Submarine Cable Analysis for Marine Renewable Energy Development

Contents

1 Background

Demand for abundant and diverse resources in the oceans is growing, necessitating marine spatial planning. To inform development of Marine Hydrokinetic (MHK) and Offshore Wind (OSW) resources, DOE has asked NREL to identify — and mitigate where possible — the competing uses between MHK/OSW technologies and subsea power/telecoms cables. The first step in this work is to identify and quantify the overlap between the MHK/OSW resource availability and existing cable routes. Several publicly available data layers are available that identify cable routes (e.g. MarineCadastre.gov currently hosts an offshore cables geographical information system (GIS) data layer) and MHK/OSW resource density (MHK Atlas, Wind Prospector). The cable route linear features, however, do not indicate the setback distance necessary to accommodate subsea cable maintenance requirements. Preliminary work was done within NREL to evaluate the influence of subsea cable setback distance on the overlap with MHK/OSW for the west coast of the U.S (Amante, Kilcher, Roberts, & Draxl, 2016). Industry reports (Communications Security, Reliability and Interoperability Council IV, 2014, 2016) from the International Cable Protection Committee (ICPC) of the North American Submarine Cable Association (NASCA; n-a-s-c-a.org) advise on setback distances that inform this analysis.

2 Methods

2.1 Study Area and Submarine Cables

The study area included the 200 nm extent of US waters downloaded from MarineRegions.org[1] and overlapping the offshore cable data layer available through MarineCadastre.gov.[2] See Figure **??**.

TODO: add citations to bibliography:

- MarineRegions.org > Exclusive Economic Zones Boundaries (EEZ), version: World EEZ v9 (2016-10-21, 123 MB). Suggested citation:
  - Flanders Marine Institute (2016). Maritime Boundaries Geodatabase, version 1. Available online at http://www.marineregions.org/. Consulted on 2017-04-25.
- MarineCadastre.gov cable metadata

See Table 1 and Figure **??**.

2.2 Depth

The bathymetric depth comes from the GEBCO 30 arc-second grid. Here's there requested attribution:

GEBCO_2014 Grid, version 20150318, www.gebco.net

[1] MarineRegions.org US exclusive economic zone (EEZ) data, version World_EEZ_v9_20161021

[2] MarineCadastre.gov cable metadata: https://coast.noaa.gov/dataservices/Metadata/TransformMetadata?u=https://coast.noaa.gov/data/Documents/Metadata/harvest/MarineCadastre/NOAAChartedSubmarineCables.xml&f=html

2.3 Renewable Energy

NREL.

2.4 Avoidance Zones for Siting New Facilities

"ICPC Recommendation 13 No. 2, which establishes a methodology for determining site-specific proximity limits between submarine cables and offshore wind facilities and a default separation distance in shallower waters of 500 meters on either side of an in-service submarine cable — a separation standard the principles of which also apply to other offshore renewable energy projects."

"Subsea Cables UK Guideline No. 6 (endorsed by NASCA), which establishes principles for determining safe proximity distances and negotiating proximity agreements between offshore wind farms and submarine cables and reflects extensive experience in the United Kingdom with managing spatial conflicts between offshore wind farms and submarine cables."

"endorse a default separation distance of 500 meters in water depths of less than 75 meters and the greater of 500 meters or two times the depth of water in greater water depths."

1. **Default separation distance** by depth:
    - `<= 250 m`: 500 m
    - `> 250 m`: 2 x depth

Psudocode:

```
# buffer based on depth
cables_buffers = list()
for (x in unique(cable_cells$depth)){

  cables_buffers[str(x)] = cable_cells %>%
    subset(depth == x) %>%
    buffer(x)

}
cable_buf = merge(cables_buffers)

# smooth out jagged edges between cells
cable_buf = simplify(cable_buf)
```

2.5 Separation Zones for Routing New Cables

"ICPC Recommendation 2 No. 10: parallel submarine cables maintain a separation distance of the lesser of 3 times depth of water or (where not achievable) 2 times the depth of water following consultation and agreement between affected parties — a separation standard the principles of which also apply to spacing of submarine cables and other marine infrastructure"

At least 2 separation zones based on depth:

1. **Minimum**: 2 times the depth of water

2. **Recommended**: 3 times depth of water

Psudocode:

```
# convert depth (GEBCO 30 sec resolution) to polygons of cells
depth_cells = as.polygon(depth_raster)
```

```
# intersect cables with depth cells
cable_cells = intersect(cables_lines, depth_cells)

# buffer based on depth
cables_buffers = list()
for (x in unique(cable_cells$depth)){

  cables_buffers[str(x)] = cable_cells %>%
    subset(depth == x) %>%
    buffer(x)

}
cable_buf = merge(cables_buffers)

# smooth out jagged edges between cells
cable_buf = simplify(cable_buf)
```

2.6 Depth-Varying Cable Buffer

A depth-varying buffer to the offshore cables, 2 * depth for "minimum" and 3 * depth for "recommended" separation zones for routing new cables, by first intersecting depth with cables, then iterating over each depth to apply the appropriate buffers before finally dissolving all buffers. In order to apply the buffer, I needed to project from geographic coordinates to a projection that minimizes area distortion, so chose Albers Equal Area and applied the "one-sixth rule" based on the extent of the cable features to minimize distortion.

3 Results

3.1 Cable Buffer

Generated by:

- create_cable-buffer.R
- extract_cable-energy.R

Google Earth files (*.kml):

- buf_2xdepth-incr100m.kml
- buf_3xdepth-incr100m.kml
- lns_d1x.kml

3.2 Overlap of Cable Buffer with Renewable Energy

Extract average and area of overlap between zones and renewable energy potential areas, possibly at various depth bins.

3.2.1 Wind

units: wind speed (m/s) at 90m hub height

3.2.2 Wave

units: wave energy flux (kW/m)

3.2.3 Tidal

units: mean power (W/m^2)

3.3 Detailed Maps by US Territory of Cable Buffer and Renewable Energy

3.3.1 Alaska

See Figure 1.

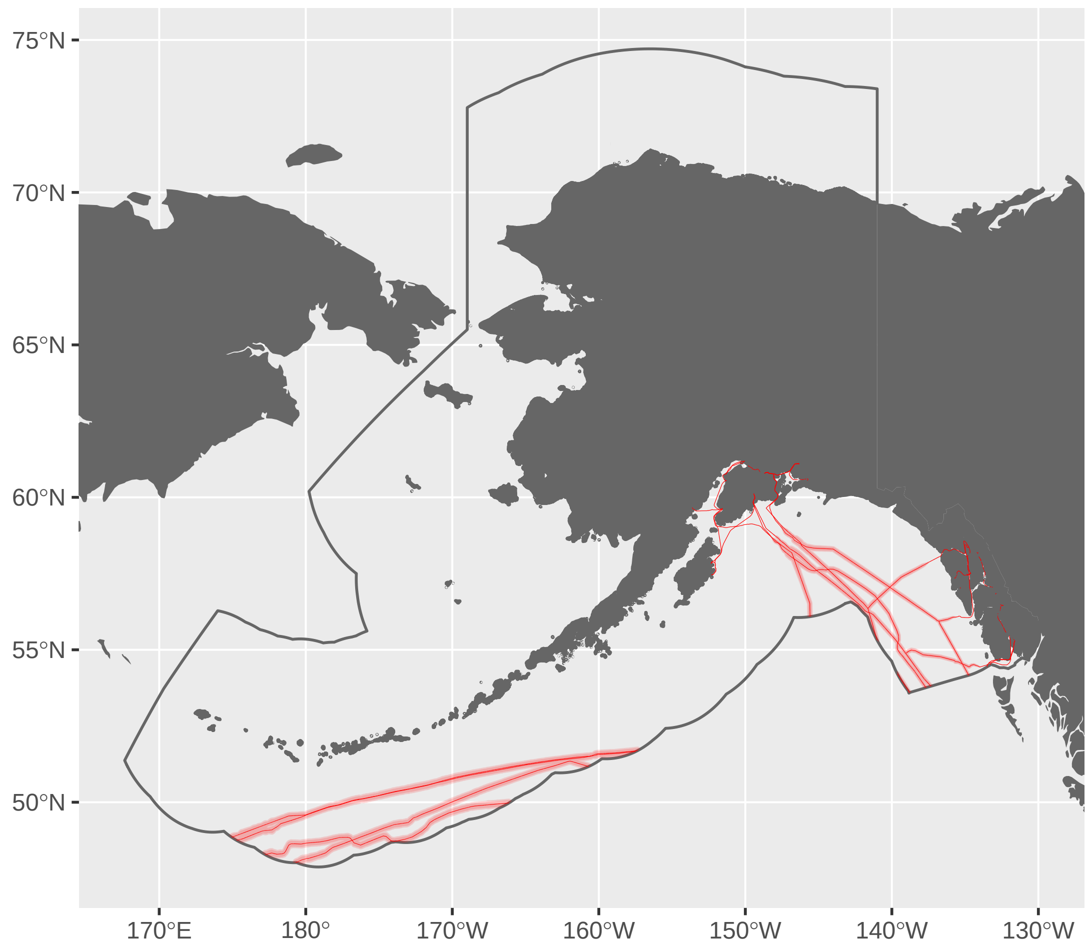

Figure 1: Cable buffers for Alaska.

3.3.1.1 Tidal

See Figure 2.

