habitat is shown in Figure 13.

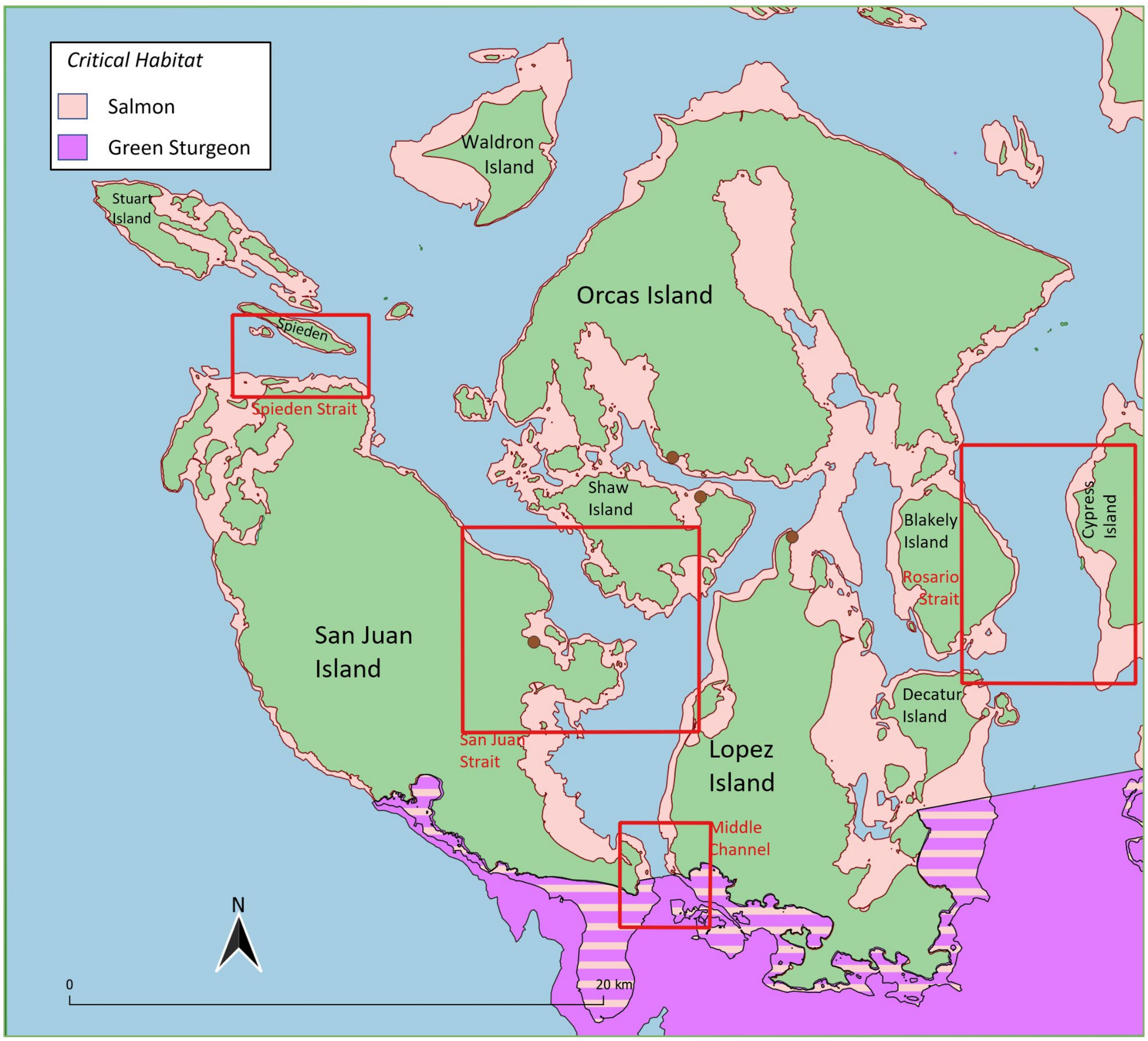

Figure 13. Critical habitat map for threatened species Chinook salmon (*Oncorhynchus tshawytscha*) and green sturgeon (*Acipenser medirostris*) around the San Juan Islands (NOAA Fisheries). The red boxes delineate the four channels that have been examined for tidal resources.

5.2.3.2 Steelhead

Figure 14. Steelhead (NOAA Fisheries).

Steelhead (*Oncorhynchus mykiss*) hatch in rivers and streams and migrate to the ocean to grow and mature. They weigh up to 25 kg, measure up to 1.1 m long, and can live up to 11 years (Figure 14). The Puget Sound steelhead DPS includes all naturally spawned anadromous populations from streams in the river basins of the Strait of Juan de Fuca (72 FR 26722). Critical habitat for the Puget Sound steelhead DPS has been proposed, but Puget Sound and its tributaries have been excluded (78 FR 2726). Steelhead only ephemerally use the nearshore marine waters, unlike most other Pacific salmonids (e.g., Puget Sound Chinook). The species' lengthy freshwater rearing period results in large smolts that are prepared to move rapidly through estuaries and nearshore waters to forage on larger prey in offshore marine areas. There are no specific nearshore areas within the geographical area occupied by Puget Sound steelhead that are considered to be critical habitat. Steelhead feed on insects, mollusks, crustaceans, fish eggs, and other small fishes.

5.2.3.3 North American Green Sturgeon

Figure 15. Green sturgeon (NOAA Fisheries).

Green sturgeon (*Acipenser medirostris*) are long-lived, slow-growing fish that can live between 60 to 70 years. They weigh up to 160 kg and measure between 1.3 and 2 m long, on average (Figure 15). Green sturgeon inhabit coastal marine waters as sub-adults and adults and spawn in freshwater. Juveniles mature in fresh and estuarine waters for several years before migrating to coastal marine habitats. Key elements needed for green sturgeon success in nearshore coastal marine areas include migratory corridors for the passage of fish within marine and between estuarine and marine habitats, and nearshore marine waters with adequate dissolved oxygen levels and acceptably low levels of contaminants. Adults of the southern DPS migrate seasonally along the U.S. West Coast. They are distributed in bays and estuaries in Washington, Oregon, and California during summer and fall. During winter and spring, they congregate off northern Vancouver Island in British Columbia. Green sturgeon forage for benthic invertebrates and fish (74 FR 52300). Critical habitat in the San Juan Islands is shown in Figure 13.

5.2.3.4 Pacific Eulachon

Figure 16. Pacific eulachon (NOAA Fisheries).

Eulachon (*Thaleichthys pacificus*) spawn in the lower portions of rivers at 2–5 years of age. They weigh up to 70 grams (g) and measure around 20 centimeters (cm) long (Figure 16). They are distributed from northern California to southwest Alaska. Most eulachon distributed south of the United States-Canada border originate in the Columbia River Basin; their largest and most consistent spawning runs return to the main stem of the Columbia River and the Cowlitz River. After hatching in rivers, the larvae are transported downstream and may stay in surface waters of estuaries for several weeks before entering the ocean. Juveniles are found near the ocean bottom in waters between 20 to 150 m deep. Adults and juveniles feed on the zooplankton commonly at depths of 20 to 50 m in nearshore marine waters. There is currently little information available about eulachon movements in nearshore marine areas (76 FR 65324).

5.2.3.5 Puget Sound Yelloweye Rockfish

Yelloweye rockfish (*Sebastes ruberrimus*) are among the longest-lived rockfishes—up to 150 years. They are very slow-growing and late to mature. They weigh up to 18 kg and measure up to 1 m long (Figure 17). The Puget Sound/Georgia Basin DPS of yelloweye rockfish is listed as threatened. Adult yelloweye rockfish remain near the seabed and have relatively small home ranges. Similar to bocaccio, they occupy habitats between 30 and 425 m deep, within and adjacent to areas where rocky habitats are very rough and highly corrugated. The description of critical habitat for yelloweye rockfish in the Puget Sound/Georgia Basin is similar to that for bocaccio (79 FR 68041), as shown in Figure 11.

Figure 17. Pacific rockfish (NOAA Fisheries).

5.2.4 Protected Marine Mammals

Descriptions and distribution patterns of the species protected throughout their range under the MMPA are described below.

5.2.4.1 Southern Resident Killer Whale

See Section 4.2.2.1.

5.2.4.2 Humpback Whale

See Section 4.2.2.2.

5.2.4.3 Gray Whale

Gray whales (*Eschrichtius robustus*) are regularly found in the North Pacific Ocean. They weigh up to 40 tons (t) and measure between 13 and 15 m long. Gray whales have a mottled gray body with broad pectoral flippers and dorsal humps (Figure 18). They inhabit shallow coastal waters. Most of the Eastern North Pacific stock migrates to the northern Bering and Chukchi Seas to feed, but some remain off the Pacific Coast. Gray whales migrate south in the fall to breed off the coast of Baja California. They are observed in spring and summer in the inland waters of Washington State. The areas around the San Juan Islands are biologically important areas for the migration of gray whales because they feed on benthic amphipods in the sediment found there.

Figure 18. Gray whale (NOAA Fisheries).

5.2.4.4 Short-finned Pilot Whale

Short-finned pilot whales (*Globicephala macrorhynchus;* Figure 19) are one of two species of pilot whales. They have a bulbous melon head with no obvious rostrum and a black or dark brown body with a large gray saddle behind the dorsal fin. They measure between 3.5 and 7.5 m long and weigh between 1 and 3 T. Their lifespan is 35 to 60 years. In the United States, they are found along the East and West Coast and around the Hawaiian Islands. Approximately 800 animals comprise the West Coast stock.

Figure 19. Short-finned pilot whale (NOAA Fisheries).

5.2.4.5 California Sea Lion

California sea lions (*Zalophus californianus*) are “eared” seals from the west coast of North America (Figure 20). Females weigh around 109 kg and measure around 1.8 m in length; males weigh around 318 kg and measure around 2.2 m in length. Their lifespan is around 20 to 30 years. California sea lions live in coastal waters and are capable of hauling out and moving about on land, where they are found on beaches, ports, jetties, and buoys, and occur from Baja California to the waters of western Canada. There are no major breeding colonies located near the Washington coast or Puget Sound. California sea lions are deep diving animals that feed mainly in upwelling areas on prey that includes squid, anchovies, mackerel, rockfish, and sardines. They are known to be opportunistic feeders and move into areas that feature rich resources.

Figure 20. California sea lion (NOAA Fisheries).

5.2.4.6 Harbor Porpoise (Northern Oregon/Washington Coast and Washington Inland Waters Stocks)

Harbor porpoises (*Phocoena phocoena*) weigh between 61 and 77 kg and measure around 1.6 m in length (Figure 21). Their average lifespan is 24 years. Harbor porpoises inhabit waters east of Cape Flattery year-round and are often found in harbors, bays, and estuaries in water less than 200 m deep. They feed on demersal and benthic species, including herring, capelin, and cephalopods.