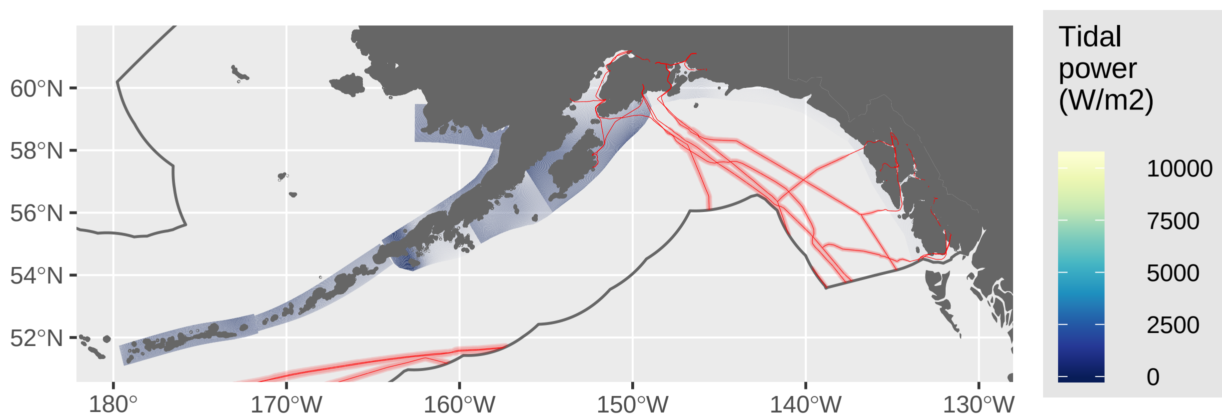

Figure 2: Tidal energy for Alaska.

3.3.1.2 Wave

See Figure 3.

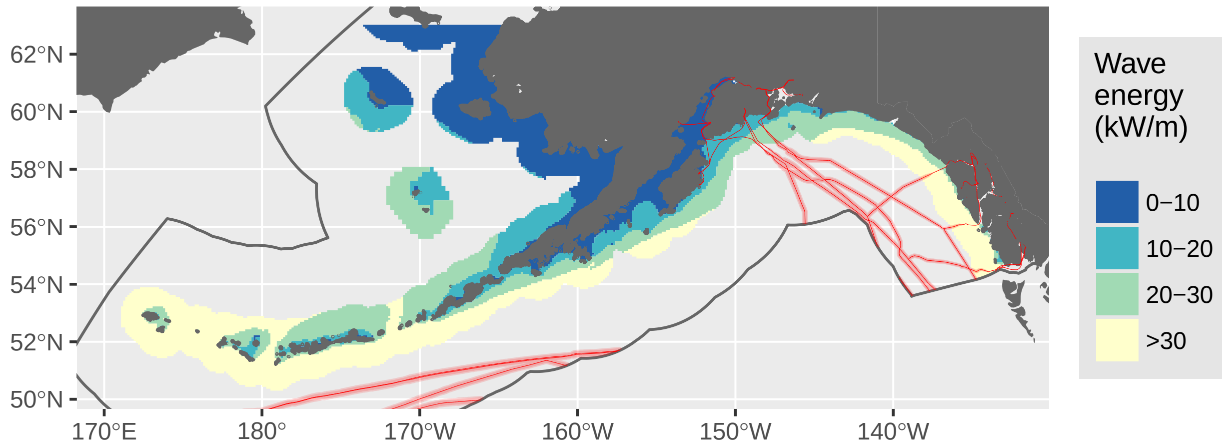

Figure 3: Wave energy for Alaska.

3.3.2 East

See Figure 4.

3.3.2.1 Tidal

See Figure 5.

3.3.2.2 Wave

See Figure 6.

3.3.2.3 Wind

See Figure 7.

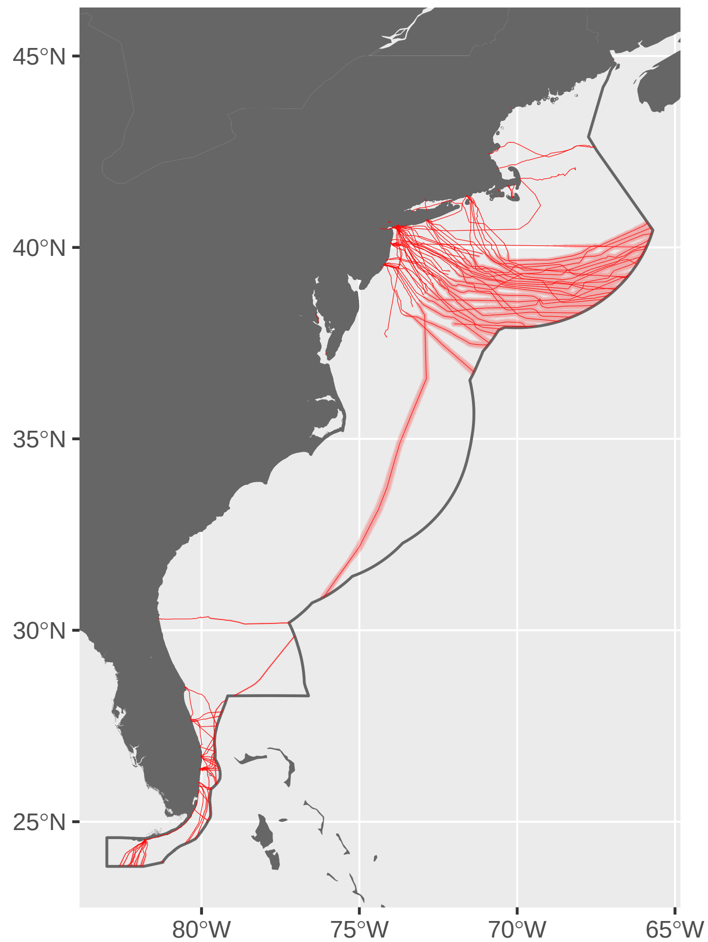

Figure 4: Cable buffers for East.

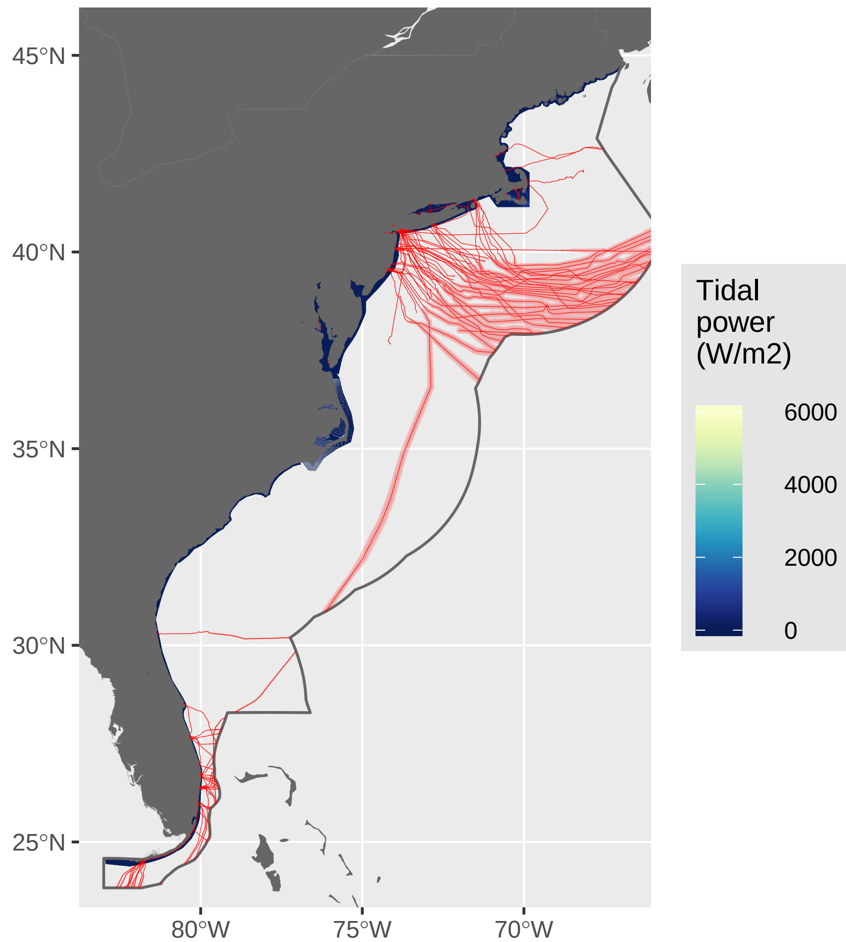

Figure 5: Tidal energy for East.

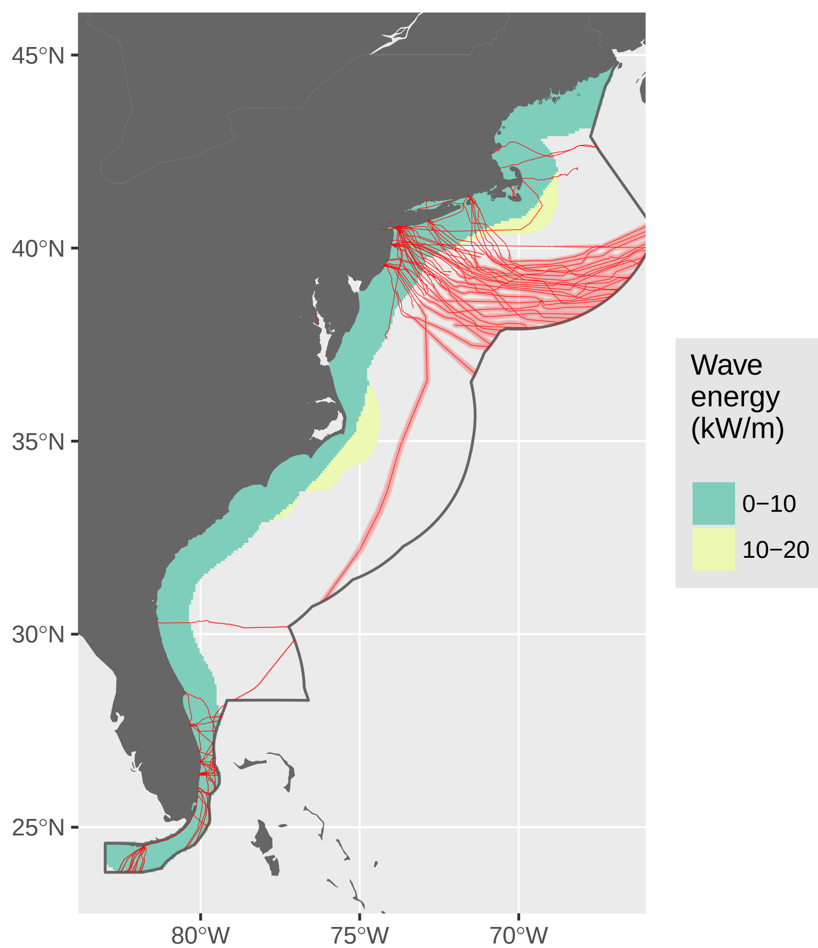

Figure 6: Wave energy for East.

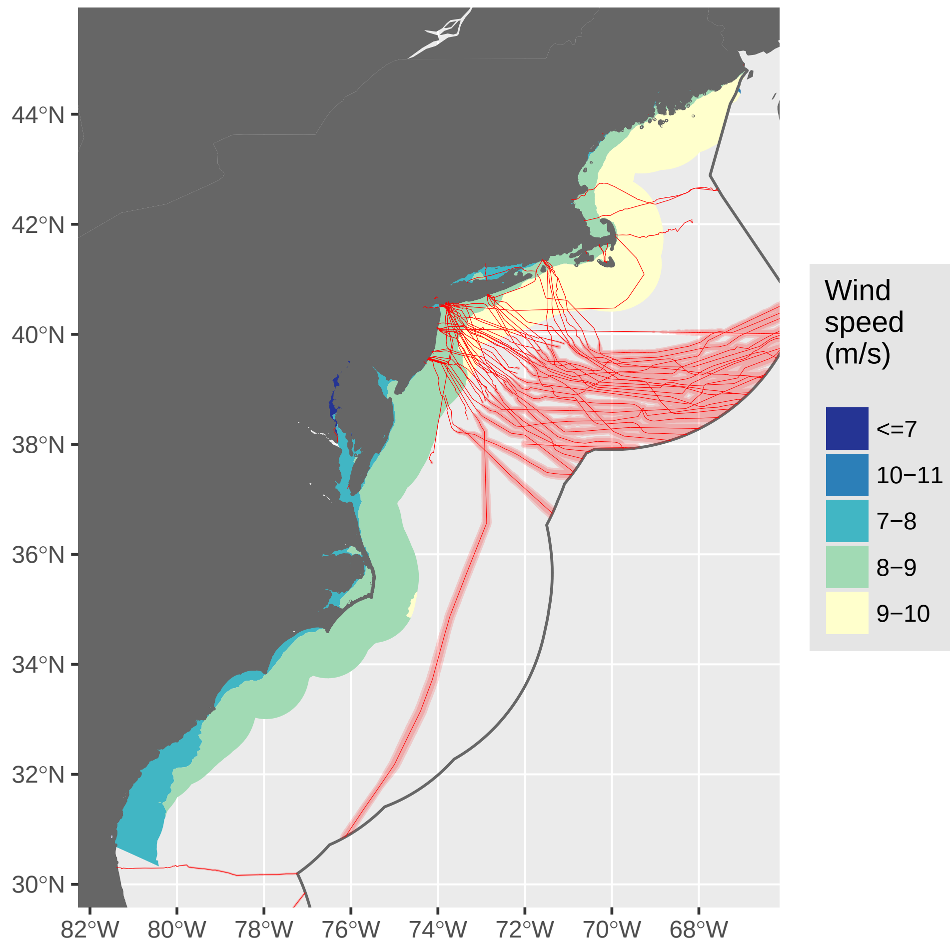

Figure 7: Wind energy for East.

3.3.3 Guam

See Figure 8.

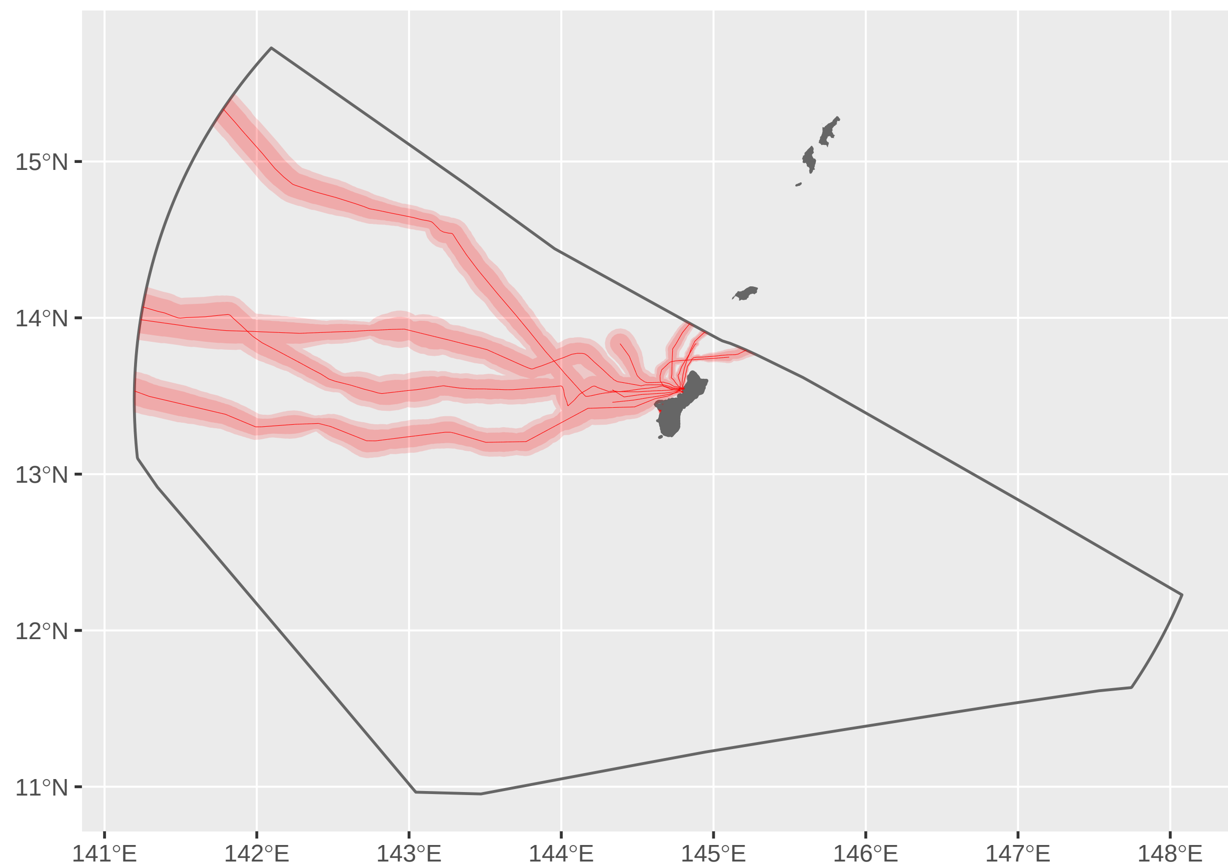

Figure 8: Cable buffers for Guam.

3.3.4 Gulf of Mexico

See Figure 9.

3.3.4.1 Tidal

See Figure 10.

3.3.4.2 Wave

See Figure 11.

3.3.4.3 Wind

See Figure 12.

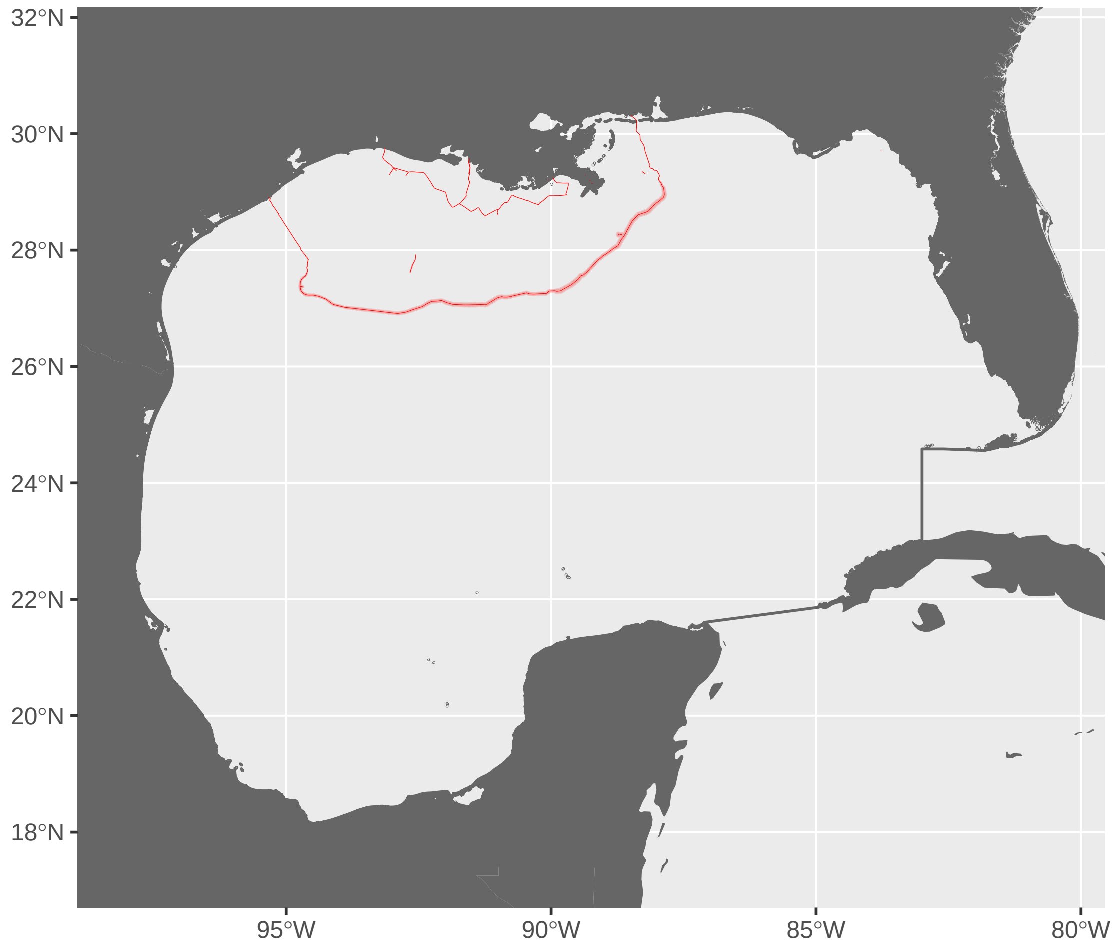

Figure 9: Cable buffers for Gulf of Mexico.