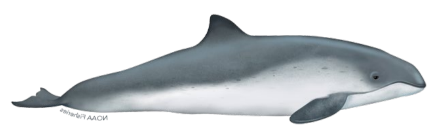

Figure 21. Harbor porpoise (NOAA Fisheries).

5.2.4.7 Harbor Seal (Washington Inland Waters Stocks)

Figure 22. Harbor seal (NOAA Fisheries).

Harbor seals are one of the most common marine mammals along the U.S. West and East Coasts. They are part of the true seal family and have short flippers (Figure 22). They weigh up to 129 kg and measure up to 1.82 m in length. Their lifespan is about 25 to 30 years. The Washington Inland Waters Stock of harbor seals (*Phoca vitulina*) inhabits marine and estuarine areas along the Washington coast from Cape Flattery through Puget Sound and the San Juan Islands. Harbor seals have small home ranges. They mate at sea and females give birth during the spring and summer. They are deep and shallow divers and feed on fish, shellfish, and crustaceans. While they haul out to rest and breed, they are generally not capable of extensive movement on land.

5.2.4.8 Steller Sea Lion

Figure 23. Steller sea lion (NOAA Fisheries).

The steller sea lion (*Eumetopias jubatus*) is the largest member of the “eared” seals family (Figure 23). Adult males measure up to 3.3 m in length and can weigh up to 1,100 kg. Adult females are around 2.6 m and weigh up to 360 kg. The eastern DPS steller sea lion includes sea lions originating from southeast Alaska, British Columbia, Oregon, California, and Washington. They are distributed along the coast and also inhabit deeper continental slope and pelagic waters during the nonbreeding season.

5.2.4.9 Northern Elephant Seal

Figure 24. Northern elephant seal (NOAA Fisheries).

The northern elephant seal (*Mirounga angustirostris*) is the largest of the “true” seals in the Northern Hemisphere (Figure 24). Males are recognized by their large, inflatable noses. Males measure up to 4 m long and weigh around 2 T. Females measure around 3 m long and weigh up to 590 kg. Northern elephant seals are found in the eastern and North Pacific Ocean and typically breed in winter in the Channel Islands of California or Baja California in Mexico. Males feed near the Aleutian Islands and in the Gulf of Alaska, and females feed farther south in the offshore waters of Washington and Oregon. They typically feed on cephalopods (squids and octopi) and fish. Northern elephant seals have been sighted in the San Juan Islands.

5.2.4.10 Minke Whale

Figure 25. Minke whale (NOAA Fisheries).

Minke whales (*Balaenoptera acutorostrata*) are the smallest members of the baleen whale family in North American waters (Figure 25). They weigh up to 9,000 kg and can measure up to 11 m long. They can live up to 50 years. Minke whales are found in both coastal and oceanic areas and can occur in polar, temperate, and tropical waters in most seas and areas worldwide. In the inland waters of California, Oregon, and Washington, minke whales are considered residents because they establish home ranges. They are opportunistic feeders and typically feed on crustaceans, plankton, and small fish. Minke whales are seen in the San Juan waters.

5.2.4.11 Dall's Porpoise

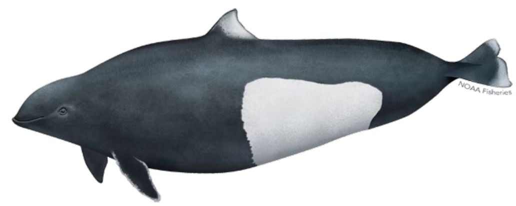

Figure 26. Dall's porpoise (NOAA Fisheries).

Dall's porpoises (*Phocoenoides dalli*) weigh up to 200 kg and measure around 2.2 m long (Figure 26). They are common in the North Pacific Ocean and can be found off the U.S. West Coast from California to the Bering Sea in Alaska. There are two stocks of Dall's porpoise in the region: the Alaska stock and the California/Oregon/Washington stock. They occur in temperate to boreal waters that are more than 180 m deep and feature temperatures between 2 and 17°C. They can be found offshore, inshore, and nearshore in oceanic waters of the North Pacific Ocean. They are commonly seen in the inshore waters of Washington, British Columbia, and Alaska.

5.2.5 Other Key Species

5.2.5.1 Sunflower Sea Star

Figure 27. Sunflower sea star (Oregon Conservation Strategy).

The sunflower sea star (*Pycnopodia helianthoides*) is a large sea star, iconic of the northeast Pacific Ocean (Figure 27). It is among the largest sea stars in the world with a maximum arm span of 1 m and 16 to 24 limbs. It has been declared a critically endangered species by the International Union for Conservation of Nature (IUCN) (Gravem et al. 2020). Its distribution ranges from California to Alaska, but it is no longer observed in Oregon and California, and it is present in Puget Sound and Alaska in low numbers. It occurs on many different types of marine habitats, including mud, sand, shell, gravel, rocky bottoms, kelp forest, and lower intertidal, at depths from 0 to 435 m.

5.3 Essential Fish Habitat around San Juan Islands

Essential fish habitat (EFH) is defined by the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (MSA) as "waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." EFH on the West Coast of the United States is identified in fishery management plans (FMPs). EFHs have been identified in Puget Sound for the following groups:

- Coastal Pelagic Species – all life stages
- Pacific Coast Salmon – juveniles and adults
- Pacific Coast Groundfish – all life stages.

5.3.1 Coastal Pelagic Species

Fisheries stocks managed under the coastal pelagic species (CPS) FMP include four finfish, market squid, and krill (Costal Pelagic Species Fishery Management Plan 2019) and are listed below:

- Pacific sardine (*Sardinops sagax*)
- Pacific (chub) mackerel (*Scomber japonicus*)
- Northern anchovy (*Engraulis mordax*, central and northern populations)
- Market squid (*Doryteuthis opalescens*)
- Jack mackerel (*Trachurus symmetricus*)
- Krill (*Euphausiid species*).

CPS finfish are pelagic, generally occurring and harvested above the thermocline in the upper mixed layer. The definition of EFH for CPS finfish is based on a thermal range bordered by the geographic area where CPS occur at any life stage, where CPS have occurred historically during periods of similar environmental conditions, or where environmental conditions do not preclude colonization by CPS. The east-west geographic boundary of EFH for CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington, offshore to the limits of the Exclusive Economic Zone (EEZ), and above the thermocline where sea surface temperatures range between 10 and 26°C. The northern boundary is defined as the position of the 10°C isotherm. The EFH designation for all species of krill extends the length of the West Coast, from the shoreline to the 1,000-fathom isobath, and to a depth of 400 m.

5.3.2 Pacific Coast Salmon

This FMP covers the coastwide aggregate of natural and hatchery salmon species in the EEZ off the coasts of Washington, Oregon, and California (Pacific Fishery Management Council 2021a). Chinook salmon, Coho salmon (*Oncorhynchus kisutch)*, and pink salmon (*Oncorhynchus gorbuscha*) are the main species covered by the plan. In the estuarine and marine areas, salmon EFH extends from the extreme high tide line in nearshore and tidal submerged environments within state territorial waters, out to the full extent of the EEZ (370.4 km) offshore of Washington, Oregon, and California north of Point Conception. EFH for Pacific Coast salmon also includes habitat areas of particular concern (HAPCs) that are smaller habitat areas within EFH and are priority areas for conservation and management efforts. In the

Salish Sea, HAPCs for Pacific Coast salmon include estuaries (e.g., bays, sounds, inlets, river mouths, deltas) and marine and estuarine submerged aquatic vegetation (e.g., kelp, eelgrass) (Pacific Coast Salmon Fishery Management Plan 2014). The inland extent of the estuary HAPC is the high-water tidal level along the shoreline or the upriver extent of saltwater intrusion; the seaward extent is an imaginary line closing the mouth of a river, bay, or sound. Juvenile salmonids use estuarine aquatic vegetation habitat (e.g., eelgrass, kelp) for refuge from predators, rearing, and feeding, as they transition to life in the open ocean. In the Puget Sound, pink salmon and some ocean-type Chinook salmon enter the estuary at a very small size and rear in the shallow nearshore waters (less than 3 m deep) until they reach 70 mm in length and then move offshore.

5.3.3 Pacific Coast Groundfish

This FMP includes species inhabiting the bottom of the water column from Washington to southern California, including the Strait Juan de Fuca (Pacific Fishery Management Council 2020). EFH for Pacific Coast groundfish includes all waters and substrate at depths less than or equal to 3,500 m to the mean higher high-water level. In Washington, HAPCs for the Pacific Coast groundfish are all waters and the sea bottom in state waters from the 3-nautical-mile boundary of the territorial sea, shoreward to the mean higher high-water level. HAPCs for groundfish include estuaries, canopy kelp forests, seagrass beds, and rocky reefs, which can be found around the San Juan Islands. There are four groups of groundfish with species that potentially inhabit San Juan Islands waters based on their occurrence in Puget Sound: flatfish; rockfish; roundfish; and sharks, skates, and chimaeras. Common flatfish species encountered around San Juan Islands are dover sole (*Microstomus pacificus*), starry flounder (*Platichthys stellatus*), sand sole (*Psettichthys melanostictus*), and English sole (*Parophrys vetulus*). They are distributed in shallow-water coastal, bay, and estuarine habitats and are encountered on soft mud, sandy substrates, and eelgrass beds. Rockfishes inhabiting the areas around the San Juan Islands are bocaccio, yelloweye rockfish, canary rockfish, and the brown rockfish (*Sebastes auriculatus*) that are common in waters less than 53 m deep. Larval rockfish are important food sources for juvenile salmon and other marine fish and seabirds. Roundfish include lingcod (*Ophiodon elongatus*) and Pacific cod (*Gadus macrocephalus*). In Puget Sound, lingcod inhabit intertidal areas to depths of 475 m. Larvae and juveniles mature in the sandy and rocky substrata in subtidal zones and are common in estuaries. Pacific cod inhabit shallow, soft-bottom habitats from 50 to 300 m deep.

5.4 Seabirds around San Juan Islands

The San Juan Islands provide some of the last remaining undeveloped seabird nesting habitat in the Salish Sea (U.S. Fish and Wildlife Service 2010). The suitability of larger islands within the San Juan archipelago for seabird nesting has been reduced due to habitat loss and threats associated with development and disturbance. The Strait of Juan de Fuca is a major summer feeding area for several seabirds, such as rhinoceros auklets, tufted puffins, and pigeon guillemots.

5.4.1 Rhinoceros Auklet

Rhinoceros auklets (*Cerorhinca monocerata*) are medium-sized seabirds with an orangish bill and dark plumage (Figure 28). They measure around 29 cm in length and weigh around 500 g. They can dive as deep as 57 m. They are distributed from California to the Aleutian Islands in Alaska. Among the rhinoceros auklets that breed in North America, 13 percent are in Washington State in two colonies—one located on Destruction Island and one on Protection Island, in the Strait of Juan de Fuca. Throughout the breeding season in spring and summer, they forage within the Strait of Juan de Fuca.