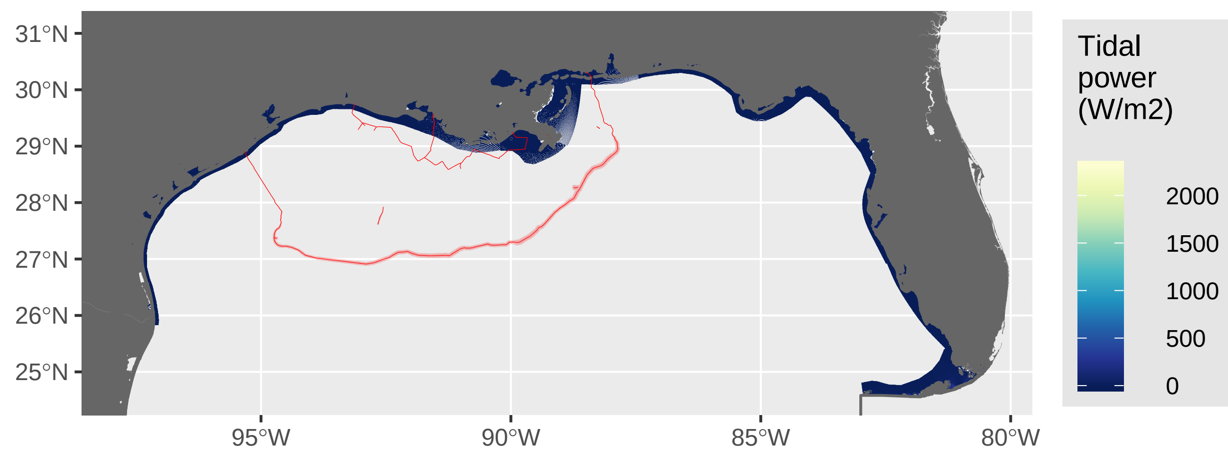

Figure 10: Tidal energy for Gulf of Mexico.

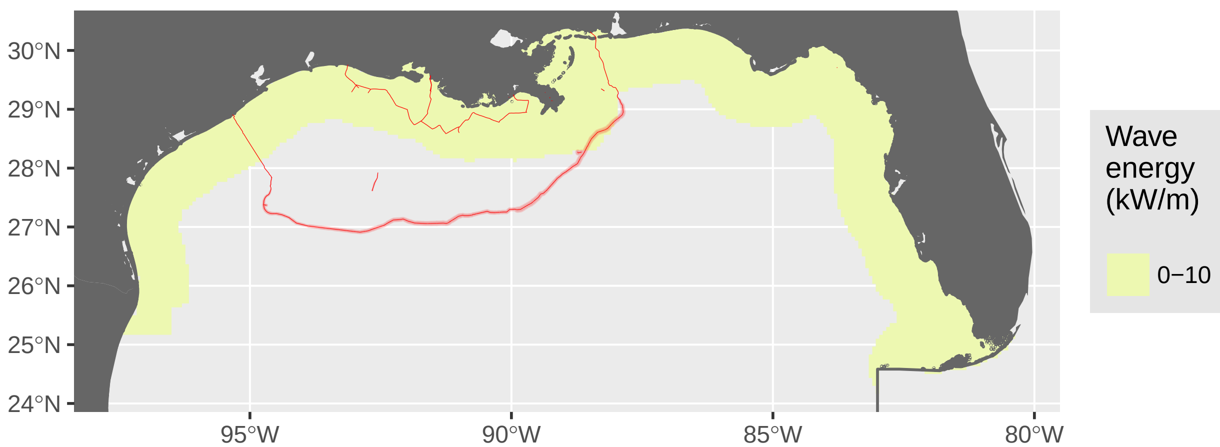

Figure 11: Wave energy for Gulf of Mexico.

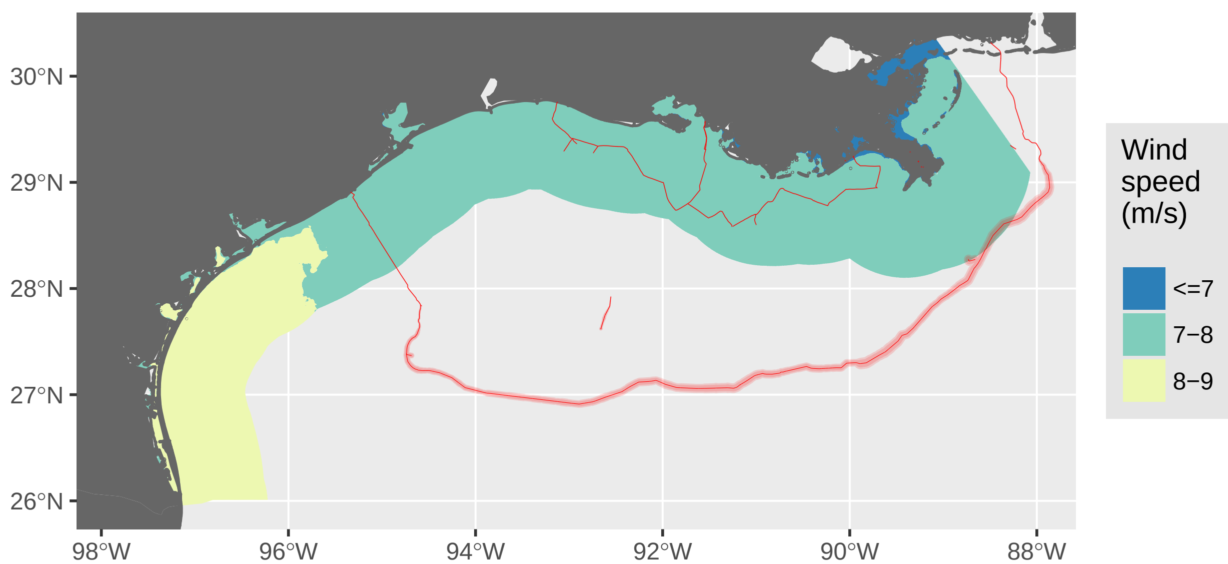

Figure 12: Wind energy for Gulf of Mexico.

3.3.5 Hawaii

See Figure 13.

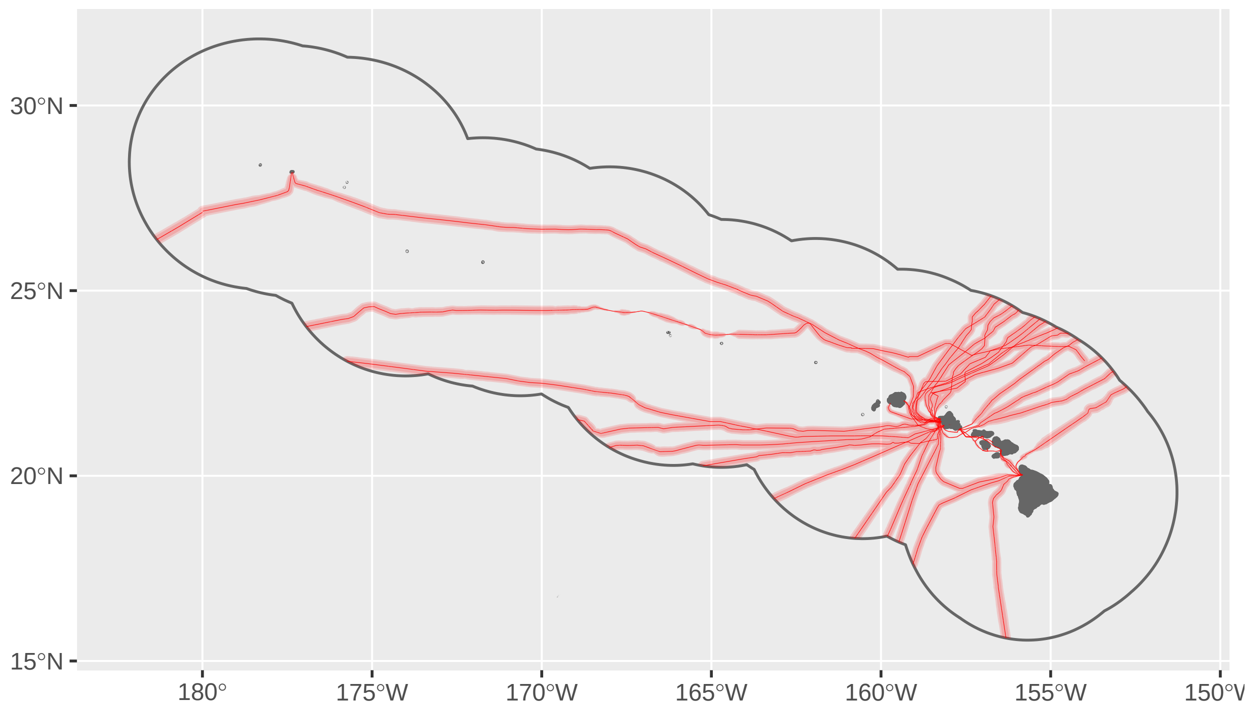

Figure 13: Cable buffers for Hawaii.

3.3.5.1 Wave

See Figure 14.

3.3.5.2 Wind

See Figure 15.

3.3.6 Johnston Atoll

See Figure 16.

3.3.7 N Mariana Islands

See Figure 17.

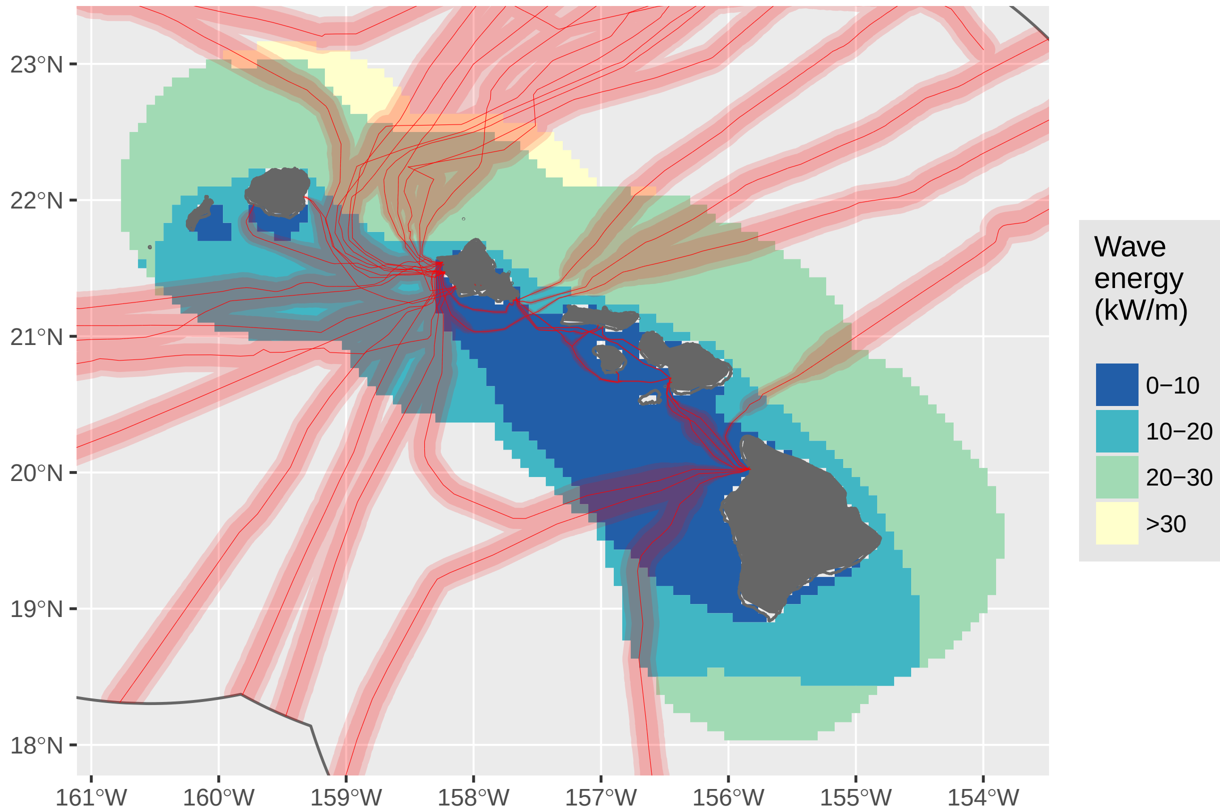

Figure 14: Wave energy for Hawaii.

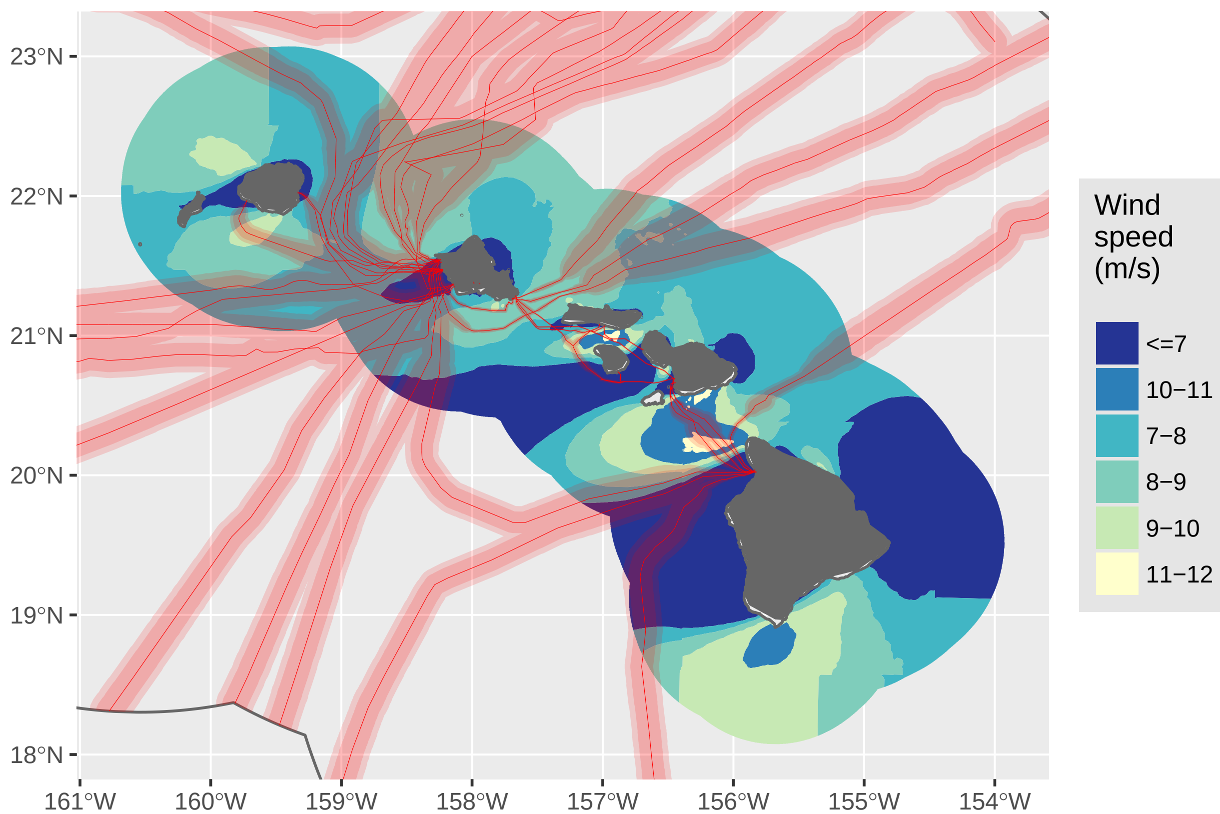

Figure 15: Wind energy for Hawaii.

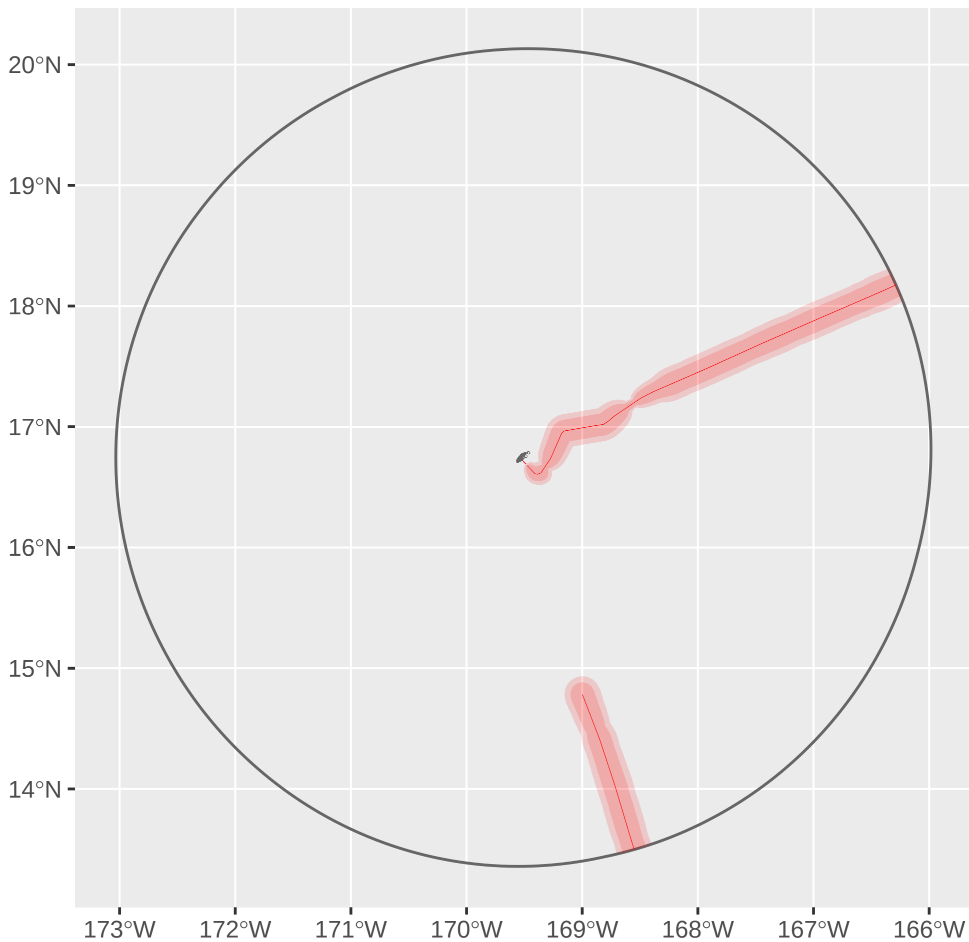

Figure 16: Cable buffers for Johnston Atoll.