Figure 28. Rhinoceros auklet (Cathie Brown).

5.4.2 Marbled Murrelet

Marbled murrelet (*Brachyramphus marmoratus*) are members of the auk family. They measure around 25 cm in length and have a slender black bill (Figure 29). They inhabit the nearshore marine environment in western North America. In Washington, they are most abundant in the northern Puget Sound and the Strait of Juan de Fuca. They are considered a threatened species by the IUCN and are federally listed under the ESA as a threatened species in Washington, Oregon, and California, and state-listed as threatened in Oregon and Washington.

Figure 29. Marbled murrelet (Thomas Hammer, Hammer Environmental L.P.).

5.4.3 Tufted Puffin

Tufted puffin (*Fratercula cirrhata*) are members of the auk family; they have stout, black-feathered bodies; a white facial patch; large colorful bills; and two yellow head tufts (Figure 30). They are around 35 cm in length and weigh about 750 g. In North America, they breed from California to Alaska, and around 0.8 percent of their global population breeds in Washington, on Protection and Smith Islands. They occur in Washington from April to late September. The Protection Island reserve contains one of the last two nesting colonies of puffins in Puget Sound; about 70 percent of the tufted puffin nest on the island. They are considered a species of least concern by the IUCN.

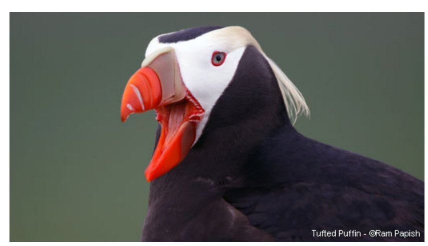

Figure 30. Tufted puffin (Rath Papish).

5.4.4 Pigeon Guillemot

Pigeon guillemot (*Cepphus columba*) are in the same family as puffins; they have black plumage with white wing patches and bright red legs and feet (Figure 31). They measure around 34 cm in length and weigh around 500 g. They forage at depths of 15 to 20 m. Pigeon guillemot nest on more than one-third of the San Juan Islands and can be seen year around within the Salish Sea. They are considered a species of least concern by the IUCN.

Figure 31. Pigeon guillemot (National Audubon Society).

5.4.5 Pelagic Cormorant

The pelagic cormorant (*Phalacrocora pelagicus*) is the smallest cormorant in the Pacific. They have purple-black feathers and a bold white flank (Figure 32). They measure around 76 cm in length and have a wingspan of about 1 m. They can dive up to 43 m in depth. They can be seen year-round within the Salish Sea and are on colony from April to October. They are considered a species of least concern by the IUCN.

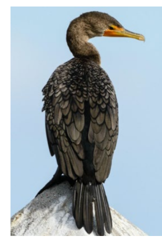

Figure 32. Pelagic cormorant (Linda Tanner).

5.4.6 Double-crested Cormorant

Double-crested cormorants (*Phalacrocorax auritus*) are the largest cormorants in the Pacific. They have a yellow face, gular pouch, and a long, blunt bill that is hooked at the tip (Figure 33). They measure around 80 cm in length and can dive to a depth of 1.5–7.5 m. Double-crested cormorants are resident within the Puget Sound and can be found on colonies from late March to mid-November. They are considered a species of least concern by the IUCN.

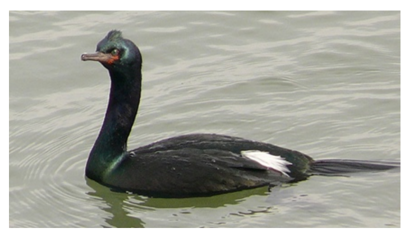

Figure 33. Double-crested cormorant (Richard Hebhardt).

5.4.7 Common Murre

Common murre (*Uria aalge*) cluster in dense colonies on the flat tops and wide ledges of islands. They have a white breast and sleek black feathers (Figure 34). They are around 42 cm in length with around 67 cm in wingspan. They occur from California to Alaska and spend most of their time at sea, only coming to land to breed on rocky cliff shores or islands. They usually dive to depths of 30 to 60 m. They are considered a species of least concern by the IUCN.

Figure 34. Common murre (U.S. Fish and Wildlife Service).

6.0 Delineating Areas in the Western Passage for Floating Tidal Technologies

Western Passage is located in the state of Maine, close to the border with Canada (see Figure 35). Areas within the waters of Western Passage must be assessed for tidal current speeds and resources that could support energy harvest, as well as for areas where sensitive and/or protected living organisms might be at risk of being damaged by the marine energy technology.

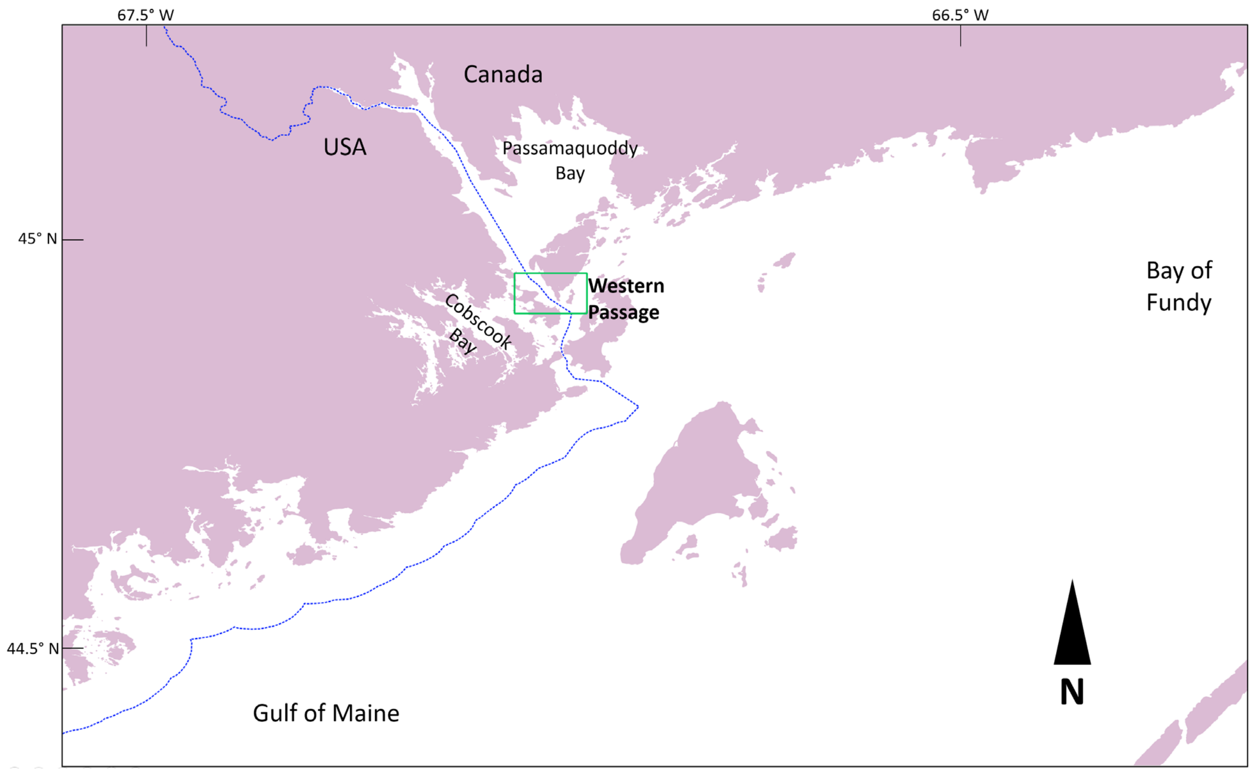

Figure 35. Map of Western Passage in the state of Maine.

6.1 Bathymetry and Tidal Resources

The bathymetry (Figure 36) and the tidal currents maps (Figures 37 and 38) in Western Passage are based on the assessments from Yang et al. (2020). Based on the information available, sufficient tidal power is observed in the southeastern part of Western Passage, between Cummings Cove and Eastport.

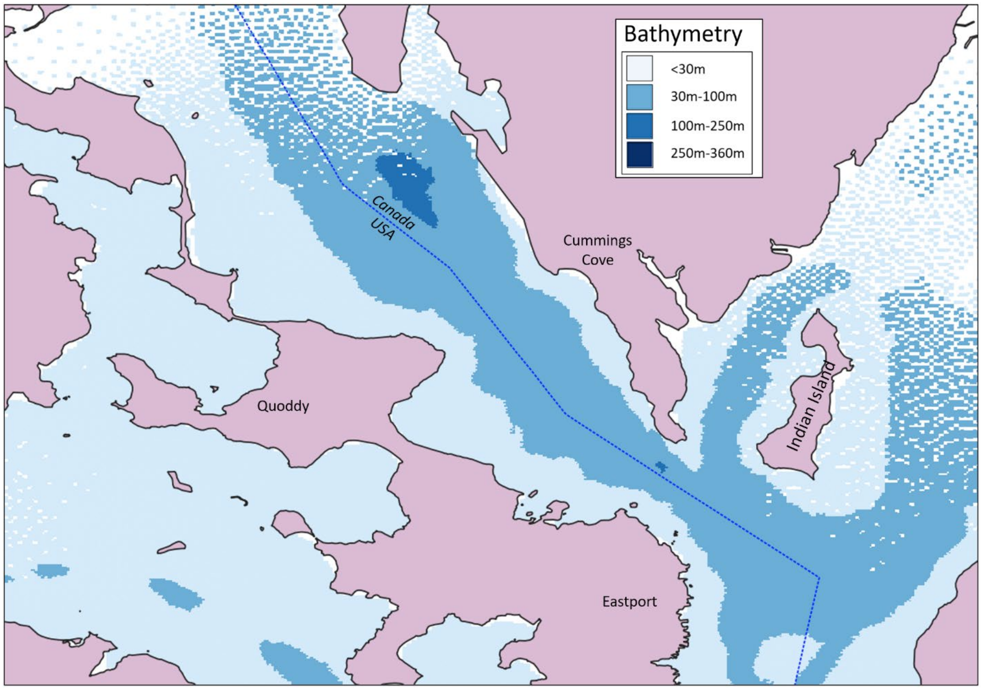

Figure 36. Bathymetric chart for Western Passage (Yang et al. 2020).