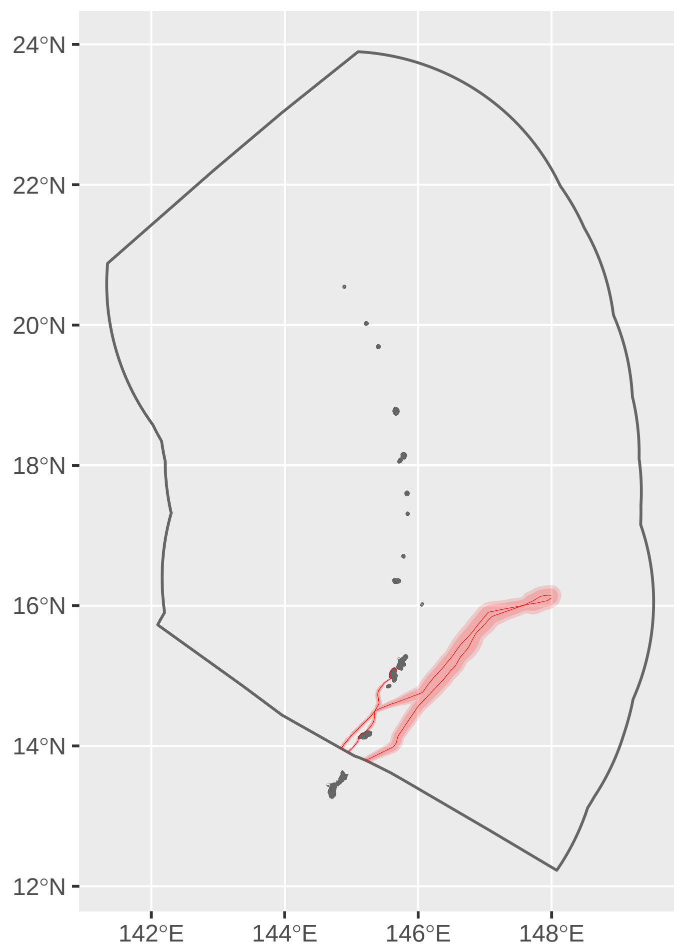

Figure 17: Cable buffers for N Mariana Islands.

3.3.8 Palmyra Atoll

See Figure 18.

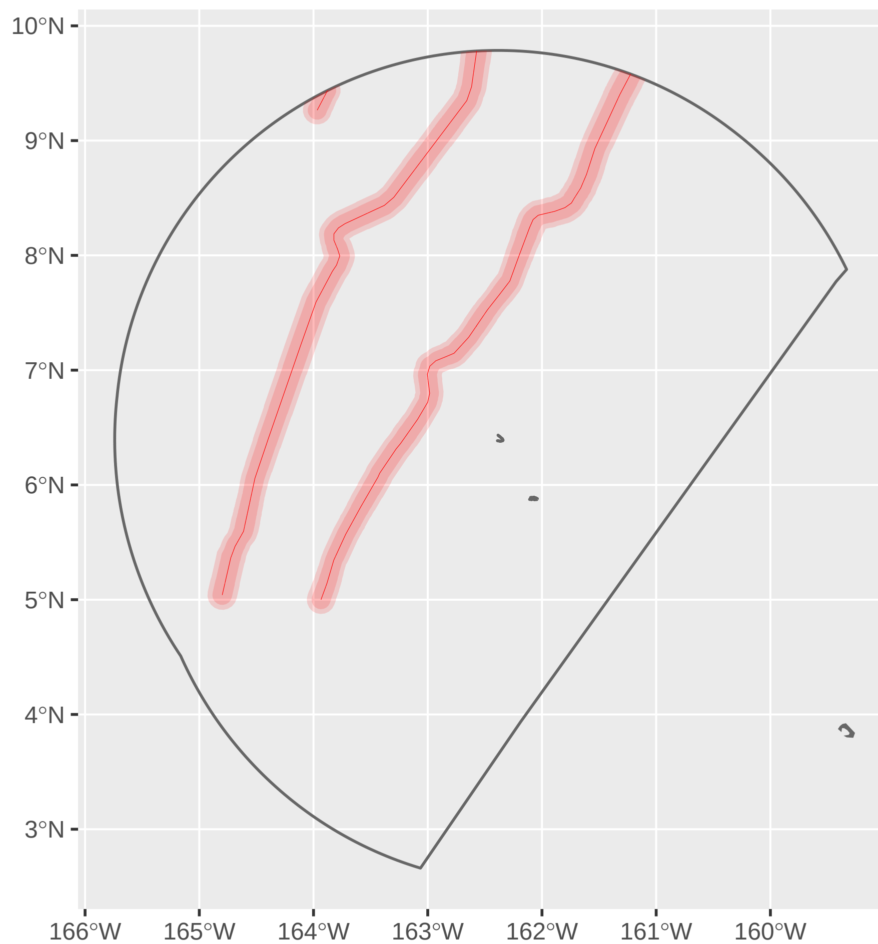

Figure 18: Cable buffers for Palmyra Atoll.

3.3.9 Puerto Rico

See Figure 19.

3.3.9.1 Tidal

See Figure 20.

3.3.9.2 Wave

See Figure 21.

3.3.10 US Virgin Islands

See Figure 22.

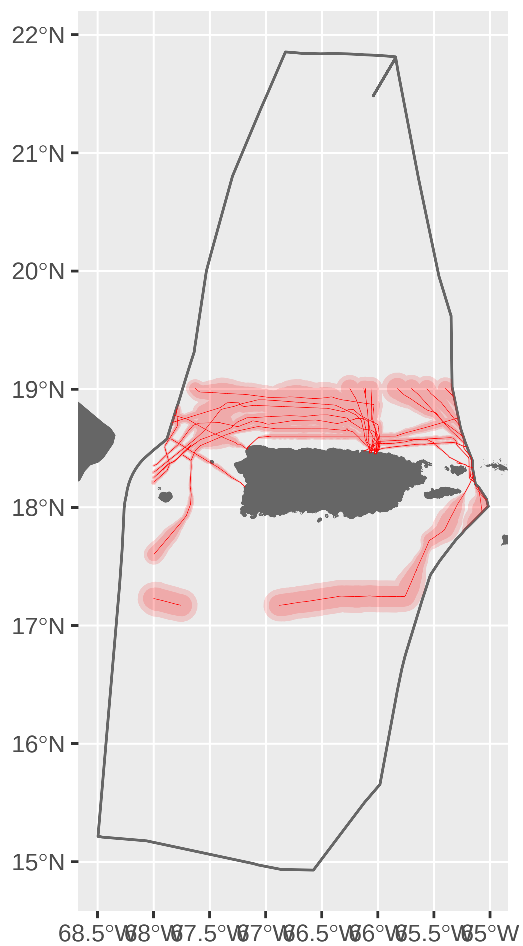

Figure 19: Cable buffers for Puerto Rico.

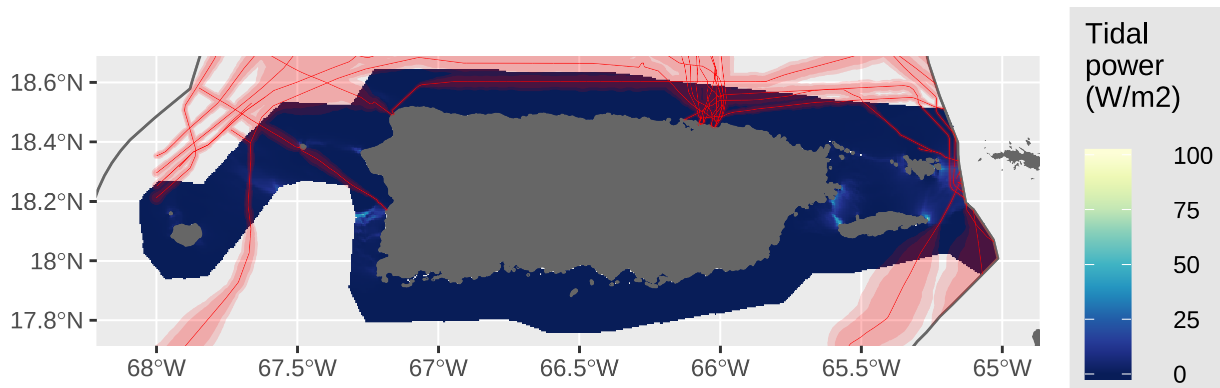

Figure 20: Tidal energy for Puerto Rico.

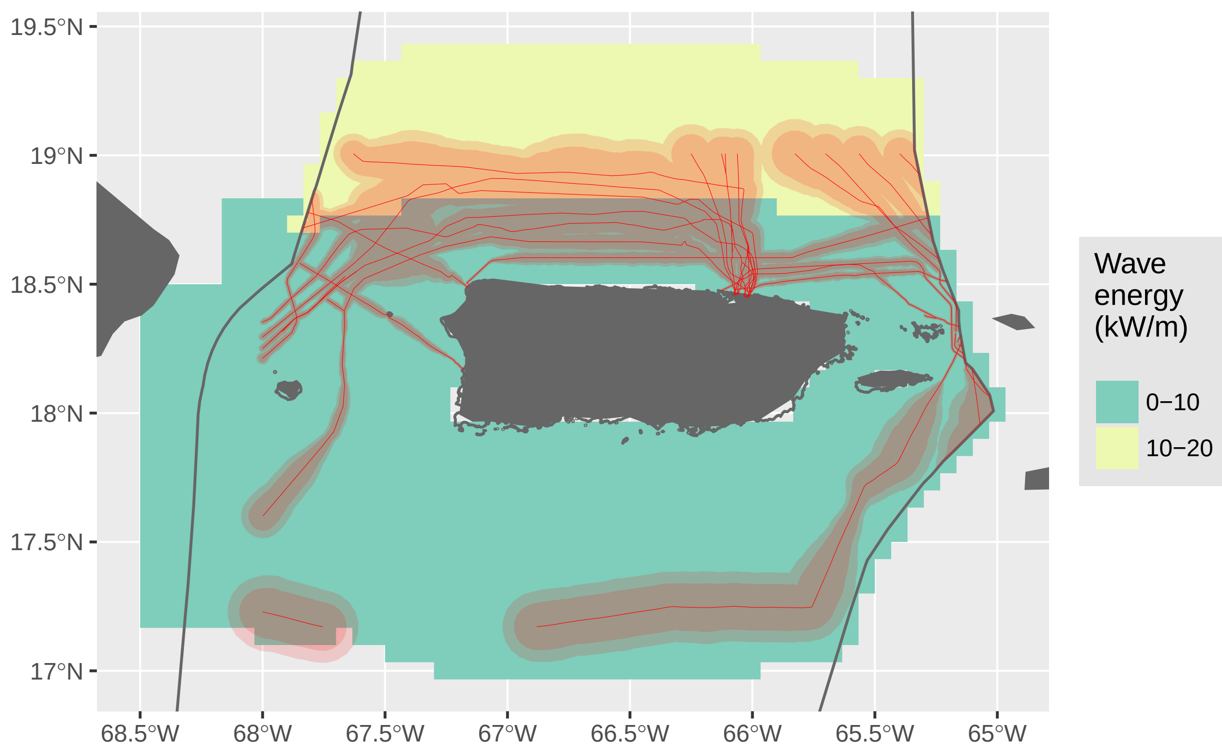

Figure 21: Wave energy for Puerto Rico.