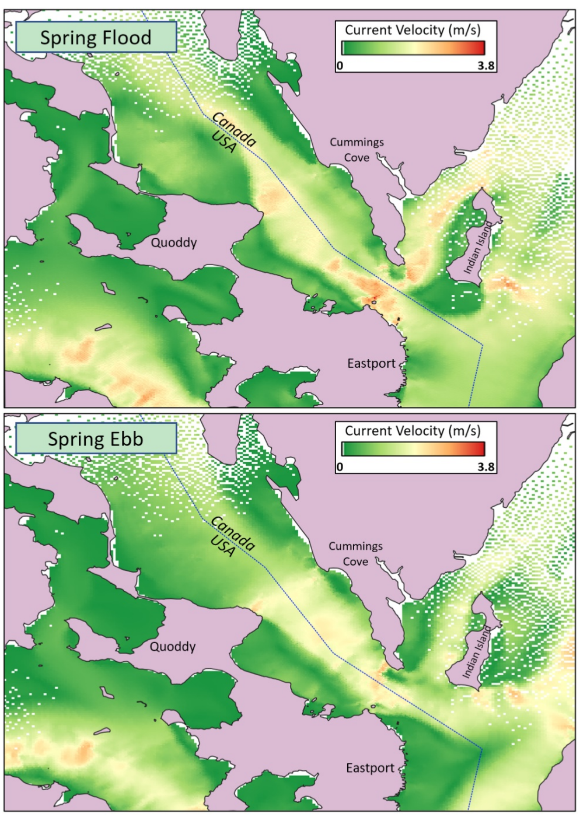

Figure 37. Maximum current velocity in Western Passage during the spring flood in the upper panel and the spring ebb in the lower panel (Yang et al. 2020).

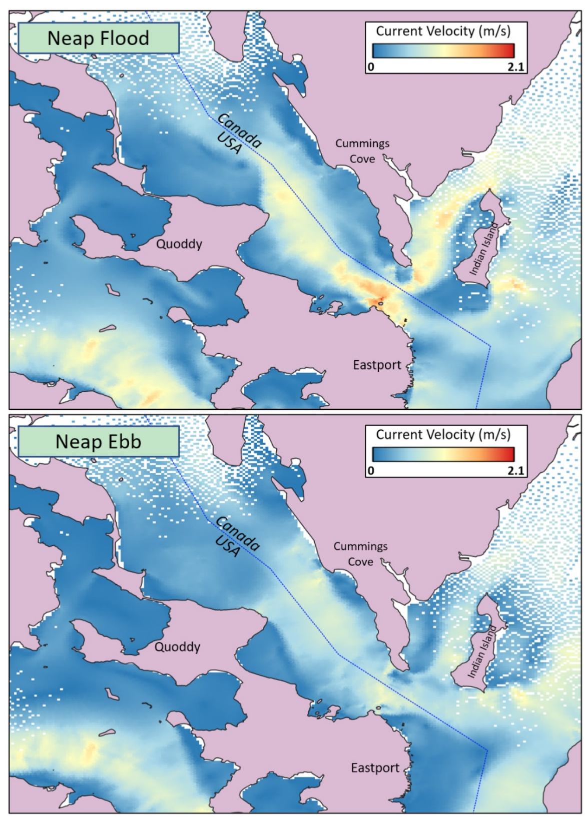

Figure 38. Maximum current velocity in Western Passage during the neap flood in the upper panel and the neap ebb in the lower panel (Yang et al. 2020).

6.2 Protected and Sensitive Marine Animals and Habitats around Western Passage

The species and habitats that will drive placement of a tidal project in Western Passage are described here, under the specific protection mechanisms of importance.

6.2.1 Species and Habitats around Western Passage

Several marine species that are federally or state-listed as endangered or threatened (State of Maine Title 12, §6975; National Archives Federal Register) are known to be seasonally or annually present in the Gulf of Maine. Most can be found in Western Passage. See Table 4 for more information. Critical habitats of these species in the State of Maine do not overlap Western Passage and are, therefore, not described here.

Table 4. Federal or state status (threatened, endangered) of the marine species that can potentially occur in Western Passage.

	Threatened		**Endangered**		
Species	State of Maine	Federal	State of Maine	Federal	Notes
Atlantic salmon (*Salmo salar*)				X	Gulf of Maine DPS (74 FR 29344)
Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus)*		X			Gulf of Maine DPS (78 FR 69310)
North Atlantic right whale (*Eubalaena glacialis)*			X	X	73 FR 12024
Fin whale (*Balaenoptera physalus)*			X	X	35 FR 8491
Sei whale (*Balaenoptera borealis*)			X	X	35 FR 18319
Leatherback sea turtle (*Dermochelys coriacea)*			X	X	35 FR 8491
Loggerhead sea turtle (*Caretta caretta)*	X	X			Northwest Atlantic Ocean DPS (76 FR 58867)
Shortnose sturgeon (*Acipenser brevirostrum*)			X	X	32 FR 4001

6.2.2 Endangered Species around Western Passage

6.2.2.1 Atlantic Salmon (*Salmo salar*)

Figure 39. Atlantic salmon (NOAA Fisheries).

Atlantic salmon are anadromous species; spawning and rearing of juveniles occur in rivers, and smolts migrate to saltwater to feed, grow, and mature (Figure 39). Their average mature weight is 3.4 to 5.4 kg, but they can grow to 13.6 kg, measuring 70 cm long, and can live up to 7 years. Wild populations of U.S. Atlantic salmon are found in at least eight rivers in Maine. The Gulf of Maine DPS is listed as endangered under the ESA and considered to be one of the species most at risk for extinction in the future.[1] Recovery efforts for Atlantic salmon focus on improving the access to quality habitat to prevent extinction. In spring, U.S. Atlantic salmon leave Maine rivers and reach the seas off Newfoundland and Labrador, Canada, by mid-summer. Maturing fish migrate back to their native rivers in Maine to spawn after one to three years.

6.2.2.2 Shortnose Sturgeon (*Acipenser brevirostrum*)

Figure 40. Shortnose sturgeon (NOAA Fisheries).

Shortnose sturgeon (Figure 40) live in rivers and coastal waters from Canada to Florida. Larvae hatch in rivers; juveniles and adults spend most of their time in estuaries. Spawning occurs during spring. Shortnose sturgeon are slow-growing and late-maturing. They can weigh up to 22.6 kg and measure up to 1.4 m. Their average lifespan is 30 years, but they can live up to 67 years. There are three metapopulations of shortnose sturgeon: northern, mid-Atlantic, and southern. Shortnose sturgeon are found in 41 rivers and bays along the East Coast of the United States and spawn in 19 of these rivers. They are found in the Saint John River (Bay of Fundy, Canada) and in several rivers in the north of Maine, including the Penobscot, Kennebec, and Androscoggin rivers.

6.2.2.3 Fin Whale (*Balaenoptera physalus*)

Figure 41. Fin whale (NOAA Fisheries).

Fin whales are the second largest whale species and are found throughout the world's oceans (Figure 41). They weigh between 40 and 80 T and can measure up to 26 m. Their lifespan is 80 to 90 years. There are four stocks of fin whales, including the western North Atlantic stock, found along the U.S. East Coast. Fin whales are typically found in deep, offshore water. They are migratory, moving from the feeding areas near the poles in summer to tropical breeding and calving areas in winter. During spring, summer, and fall, fin whales are often observed around the sloping sides of the banks and ledges of the Gulf of Maine.

[1] Species in the spotlight: https://www.fisheries.noaa.gov/topic/endangered-species-conservation#species-in-the-spotlight

6.2.2.4 North Atlantic Right Whale (*Eubalaena glacialis*)

The North Atlantic right whale species has less than 400 individuals remaining and is one of the most endangered large whale species. North Atlantic right whales weigh up to 63 T, measure up to 16 m, and live up to 70 years (Figure 42). They mainly occur on the continental shelf along the Atlantic coast. In the spring, summer, and into fall, they can be found off New England, in the Bay of Fundy, and further north off Canada, where they feed and mate. In fall, some North Atlantic right whales travel to the shallow coastal waters off South Carolina, Georgia, and northeastern Florida.

Figure 42. North Atlantic right whale (NOAA Fisheries).

6.2.2.5 Sei Whale (*Balaenoptera borealis*)

Sei whales (Figure 43) can weigh up to 45 T, measure up to 18 m, and can live between 50 and 70 years. They are distributed in subtropical, temperate, and subpolar waters around the world. During summer, they are commonly found in the Gulf of Maine. Their movement patterns are not well described, but they are typically observed in deep waters far from the coast.

Figure 43. Sei whale (NOAA Fisheries).

6.2.2.6 Leatherback Sea Turtle (*Dermochelys coriacea*)

The leatherback sea turtle is the largest sea turtle in the world (Figure 44). They weigh between 340 and 455 kg and can measure up to 1.8 m. Their lifespan is estimated to be approximately 50 years. They are highly migratory and nest mainly on tropical and subtropical beaches. They are commonly observed on their foraging grounds off Nova Scotia and in the Gulf of Maine during fall. This is one of the species most at risk for extinction in the future.[1]

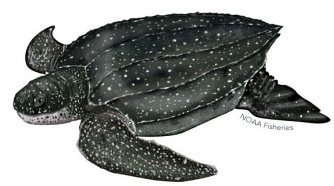

Figure 44. Leatherback sea turtle (NOAA Fisheries).

6.2.3 Threatened Species around Western Passage

6.2.3.1 Atlantic Sturgeon (*Acipenser oxyrhynchus oxyrhynchus*)

Atlantic sturgeon can weigh up to 363 kg and measure up to 4.3 m (Figure 45). Their lifespan is 60 years. Juveniles live and mature in saltwater, and adults return to their birthplace in freshwater to spawn. Atlantic sturgeons occur in rivers and coastal waters along the U.S. East Coast, from Maine to Florida. Atlantic sturgeons that hatch in the Gulf of Maine rivers are listed as threatened.

Figure 45. Atlantic sturgeon (NOAA Fisheries)

[1] Species in the spotlight: https://www.fisheries.noaa.gov/topic/endangered-species-conservation#species-in-the-spotlight

6.2.3.2 Loggerhead Sea Turtle (*Caretta caretta*)

Loggerhead sea turtles (Figure 46) are the most abundant species of sea turtle that nests in the United States. They can weigh up to 159 kg and measure up to 1 m. Their lifespan is estimated to be 70 years or more. Juveniles and adults mainly live in U.S. coastal waters. Loggerheads can be found as far north as Nova Scotia, Canada, but are more common in the southern Gulf of Maine and through the Gulf of Mexico.

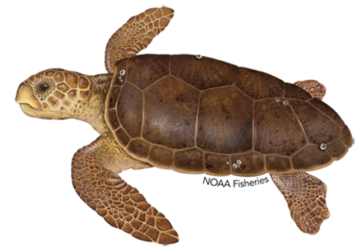

Figure 46. Loggerhead sea turtle (NOAA Fisheries).

6.2.4 Protected Marine Mammals

Several species protected throughout their range under the MMPA are thought to occur in Western Passage.

6.2.4.1 Fin Whale (*Balaenoptera physalus*)

The fin whale is also listed as depleted throughout its range under the MMPA. This means that it is in danger of extinction throughout all or much of its range. See 5.2.2.3 for more species information.

6.2.4.2 North Atlantic Right Whale (*Eubalaena glacialis*)

The North Atlantic right whale is also listed as depleted throughout its range under the MMPA. See 5.2.2.4 for more species information.

6.2.4.3 Sei Whale (*Balaenoptera borealis*)

The Sei whale is also listed as depleted throughout its range under the MMPA. See 5.2.2.5 for more species information.

6.2.4.4 Humpback Whale (*Megaptera novaengliae*)

The North Atlantic population of humpback whales feed during spring, summer, and fall throughout a range that extends across the Atlantic Ocean from the Gulf of Maine to Norway. They migrate south during winter. See 4.2.2.2 for the description of the species. In the most recent (2018) assessment, the species is listed as “Least Concern and increasing” on the global IUCN Red List.

6.2.4.5 Minke Whale (*Balaenoptera acutorostrata*)

The North Atlantic minke whale (*Balaenoptera acutorostrata acutorostrata*) is one of the two minke whale species present in the Northern Hemisphere. They are found throughout the northern Atlantic and migrate between the Arctic (summer) and the equator (winter). Minke whales have been observed in Western Passage (ORPC 2013). See 4.2.4.10 for the description of the species.

6.2.4.6 Harbor Porpoise (*Phocoena phocoena*)

In the North Atlantic, harbor porpoises are found from West Greenland to Cape Hatteras, North Carolina. They have been observed in Western Passage (ORPC 2013).[1] See 4.2.4.6 for the description of the species.

6.2.4.7 Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)

Atlantic white-sided dolphins weigh between 180 and 226 kg, can measure up to 2.7 m, and live at least 22 years (Figure 47). They are distributed in the temperate waters of the North Atlantic Ocean and are found off the coast of North Carolina to Maine. Their range includes the Gulf of Maine, and they are known to be present in Cobscook Bay (77 FR 15045). They move closer inshore and north during the summer.

Figure 47. Atlantic white-sided dolphin (NOAA Fisheries).

6.2.4.8 Gray Seal (*Halichoerus grypus*)

Gray seals can weigh up to 400 kg and measure up to 3 m (Figure 48). Their lifespan is between 25 to 35 years. They are found in coastal waters throughout the North Atlantic Ocean. The western North Atlantic stock is distributed in eastern Canada and northeastern United States. Gray seals often live the same areas as harbor seals. In the western Atlantic Ocean, females give birth from December to February. They have been observed in Western Passage (ORPC 2013).

Figure 48. Gray seal (NOAA Fisheries).

6.2.4.9 Harbor Seal (*Phoca vitulina*)

Harbor seals can weigh up to 129 kg and measure between 1.5 and 1.8 m (Figure 49). Their lifespan is about 25 to 30 years. One stock of harbor seal is identified in the western North Atlantic. The population of harbor seals in New England is stable. Harbor seals have been observed in Western Passage (ORPC 2013).

Figure 49. Harbor seal (NOAA Fisheries).

6.2.5 Other Key Species

The great white shark (*Carcharodon carcharia)* and porbeagle shark *(Lamna nasus)* have been observed in Western Passage (Staines et al. 2020).

[1] https://tethys.pnnl.gov/project-sites/western-passage-tidal-energy-project

6.2.5.1 White Shark (*Carcharodon carcharia*)

The white shark is the world's largest known predatory fish (Figure 50). It feeds on a broad spectrum of prey, from small fish, such as halibut, to large seals and dolphins. White shark populations reside around highly productive temperate coastal waters (waters characterized by an abundance of fishes and marine mammals), and their range includes the Atlantic Ocean near Western Passage.

Figure 50. White shark (NOAA Fisheries).

6.2.5.2 Porbeagle Shark (*Lamna nasus*)

The porbeagle shark is a species of mackerel shark widely distributed in the cold and temperate marine waters of the North Atlantic and Southern Hemisphere (Figure 51). They are most often found over food-rich banks on the outer continental shelf. They also conduct long-distance seasonal migrations, generally shifting between shallower and deeper water. This species has been declared vulnerable by the IUCN.

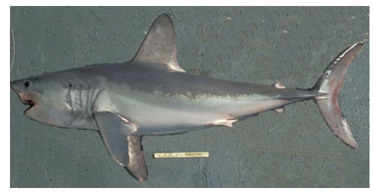

Figure 51. Porbeagle shark (NOAA Fisheries).

6.3 Essential Fish Habitat around Western Passage

EFH in New England is identified in FMPs. EFHs have been identified for the following groups in the Gulf of Maine:

- Atlantic sea scallops (*Placopecten magellanicus*) – all life stages
- Northeast Multispecies (Groundfish) – all life stages
- Small-mesh Multispecies – all life stages
- Atlantic herring (*Clupea harengus harengus*) – all life stages
- Skates – all life stages
- Atlantic salmon.

6.3.1 Atlantic Sea Scallop (*Placopecten magellanicus*)

The FMP covers Atlantic Sea scallops (Figure 52) inhabiting U.S. waters in the Gulf of Maine, Georges Bank, and the Mid-Atlantic Bight (New England Fishery Management Council 1982). Sea scallops typically occur at depths ranging from 18 to 110 m, but they can also occur in shallower water (to 2 m depth) in estuaries and embayment along the coast of Maine. In the Gulf of Maine, scallop beds occur in inshore areas from Penobscot Bay and eastward, as well as in Cape Cod Bay. Sea scallop adults spawn eggs at the bottom of the water column, at depth between 13 and 180 m. Hatched larvae are distributed throughout the water column and are distributed by currents.

Figure 52. Atlantic Sea Scallop (NOAA Fisheries).

6.3.2 Northeast Multispecies (Groundfish)

Fisheries stocks under the Northeast Multispecies FMP include

- Atlantic cod (*Gadus morhua*)
- Haddock (*Melanogrammus aeglefinus*)
- Redfish (*Sebastes* spp.)
- Pollock (*Pollachius virens*)
- Whiting (*Merluccius bilinearis*)
- Red hake (*Urophycis chuss*)
- White hake (*Urophycis tenuis*)
- Yellowtail flounder (*Limanda ferruginea*)
- Atlantic halibut (*Hippoglossus hippoglossus*)
- Atlantic wolffish (*Anarhichas lupus*)
- Ocean pout (*Zoarces americanus*)
- American plaice (*Hippoglossoides platessoides*)
- Witch flounder (*Glyptocephalus cynoglossus*)
- Winter flounder (*Pseudopleuronectes americanus*)
- Windowpane flounder (*Lophopsetta masculata*).

This FMP covers the continental shelf along the northeast coast of the United States, from Georges Bank south to the Mid-Atlantic Bight, and in the Gulf of Maine (New England Fishery Management Council 1985).

6.3.3 Small-mesh Multispecies

This FMP consists of two stocks of whiting, two stocks of red hake, and one stock of offshore hake (*Merluccius albidus*) (New England Fishery Management Council 2018). This fishery uses small-mesh nets and is regulated through a species exemption from the Northeast Multispecies FMP. EFH for offshore hake includes bottom habitats for juveniles and adults along the continental shelf and pelagic waters less than 1,250 m depth for eggs and larvae. EFH whiting and red hake are described in the Northeast Multispecies FMP.

6.3.4 Atlantic Herring (*Clupea harengus*)

The Atlantic herring (Figure 53) FMP covers all Atlantic herring within the U.S. territorial sea and EEZ (New England Fishery Management Council 1999). Spawning occurs in the Gulf of Maine at 10 to 100 m depth on coastal banks. After hatching, larvae are pelagic and are distributed in the nearshore and estuarine waters of the Gulf of Maine during winter. Juvenile and adult herring are present in the Bay of Fundy.

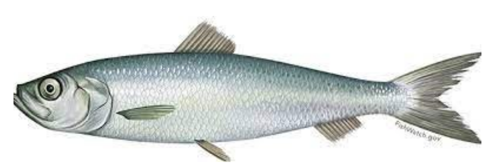

Figure 53. Atlantic herring (NOAA Fisheries).

6.3.5 Skates

Fisheries stocks under the Skates FMP (New England Fishery Management Council 2003) include

- Barndoor skate (*Dipturus laevis*)
- Clearnose skate (*Raja eglanteria*)
- Little skate (*Leucoraja erinacea*)
- Rosette skate (*Leucoraja garmani*)
- Smooth skate (*Malacoraja senta*)
- Thorny skate (*Amblyraja radiata*)
- Winter skate (*Leucoraja ocellata*).

EFHs for the Skates FMP are soft-bottom habitat along the continental shelf, from the shoreline to around 200 m depth.

6.3.6 Atlantic Salmon (*Salmo salar*)

This FMP includes all anadromous salmonids of U.S. origin in the North Atlantic area throughout their migratory ranges in the United States (New England Fishery Management Council 1987). EFHs for Atlantic salmon cover most rivers, estuaries, and bays in Maine. EFHs for Atlantic salmon also include HAPCs in seven Maine rivers: Dennys, Machias, East Machias, Pleasant, Narraguagus, Ducktrap, and Sheepscot.

6.4 Seabirds around Western Passage

Several species of seabirds are present in the area around Western Passage.

6.4.1 Eiders

King eiders and common eiders (*Somateria mollissima),* the largest of all Northern Hemisphere ducks (Figure 54), reside around Western Passage. Breeding males are sharply marked in white and black, with pistachio-green accents on the neck. Females are barred in warm brown and black. These birds gather along rocky ocean shores, diving for mussels and other shellfish (Cornell Lab of Ornithology 2021). Common eiders are listed as “near threatened” and king eiders as “least concern” in IUCN Red List of Threatened Species 2018 (e.T22680405A132525971 and e.T22680409A132526730, respectively).

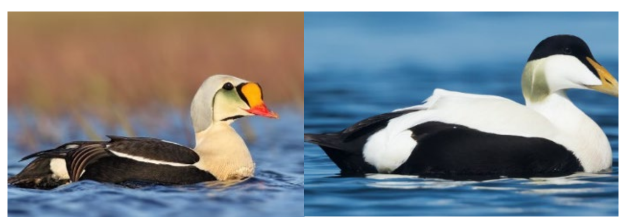

Figure 54. King eider (by Dan Behm) and common eider (by Corey Hayes).

6.4.2 Grebes

Figure 55. Horned grebe (by Ken Crebbin) and pied-billed grebe (by Shimmering Energy).

Horned grebe (*Podiceps auritus*; migration and nonbreeding) and pied-billed grebe (*Podilymbus podiceps;* only breeding) (Figure 55) reside and/or breed around Western Passage. Horned grebes are sighted in summer with gray-black heads and back, brick-red necks, and blazing yellow-orange "horns" on the head. In winter, they transition to a much more subdued gray and white, with a neat black cap and white cheek that helps separate them from the similar eared grebe. In winter, horned grebes gather in flocks and dive for fish and other small prey in lakes and bays. The pied-billed grebe is common across much of North America. These small brown birds have unusually thick bills that turn silver and black in summer. They inhabit sluggish rivers, freshwater marshes, lakes, and estuaries (Cornell Lab of Ornithology 2021). Horned grebes are listed as “vulnerable” and pied-billed grebes “least concern” in the IUCN Red List of Threatened Species (2018 e.T22696606A132066871 and 2016 e.T22696574A93571798, respectively).