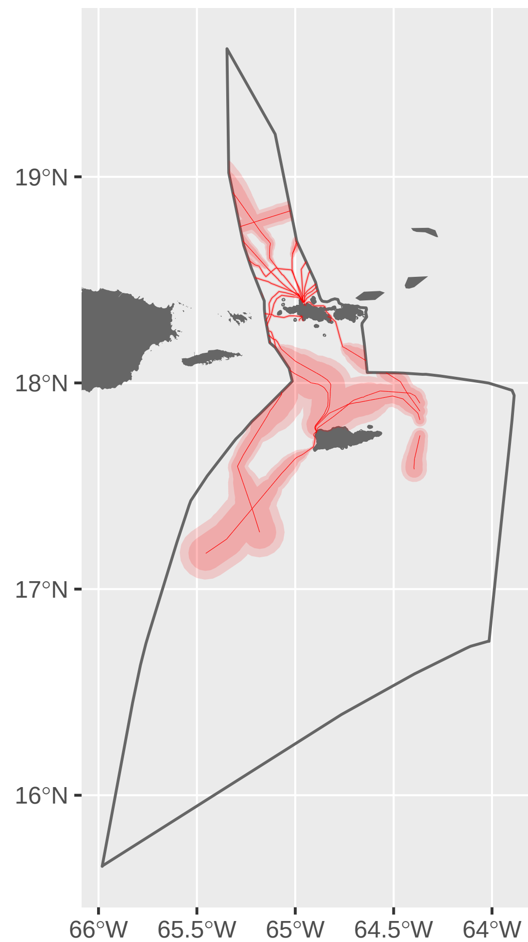

Figure 22: Cable buffers for US Virgin Islands.

3.3.10.1 Tidal

See Figure 23.

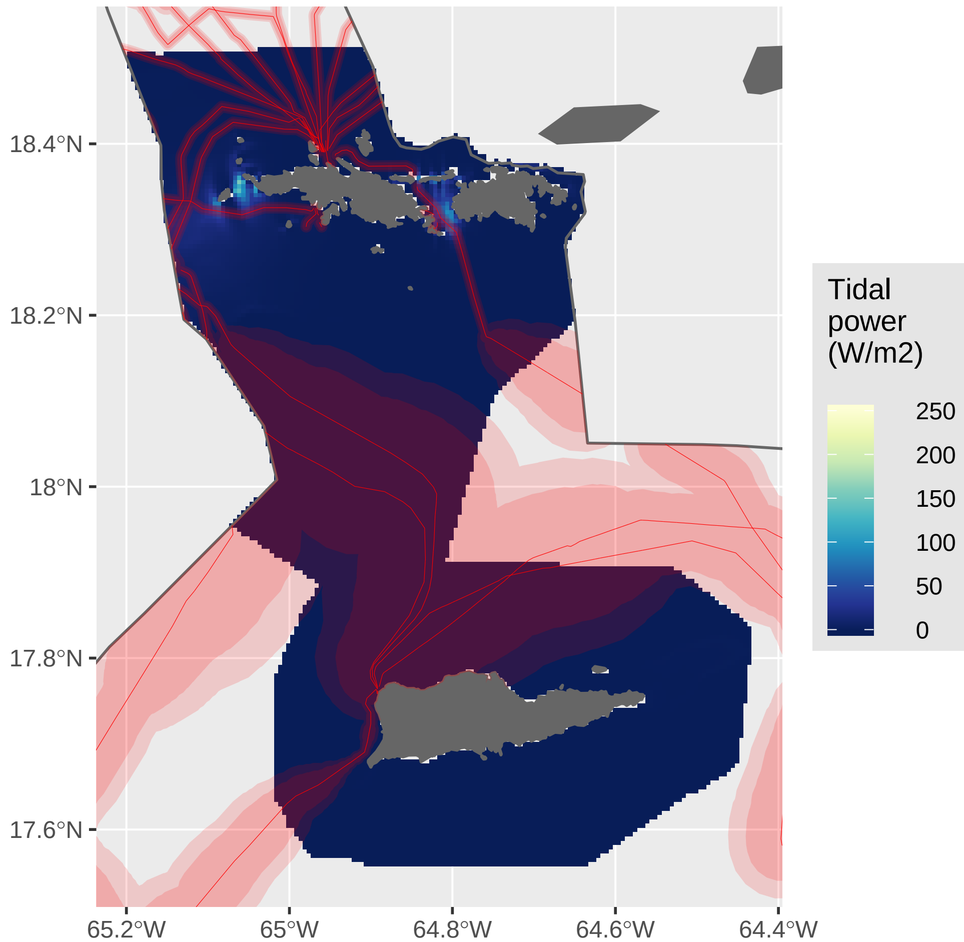

Figure 23: Tidal energy for US Virgin Islands.

3.3.10.2 Wave

See Figure 24.

3.3.11 Wake Island

See Figure 25.

3.3.12 West

See Figure 26.

3.3.12.1 Tidal

See Figure 27.

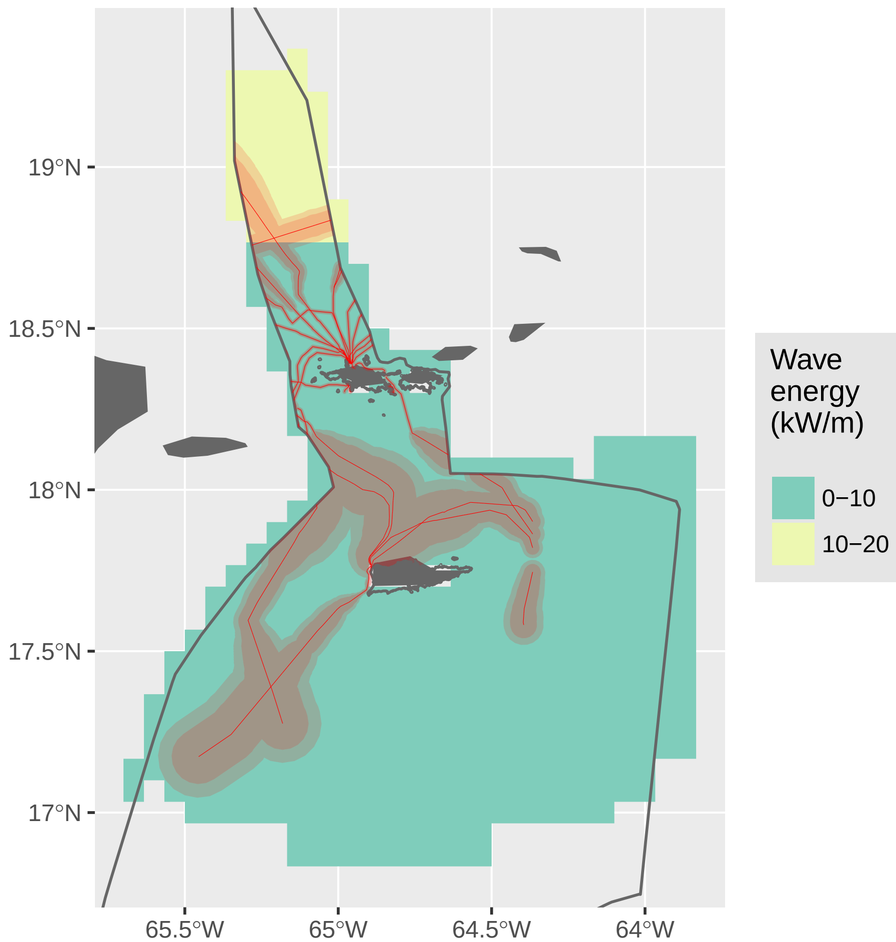

Figure 24: Wave energy for US Virgin Islands.

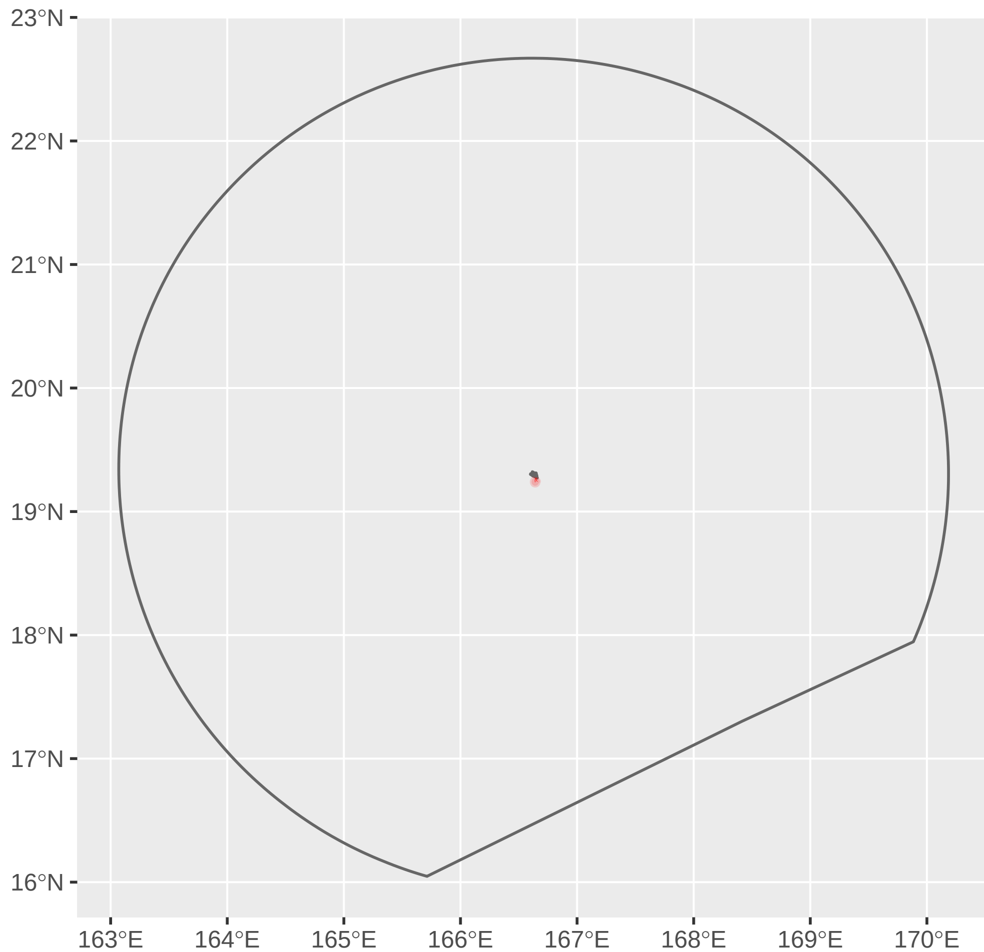

Figure 25: Cable buffers for Wake Island.