6.4.3 Mergansers

Figure 56. Hooded merganser (by Jason Major), common merganser (by Ray Hennessy), and red-breasted merganser (by Ian Davies).

Hooded mergansers (*Lophodytes cucullatus*), common mergansers (Goosander; *Mergus merganser*), and red-breasted mergansers (*Mergus serrator*) (Figure 56) reside around Western Passage. Mergansers are fairly common on small ponds and streams across their breeding range. Common mergansers nest in hollow trees; in winter they form flocks on larger bodies of water. Adult male hooded mergansers have sharp black and white patterns set off by chestnut flanks. Females have a cinnamon crest. Hooded mergansers are fairly common on small ponds and rivers, where they dive for fish, crayfish, and other food. The red-breasted merganser is a shaggy-headed diving duck, also known as the “sawbill,” named for its thin bill with tiny serrations on it that it uses to hold slippery fish. It breeds in the boreal forest on freshwater and saltwater wetlands (Cornell Lab of Ornithology 2021). All three merganser species are listed as “least concern” in the IUCN Red List of Threatened Species (2016 e.T22680472A92863561, 2018 e.T22680492A132054083, and 2018 e.T22680485A132053220, respectively).

6.4.4 Black Guillemot (*Cepphus 37rille*)

Black guillemots (*Cepphus 37rille)* have black and white plumage and red legs (Figure 57). They are present on the rocky coasts of the North Atlantic. They forage close to shore, flapping their wings to power deep dives for fish and invertebrates near the sea bottom. Some individuals stay close to shore year-round, while others move out to sea to forage (Cornell Lab of Ornithology 2021). This species is listed as "least concern" in the IUCN Red List of Threatened Species (2018: e.T22694861A132577878).

Figure 57. Black guillemot (by Yann Kolbeinsson).

6.4.5 Great Blue Heron (*Ardea Herodias*)

The great blue heron (*Ardea Herodias*) has blue-gray plumage (Figure 58) and lives around shorelines, riverbanks, and the edges of marshes, estuaries, and ponds (Cornell Lab of Ornithology 2021). It is listed as "least concern" in the IUCN Red List of Threatened Species (2020: e.T181500967A181565357).

Figure 58. Great blue heron (by Jonathan Fredin).

6.4.6 Bald Eagle (*Haliaeetus leucocephalus*)

The bald eagle (*Haliaeetus leucocephalus*) has a white-feathered head in contrast to chocolate-brown body and wings (Figure 59). They chase other birds for their food or scavenge for dead animals. Once endangered by hunting and pesticides, bald eagles have flourished under protection. They are often found near water, where they catch fish (Cornell Lab of Ornithology 2021). It is listed as "least concern" in the IUCN Red List of Threatened Species (2016: e.T22695144A93492523).

Figure 59. Bald eagle (by Keith Williams).

6.4.7 Gulls

European herring gulls (*Larus argentatus*) reside in Western Passage, and ring-billed gulls (*Larus delawarensis*) (Figure 60) migrate through the area. Herring gulls are gray and white with pink legs. They are found across much of coastal North America in winter. Most ring-billed gulls nest in the interior of the continent, near freshwater. They also frequent reservoirs, lakes, marshes, mudflats, and beaches. A black band encircling the yellow bill helps distinguish adults from other gulls (Cornell Lab of Ornithology 2021). Both species are listed as "least threatened" in the IUCN Red List of Threatened Species (2018: e.T62030608A132672776 and 2018: e.T22694317A132541912, respectively).

Figure 60. Herring gull (by Ben Bunn) and ring-billed gulls (by Miguel de la Bastide).

7.0 Assessment of Environmental Effects from Marine Energy Devices to Marine Animals and Seabirds in San Juan Islands and Western Passage

Regulatory processes that address the safety of marine animals and seabirds from development projects are based on the likely risk to those animals from development. In this case, the risks would be associated with the construction and operation of floating tidal devices. The construction phase of installing floating tidal turbines is similar to that of many other in water projects and is likely to be subject to restrictions based on work windows to protect vulnerable marine species during specific life history stages.

There are few true analogues to many of the risks associated with operational floating tidal turbines. However, potential effects of operational turbines and their associated systems have been examined in depth by a number of research groups, as brought together in the Ocean Energy Systems-Environmental 2020 State of the Science report (Copping and Hemery 2020).

The greatest perceived threats to marine animals and birds from marine energy devices that will influence the regulatory processes may include the following:

- risk of collision with tidal turbine blades
- effects of underwater noise from the device
- effects of electromagnetic fields from the power export cable
- changes in benthic and pelagic habitat
- entanglement in mooring lines and inter-array cables
- haul out on floating device and/or roosting of seabirds on device
- displacement of animals from critical habitats by anchors, mooring lines, or the device.

Each of these risks may require some investigation; while there are increasing bodies of knowledge for most of these stressors on marine animals and habitats (Copping and Hemery 2020), specific details of these interactions have not been studied for most of the species in the San Juan Islands or Western Passage.

One area where pertinent research can be brought to bear on floating tidal turbines involves the potential effect of underwater acoustic frequencies on marine mammals. Evaluating the potential for underwater noise from the generator and other moving parts of the tidal device to disturb marine mammal navigation and communication requires an understanding of the hearing ranges of key species, particularly marine mammals and some species of fish. Information about the hearing range of marine mammals can help determine whether there is likely to be any overlap with the frequency from the marine energy device. The hearing ranges of marine mammals underwater are detailed in Table 5.

Table 5. Marine mammal underwater functional hearing ranges (Southall et al. 2019).

Functional Hearing Group	Relevant Species	Functional Hearing Range
Low-frequency cetaceans	Humpback and gray whales	10 Hz to 30 kHz
High-frequency cetaceans	Killer whale	100 Hz to 150 kHz
Very high-frequency cetaceans	Harbor porpoise	150 Hz to 180 kHz
Phocid pinnipeds	Harbor seal	100 Hz to 100 kHz
Otariid pinnipeds	California sea lion	100 Hz to 50 kHz

8.0 Environmental Data Collection for Initial Development of Floating Tidal Turbines, Post-Installation Monitoring Needs, and Mitigation

Regulators routinely require that applicants for marine development projects provide baseline data before construction, as well as potentially requiring environmental monitoring data around the device after construction but before operation begins. In addition, all projects will be required to carry out some level of compliance monitoring during operation. Mitigation is not generally considered as a key factor in MRE development at this time. Each of these types of data collection is briefly addressed here.

8.1 Baseline Data Collection

The information gathered for this assessment was derived from publicly available databases and was examined based on the suitability for the deployment and operation of floating tidal technologies. While these data resemble the information likely to be required for regulatory assessment, this analysis does not describe or replace any regulatory requirements. However, after extensive searches of online data sets and information sources, it is the opinion of the authors that there are unlikely to be significant additional sources of information on the presence of marine animals or habitats of interest in the San Juan Islands or Western Passage that will support the development of floating tidal energy. The choice of a site for floating tidal turbines will be based on measurements and models of the tidal resource, as well as the type of baseline data noted here, in order to avoid and minimize interaction and harm to marine species. Once the site is chosen, it will be necessary for the developer to undertake a detailed seafloor survey. This survey will provide vital information that will support installation of anchors and cables and will also provide an up to date and detailed assessment of the benthic habitats.

With the exception of the more detailed seafloor survey that will provide additional data on benthic habitats, it is the opinion of the authors that the collection of one to two years of additional data on the presence of species of interest and their habitats in the area of the San Juan Islands or Western Passage would not add to the existing data to provide further insight on how the development of floating tidal turbines will affect these species. The regulators will decide on the adequacy of these data for assessing the baseline conditions of the areas of interest; however, the authors expect they will take into account that additional data collection over a short period of time is not likely to further inform a baseline assessment of the areas.

The baseline data and information collected in this report form a snapshot and (in some cases) inform trends in marine animals' distribution and presence of critical habitats. Combined with physical data and ancillary information, this information can be used for an initial assessment for where floating tidal technologies might succeed, while ensuring minimal effects to precious marine resources. Such an initial assessment is shown as an example of this process in Table 6.

Table 6. Summary of environmental and logistical parameters of interest for siting floating tidal technologies in San Juan Islands. The four channels of interest and the tidal current information are drawn from the Yang et al. (2020) assessment of tidal currents. The existing infrastructure information is courtesy of San Juan County and the Washington State Ferry System. The information on endangered species and critical habitats is drawn from the sources in this report.

<table>
<tr><th>San Juan Islands Channels</th><th>Maximum Tidal Energy at Spring Tide (m/s)</th><th>Minimum Tidal Energy at Neap Tide (m/s)</th><th>Existing Infrastructure</th><th>Ferry Route</th><th>Navigation Route</th><th>Endangered Species Presence and Abundance</th><th>Critical Habitats</th><th>Protected Marine Mammals Presence</th><th>Essential Fish Habitats</th><th>Seabirds Presence and Abundance</th></tr>
<tr><td>Spieden Channel</td><td>2.55</td><td>1.37</td><td></td><td>Yes</td><td>Major route</td><td>Southern Resident Killer Whale (SRKW) ++

Humpback Whale (HW) ++

Bocaccio (B) ++</td><td rowspan="3">All four channels have critical habitat for:

Southern Resident Killer Whale

Bocaccio

Yelloweye Rockfish

Chinook Salmon</td><td rowspan="4">All species*</td><td rowspan="4">All four channels have essential fish habitat for:

CPS

Pacific Coast Salmon

Pacific Coast Groundfish</td><td>All species** ++</td></tr>
<tr><td>San Juan Channel</td><td>2.61</td><td>1.15</td><td>Conduit

Subsea cable

Ferry terminal</td><td>Yes</td><td>Small vessels only</td><td>SRKW +
HW +
B ++</td><td>All species** +</td></tr>
<tr><td>Rosario Strait</td><td>3.14</td><td>1.80</td><td>Conduit</td><td>Ferry crosses very southern tip only</td><td>Secondary route</td><td>SRKW +
HW +
B +</td><td>All species** ++</td></tr>
<tr><td>Middle Channel</td><td>3.28</td><td>1.62</td><td></td><td>No</td><td>Secondary route</td><td>SRKW ++
HW ++
B +</td><td>Middle channel also has critical habitat for:

Green Sturgeon</td><td>All species** +</td></tr>
</table>

Most desirable | Moderately desirable | Least desirable

* Southern resident killer whale, humpback whale, gray whale, short-finned pilot whale, California sea lion, harbor porpoise, harbor seal, Steller sea lion, northern elephant seal, minke whale, Dall's porpoise
** Rhinoceros auklet, marbled murrelet, tufted puffin, pigeon guillemot, pelagic cormorant, double-crested cormorant, common murre
\+ Moderate abundance
\++ High abundance

8.2 Pre-Operational Monitoring

Although not common in the United States, regulators might require the collection of environmental monitoring data following installation of a floating tidal turbine, prior to granting permission to operate the turbine. If this were the case, all protocols and instruments planned for compliance monitoring around the operational turbines should be used to provide a “before” operational state and allow for comparison with an “after” operational state.