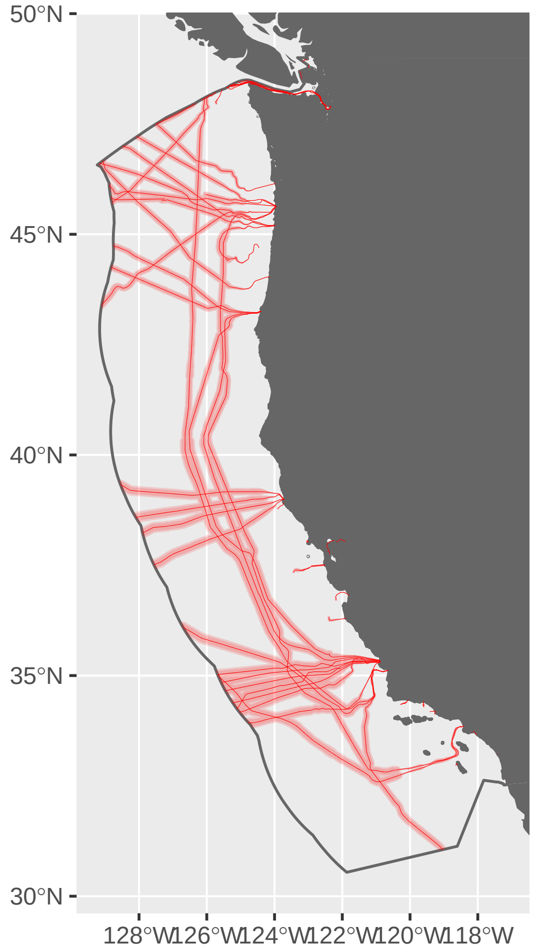

Figure 26: Cable buffers for West.

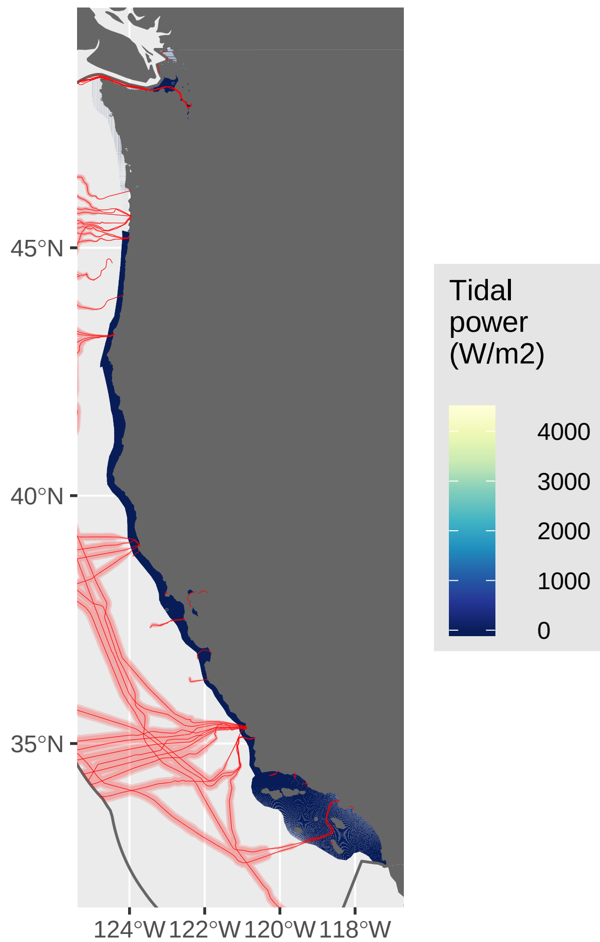

Figure 27: Tidal energy for West.

3.3.12.2 Wave

See Figure 28.

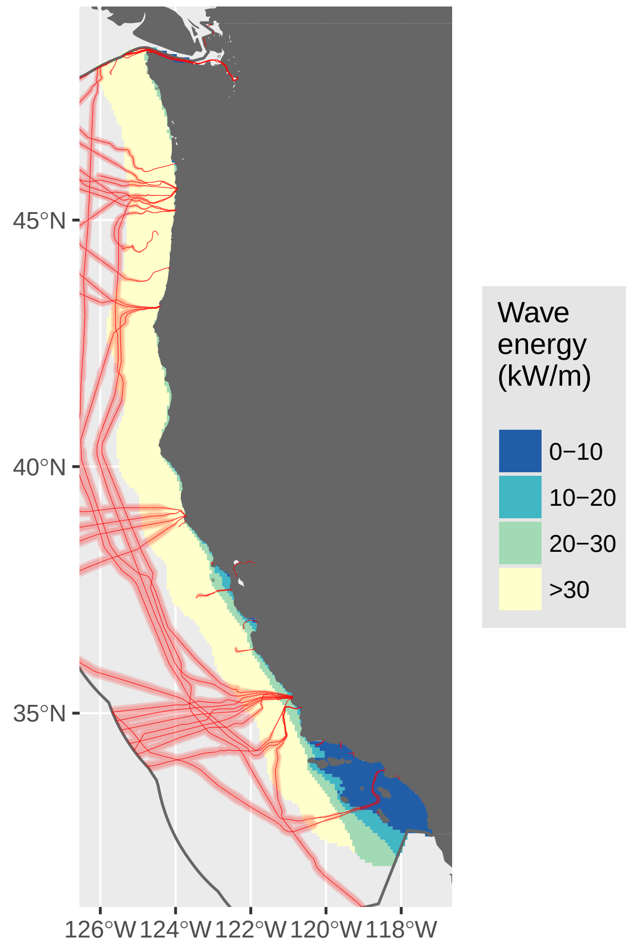

Figure 28: Wave energy for West.

3.3.12.3 Wind

See Figure 29.

4 Conclusions

4.1 Next Steps

- stacked histogram by cbl2/(cbl3-cbl2)/other; hist(wind$Speed_90)
- simplify as native geojson

Musial et al (2016):

- wind speed (m/s) – Table A-3 (p. 48): <7, 7-8, 8-9, 9-10, 10-11, total
- depth classes (m) – Table B-1 (p. 49): <30, 30-60, 60-700, 700-1000, >1000, total

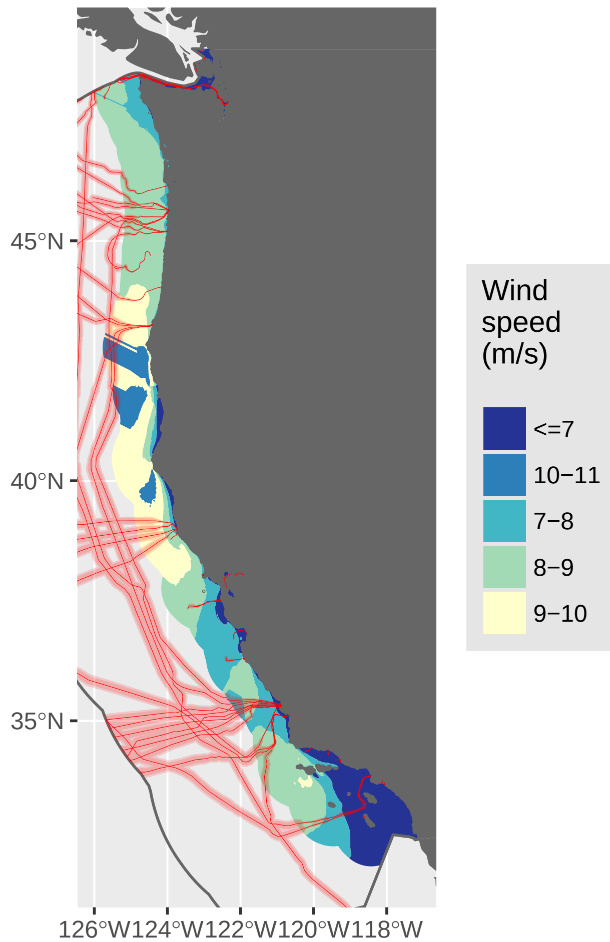

Figure 29: Wind energy for West.

- distance to shore (nm) – Table B-2 (p. 50): <3, 3-12, 12-50, 50-200, total
- by states

4.2 Communication with Stakeholders

Products will be online and readily digestable by stakeholders.

References

Amante, C., Kilcher, L., Roberts, B., & Draxl, C. (2016). *Offshore Cable Analysis: Pilot Study.*

Communications Security, Reliability and Interoperability Council IV. (2014). *Protection of Submarine Cables Through Spatial Separation.*

Communications Security, Reliability and Interoperability Council IV. (2016). *Clustering of Cables and Cable Landings.*