8.3 Compliance (Post-Installation) Monitoring

Once floating tidal turbines are installed and operational, compliance monitoring requirements will be put in place to ensure that the potential risks to marine animals and habitats were adequately scoped at the time of permitting. These requirements might last for a year or two, or potentially longer. The compliance monitoring data, if collected correctly and analyzed to answer specific questions, will add valuable knowledge to our collective understanding of potential effects of floating tidal turbines on the marine environment and should help the marine energy community better pinpoint where future data collection and analysis will progress this understanding. These data will also contribute to the parameterization and validation of numerical models that take into account the interactions between floating tidal turbines and the marine environment, lessening the need for extensive data collection and duration of compliance monitoring in the future.

The number of samples or observations to be collected, the frequency of collection, and the locations of sample/observation collection must be determined once a deployment site and other specifics are identified.

The premise behind developing a framework for monitoring around floating tidal turbines is the need to place each monitoring data collection and analysis action around questions that get to the heart of potential risk to the marine environment. It is important to note that the pace of ongoing research into animal interactions and habitat effects continues to accelerate, and it is the hope of the authors that a number of the monitoring questions posed here will be answered or advanced through research studies in the next 2 to 5 years. These advances will help further define the questions and may lessen or refocus compliance monitoring requirements.

Determining the potential risks (delineated in Section 7.0) for each location (San Juan Islands and Western Passage) will require that target marine animals or habitats be identified and that different questions may be asked. Risk in this case is defined at the likelihood of the event occurring (probability of occurrence or exposure at a damaging level) and the outcome of the event (consequence of injury or death). Each of the seven key interactions is described in the following sections and in Table 7.

8.3.1 Collision Risk

Animals that collide with a rotating tidal turbine blade may suffer recoverable injuries, injuries that later result in their death, or may be killed outright. This risk is the most difficult to resolve because it depends on the behavior and swimming capabilities of each species, as well as our limited ability to monitor and detect a rare occurrence. The instrumentation used to observe potential collisions is not well developed or commercialized, as the environment (swift moving often turbid waters) makes observations problematic. The approaches used resolve into several possibilities for interaction: whether animals will detect and avoid the turbine (at a distance of multiple rotor diameters), detect and evade the device (within one or several rotor diameters), or connect with the device including the rotor blades (Sparling et al. 2020). The key questions, animals at risk, and methods for data collection are summarized in Table 7.

8.3.2 Effects of Underwater Noise

The concern around effects of underwater noise from marine energy devices focuses on marine mammals and certain fish species who use sound extensively for communication and navigation. Two important tools can assist with the determination of this risk: the IEC TC114-40 specification for measuring underwater sound from MRE devices (IEC 2019) and U.S. standards and guidelines for levels of underwater noise that will disturb or harm marine mammals and fish (NMFS 2018). Measuring the acoustic output from each model of floating tidal turbine could provide a benchmark that will lessen the need for ongoing monitoring of the sounds output (although developers may be recording acoustic output for purposes of machine health on an ongoing basis). Monitoring (and research studies) that examine the behavior of animals around floating tidal turbines is very expensive and technically challenging and is generally not thought to be key to resolving underwater noise issues (Polagye and Bassett 2020). The key questions, animals at risk, and methods for data collection are summarized in Table 7.

8.3.3 Effects of Electromagnetic Fields

Power export cables, cables that run from the floating tidal turbine generator, and the tidal rotors all will generate electromagnetic fields (EMFs). Sensitive marine animals may be adversely affected, particularly those that spend considerable time in close proximity to the EMF source (most likely benthic organisms). Ongoing research in this area appears to indicate that the levels of EMF carried by small numbers of tidal turbines, with outputs less than 10 MW, are unlikely to be harmful to marine animals (Gill and Desender 2020). In addition, the export cables are likely to be buried or covered, separating the animals from the source. The key questions, animals at risk, and methods for data collection are summarized in Table 7.

8.3.4 Changes in Benthic and Pelagic Habitat

The presence of floating tidal turbines will require anchors in the seabed and mooring cables through the water column, in addition to the presence of the device on the surface. These installations have the potential to alter habitats, affecting the animals that rely on them, particularly benthic habitats (Hemery 2020). Baseline seafloor surveys will help establish the natural habitats, and compliance monitoring may be needed periodically to ensure that the effects (if any) are in line with what is anticipated. The key questions, animals at risk, and methods for data collection are summarized in Table 7.

8.3.5 Entanglement in Mooring Lines and Inter-array Cables

There are concerns that large marine animals could become entangled or trapped in mooring lines and inter-array cables; for the San Juan Islands and Western Passage, these are likely to be marine mammals. This concern stems from entanglement, injury, and death to marine mammals and sea turtles from lost and abandoned fishing gear. This risk is not analogous to marine energy, as there are no loose ends of lines or slack lines creating loops that might entangle animals (Garavelli 2020). This risk should be resolved from research studies, although stakeholders continue to raise the issue. The key questions, animals at risk, and methods for data collection are summarized in Table 7.

8.3.6 Haul Out on Floating Tidal Turbine and/or Roosting of Seabirds on Device

Concerns have been raised by stakeholders and regulators that seals and sea lions might haul out and seabirds might roost on floating tidal turbine hulls. Although there is little likelihood of harm to the animals from this behavior, the design of the hull can be made to discourage or make impossible this behavior, including creating a lack of level space for pinnipeds to haul out and a rough or spiky surface that will discourage bird roosting. Monitoring for this effect should not be needed; however, key questions, animals at risk, and methods for data collection are summarized in Table 7.

8.3.7 Displacement of Animals from Critical Habitats

The presence of a large number of floating tidal turbines might create a barrier effect or displace marine animals from the critical habitats they need for success. This effect could occur from the presence of the device itself, anchors in the seabed, or mooring lines in the water column. Little research or insight has been gathered about this potential interaction, as the current thinking is that small numbers of devices (one to perhaps four) are unlikely to cause this effect (Copping 2020). Therefore, no monitoring or informed modeling is possible at this time. As larger arrays are deployed in the future, research and perhaps monitoring will be needed to determine whether displacement or barrier effects are likely. At this time, key questions, animals at risk, and methods for data collection must be determined; these are summarized in Table 7.

8.3.8 Mitigation and Adaptive Management

Mitigation for potential effects of marine energy is generally not considered at this early stage of the industry's development. However, the application of adaptive management has become common in permitting marine energy devices. Adaptive management, often referred to as "learning by doing" (Williams 2011) is used to allow both the developer and the regulator to proceed with deployment and operation in the face of incomplete information (Le Lièvre 2020). In the United States, the adaptive management processes associated with marine energy have taken the form of plans for post-installation monitoring, with a built-in process for reviewing monitoring data periodically, using the results to modify monitoring requirements. One of the most developed and implemented adaptive management practices for marine energy was associated with the Ocean Renewable Power Company project in Cobscook Bay, adjacent to Western Passage in Maine (Jansujwicz and Johnson 2015).

Although mitigation has not played a role in marine energy to date, it is anticipated that, as arrays are deployed and the industry progresses, mitigation measures may come into play. In particular, the ability to identify and weigh potential mitigation (or "management") measures in advance of deployment will help the industry to remain viable through responsible development, as laid out by Ocean Energy Systems-Environmental (https://tethys.pnnl.gov/management-measures).

Table 7. Key questions, animals at risk, and methods for data collection for compliance monitoring of floating tidal turbines in San Juan Islands and Western Passage.

Potential Risk	Key Questions	Animals at Risk (San Juan Islands)	Animals at Risk (Western Passage)	Methods and Instruments for Assessment
Collision	How do animals interact with the turbine? Will animals collide with tidal turbine (probability)? What would be the outcome of a collision (consequence)?	Marine mammals: orca; other small whales, such as pilot whales and dolphins; seals; sea lions. Fish: salmon, Bocaccio, forage fish, demersal fish, sharks.	Marine mammals: seals, sea lions, dolphins. Fish: Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, forage fish, demersal fish, sharks.	Multi-sensor platforms, including passive and active acoustic devices (echosounders, acoustic cameras), stereo optical cameras or video.
Underwater Noise	What is the amplitude and frequency of sound from the floating turbine? Does the sound level exceed U.S. guidance/standards?	Marine mammals, particularly cetaceans. Some fish species, such as salmon.	Marine mammals, particularly cetaceans. Some fish species, such as salmon and sturgeon.	Hydrophones, use of IEC TC114 technical specification.
EMF	What are the EMF levels from the tidal turbine and cables? Are they likely to harm marine animals?	Crabs; perhaps some fish, such as eels.	Crabs; lobster; perhaps some fish, such as eels.	Magnetometer, some research instruments for measuring EMF.
Change in Habitat	Have habitats changed in the project area since installation and operation of the floating tidal turbine?	Benthic invertebrates, including crab, demersal fish, epifauna and infauna that are prey for benthic species. Perhaps pelagic larvae.	Benthic invertebrates, including crab and lobster, demersal fish, epifauna and infauna that are prey for benthic species. Perhaps pelagic larvae.	Seafloor surveys with video and other methods.
Entanglement	Are lines from the floating tidal device likely to entangle marine animals?	None.	None.	None.
Haul Out or Roosting	Can marine mammals and seabirds haul out or roost on the device?	Seals, sea lions, seabirds.	Seals, sea lions, seabirds.	Visual surveys of devices from land or from vessels.
Displacement	Can the device prevent marine animals from reaching their critical habitats?	Possibly marine mammals, fish, sea birds, benthic invertebrates, including crab.	Possibly marine mammals, fish, sea birds, benthic invertebrates, including crab and lobster.	None.

9.0 References

32 FR 4001. March 11, 1967. “Endangered Species Preservation Act.” *Federal Register*, Fish and Wildlife Service, Department of the Interior.

35 FR 8491. June 2, 1970. “Conservation of Endangered Species and Other Fish or Wildlife.” *Federal Register*, Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service, Department of the Interior.

70 FR 37160. June 28, 2005. “Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

70 FR 52629. September 2, 2005. “Endangered and Threatened Species; Designation of Critical Habitat for 12 Evolutionarily Significant Units of West Coast Salmon and Steelhead in Washington, Oregon, and Idaho.” *Federal Register*, National Oceanic and Atmospheric Administration.

70 FR 69903. November 18, 2005. “Endangered and Threatened Wildlife and Plants: Endangered Status for Southern Resident Killer Whales.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

71 FR 17757. April 7, 2006. “Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

71 FR 69054. November 29, 2006. “Endangered and Threatened Species; Designation of Critical Habitat for Southern Resident Killer Whale.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

72 FR 26722. May 11. 2007. “Endangered and Threatened Species: Final Listing Determination for Puget Sound Steelhead.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

73 FR 12024. March 6, 2008. “Endangered and Threatened Species; Endangered Status for North Pacific and North Atlantic Right Whales.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

74 FR 52300. October 9, 2009. “Endangered and Threatened Wildlife and Plants: Final Rulemaking to Designate Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

74 FR 29344. June 19, 2009. “Endangered and Threatened Species: Determination of Endangered Status for the Gulf of Maine Distinct Population Segment of Atlantic Salmon.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce, United States Fish and Wildlife Service, Interior.

75 FR 13012. March 18, 2010. “Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of Eulachon.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

75 FR 22276. April 28, 2010. “Reexamination of Roaming Obligations of Commercial Mobile Radio Service Providers.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

76 FR 58867. September 22, 2011. “Endangered and Threatened Species; Determination of Nine Distinct Population Segments of Loggerhead Sea Turtles as Endangered or Threatened.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce, United States Fish and Wildlife Service, Interior.

76 FR 65324. October 11, 2011. “Endangered and Threatened Species; Designation of Critical Habitat for the Southern Distinct Population Segment of Eulachon.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

78 FR 2726. January 14, 2013. “Endangered and Threatened Species; Designation of Critical Habitat for Lower Columbia River Coho Salmon and Puget Sound Steelhead.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

78 FR 69310. November 19, 2013. “Endangered and Threatened Species; Protective Regulations for the Gulf of Maine Distinct Population Segment of Atlantic Sturgeon.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

79 FR 20802. April 14, 2014. “Endangered and Threatened Species; Final Rule to Revise the Code of Federal Regulations for Species Under the Jurisdiction of the National Marine Fisheries Service.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

79 FR 68041. November 13, 2014. “Endangered and Threatened Species; Designation of Critical Habitat for the Puget Sound/Georgia Basin Distinct Population Segments of Yelloweye Rockfish, Canary Rockfish and Bocaccio.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

86 FR 21082. April 21, 2021. “Endangered and Threatened Wildlife and Plants: Designating Critical Habitat for the Central America, Mexico, and Western North Pacific Distinct Population Segments of Humpback Whales.” *Federal Register*, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Commerce.

Calambokidis J., G.H. Steiger, K. Rasmussen et al. 2000. “Migratory destinations of humpback whales that feed off California, Oregon and Washington.” *Marine Ecology Progress Series* 192: 295–304.

Copping, A.E. 2020. “Marine Renewable Energy: Environmental Effects and Monitoring Strategies.” *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*, A.E. Copping and L.G. Hemery (Eds.), report for Ocean Energy Systems (OES), 18–26. DOI: 10.2172/1632880.

Copping A.E. and L.G. Hemery, editors. 2020. *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*. Report for Ocean Energy Systems (OES). DOI: 10.2172/1632878.

Cornell Lab of Ornithology. 2021. “All About Birds.” Cornell University. https://www.birds.cornell.edu/home

Falcone E., J. Calambokidis, G.H. Steiger, M. Malleson, and J. Ford. 2005. “Humpback whales in the Puget Sound/Georgia Strait Region.” *Proceedings of the 2005 Puget Sound Georgia Basin Research Conference*, p. 4.

Garavelli L. 2020. “Encounters of Marine Animals with Marine Renewable Energy Device Mooring Systems and Subsea Cables.” *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*. A.E. Copping and L.G. Hemery (Eds.), report for Ocean Energy Systems (OES), 146–153. DOI: 10.2172/1633184.

Gill A.B. and M. Desender. 2020. “Risk to Animals from Electromagnetic Fields Emitted by Electric Cables and Marine Renewable Energy Devices.” *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*. A.E. Copping and L.G. Hemery (Eds.), report for Ocean Energy Systems (OES), 86–103. DOI: 10.2172/1633088.

Gravem S.A., W.N. Heady, V.R. Saccomanno, K.F. Alvstad, A.L.M. Gehman, T.N. Frierson, and S.L. Hamilton. 2020. “*Pycnopodia helianthoides*.” *The IUCN Red List of Threatened Species 2020*: e.T178290276A178341498.

Hemery L.G. 2020. “Changes in Benthic and Pelagic Habitats Caused by Marine Renewable Energy Devices.” *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*. A.E. Copping and L.G. Hemery (Eds.), report for Ocean Energy Systems (OES), 104–125. DOI: 10.2172/1633182.

IEC. 2019. IEC TS 62600-40:2019, Marine Energy – Wave, Tidal and Other Water Current Converters – Part 40: Acoustic characterization of marine energy converters. International Electrotechnical Commission. https://webstore.iec.ch/publication/31031

IUCN. 2021. “IUCN Red List of Threatened Species.” https://www.iucnredlist.org/

Jansujwicz J. and T. Johnson. 2015. “Understanding and Informing Permitting Decisions for Tidal Energy Development Using an Adaptive Management Framework.” *Estuaries and Coasts* 38(1): S253–S265.

Le Lièvre C. 2020. “Adaptive Management Related to Maritime Renewable Energy.” *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*. A.E. Copping and L.G. Hemery (Eds.), report for Ocean Energy Systems (OES), 242–261. DOI: 10.2172/1633206.

National Archives Federal Register. 2021. Website. https://www.federalregister.gov/

National Marine Fisheries Service. 2018. *2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater*

Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NMFS-OPR-59.

New England Fishery Management Council. 1982. *Fishery Management Plan*. Final Environmental Impact Statement. Regulatory impact review for Atlantic sea scallops (*Placopecten magellanicus*). January 1982.

New England Fishery Management Council. 1985. *Fishery Management Plan*. Environmental Impact Statement. Regulatory impact review for and initial regulatory flexibility analysis for the Northeast Multi-species fishery. August 1985.

New England Fishery Management Council. 1987. *Fishery Management Plan for Atlantic Salmon*. Incorporating an environmental impact statement and regulatory impact review/Initial regulatory flexibility analysis. October 1987.

New England Fishery Management Council. 1999. *Final Atlantic Herring Fishery Management Plan*. Incorporating the environmental impact statement and regulatory impact review. Volume I. March 8, 1999.

New England Fishery Management Council. 2003. *Northeast Skate Complex Fishery Management Plan*. An environmental impact statement, regulatory impact review, regulatory flexibility analysis, and stock assessment and fishery evaluation. September 18, 2003.

New England Fishery Management Council. 2018. *Small-mesh Multispecies Fishing Year 2018–2020 Specifications Environmental Assessment*. Regulatory impact review and initial regulatory flexibility analysis. April 30, 2018.

Olson J.K., J. Wood, R.W. Osborne, L. Barrett-Lennard, and S. Larson. 2018. Sightings of Southern Resident Killer Whales in the Salish Sea 1976–2014: the importance of a long-term opportunistic dataset. *Endangered Species Research* 37: 105–118.

ORPC. 2013. *FERC Project Progress Report No. 6*, Western Passage Tidal Energy Project (P-12680), Ocean Renewable Power Company, Portland, Maine, p. 67.

Pacific Fishery Management Council. 2014. *Pacific Coast Salmon Fishery Management Plan*. As modified by amendment 18 to the Pacific Coast Salmon Plan. Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Pacific Fishery Management Council, Portland, Oregon. September 2014.

Pacific Fishery Management Council. 2019. *Coastal Pelagic Species Fishery Management Plan: As Amended through Amendment 17*. Pacific Fishery Management Council, Portland, Oregon. https://www.pcouncil.org/documents/2019/06/cps-fmp-as-amended-through-amendment-17.pdf/

Pacific Fishery Management Council. 2020. *Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, Washington Groundfish Fishery*. Pacific Fishery Management Council, Portland, Oregon. August 2020.

Pacific Fishery Management Council. 2021a. *Pacific Coast Salmon Fishery Management Plan for Recreational Salmon Fisheries off the Coasts of Washington, Oregon, and California, as Amended through Amendment 20*. Pacific Fishery Management Council, Portland, Oregon.

Pacific Fishery Management Council. 2021b. “Tribes.” https://www.pcouncil.org/fishing-communities/tribes/

Polagye B. and C. Bassett. 2020. “Risk to Marine Animals from Underwater Noise Generated by Marine Renewable Energy Devices.” *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*. A.E. Copping and L.G. Hemery (Eds.), report for Ocean Energy Systems (OES), 66–85. DOI: 10.2172/1633082.

Southall B.L., J.J. Finneran, C. Riechmuth, et al. 2019. “Marine mammal noise exposure criteria: updated scientific recommendations for residual hearing effects.” *Aquatic Mammals* 45: 125–232.

Sparling C.E., A.C. Seitz, E. Masden, and K. Smith. 2020. “Collision Risk for Animals around Turbines.” *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*. A.E. Copping and L.G. Hemery (Eds.), report for Ocean Energy Systems (OES), 28–65. DOI: 10.2172/1632881.

Staines G., G.B. Zydlewski, H.A. Viehman, and R. Kocik. 2020. “Applying two active acoustic technologies to document presence of large marine animal targets at a marine renewable energy site.” *Journal of Marine Science and Engineering* 8: 704.

State of Maine Title 12, §6975. List of state endangered and state threatened marine species.

United States Code. Endangered Species Act of 1973, as amended. 16 U.S.C. ch. 35 § 1531 et seq.

United States Code. Magnuson-Stevens Fisheries Conservation and Management Act of 1976. 16 U.S.C. ch 38 § 1801 et seq.

United States Code. Marine Mammal Protection Act of 1972. 16 U.S.C. ch 31 § 1361 et seq.

United States v. Washington, 384 F. Supp. 312 (W.D. Wash. 1974), aff'd, 520 F.2d 676 (9th Cir. 1975).

United States v. State of Wash., 898 F. Supp. 1453 (W.D. Wash. 1995).

U.S. Fish and Wildlife Service. 2010. *Protection Island and San Juan Islands National Wildlife Refuges Comprehensive Conservation Plan and San Juan Islands Wilderness Stewardship Plan*. August 2010. Portland, Oregon.

Williams B. 2011. “Adaptive management of natural resources—framework and issues.” *Journal of Environmental Management* 92(5-6): 1346–1353. DOI: 10.1016/j.jenvman.2010.10.041.

Yang. Z., T. Wang, R. Branch, Z. Xiao, and M. Deb. 2021. “Tidal stream energy resource characterization in the Salish Sea.” *Renewable Energy* 172: 188–208.

Yang Z., T. Wang, Z. Xiao, L. Kilcher, K. Haas, H. Xue, and X. Feng. 2020. “Modeling assessment of tidal energy extraction in the Western Passage.” *Journal of Marine Science and Engineering* 8: 411.

Pacific Northwest National Laboratory

100 Dexter Ave N, Suite 500
Seattle, WA 98109
1-888-375-PNNL (7665)

www.pnnl.gov